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Giulia Guerriero · Guillermo Rey-Gozalo · Ahmed M. El-Kenawy · Riheb Hadji · Haroun Chenchouni · Arturo Sousa · Paola Di Carlo · José Lopes Velho · Ikrema Hassan · Nicola Perilli *Editors*

Recent Advances in Environmental Science from the Euro-Mediterranean and Surrounding Regions

5th Edition

Proceedings of 5th Euro-Mediterranean Conference for Environmental Integration (EMCEI-5), Italy 2023 (Volume 2)

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Recent Advances in Environmental Science from the Euro-Mediterranean and Surrounding Regions (5th Edition)

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Springer

Editors
Giulia Guerriero
Department of Biology
University of Naples Federico II
Naples, Italy

Ahmed M. El-Kenawy
Mansoura University
Mansoura, Egypt

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University of Batna 2
Batna, Algeria

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Department of Plant Biology and Ecology
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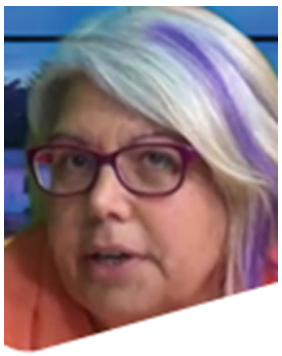
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Preface

Environmental degradation remains a pressing global issue, particularly in the Euro-Mediterranean region, where rapid urbanization, industrialization, and population growth have accelerated the strain on natural resources. The **5th Euro-Mediterranean Conference for Environmental Integration (EMCEI 2023)**, held in Cosenza, Italy, from October 2 to 5, 2023, continued its mission to address these environmental challenges through scientific research, innovation, and international collaboration. The conference focused on promoting environmental integration, aiming to bridge the gap between scientific knowledge and real-world application, fostering solutions that are environmentally, socially, and economically sustainable.

EMCEI 2023 gathered over **600 participants**, both in-person and online, from more than **80 different nations**, showcasing the global commitment to tackling environmental issues. The conference provided a platform for researchers, engineers, and policymakers from across the globe to present their latest findings and discuss innovative solutions. The event featured **16 key tracks**, encompassing a wide array of regular and satellite themes essential to environmental management.

These tracks provided a comprehensive framework for scientific discussion:

Regular Tracks

- **Track 1**: Engineering applications for environmental management
- **Track 2**: Process control, simulations, and intensification for environmental management
- **Track 3**: Ecotoxicology, environmental safety, and bioremediation
- **Track 4**: Biotechnology for environmental management
- **Track 5**: Climate-change-related effects on ecosystems
- **Track 6**: Natural resources, agriculture, and the environment
- **Track 7**: Smart technologies for environmentally friendly energy production
- **Track 8**: Remote sensing and GIS for environmental monitoring and management
- **Track 9**: Environmental impacts of natural hazards and environmental risk assessment
- **Track 10**: Sustainable management of marine and coastal environments
- **Track 11**: Sustainable management of the urban environment, the indoor, and built environment
- **Track 12**: Ecosystems and biodiversity conservation
- **Track 13**: Environmental-change-related impacts on human, animal, and ecosystem health
- **Track 14**: Other related topics

Satellite Tracks

- **Track 15**: Special Session: Social and environmental impacts of land use changes in the Amazon
- **Track 16**: MUNA Satellite Event: Conservation and sustainable use of Mediterranean biodiversity

These tracks highlighted both regional and global environmental challenges while addressing specific areas such as marine conservation, urban sustainability, and the cross-sectoral impacts of climate change. The inclusion of satellite tracks emphasized EMCEI's commitment to exploring the environmental effects of land use changes in global contexts, like the Amazon, and reinforcing biodiversity conservation efforts in the Mediterranean region.

A notable highlight of EMCEI 2023 was the celebration of the first impact factor of the *Euro-Mediterranean Journal of Environmental Integration*, published by Springer Nature. This milestone underscores the journal's growing influence and its role in advancing environmental science. In support of the conference, the journal will publish a special issue featuring selected papers from EMCEI 2023, further disseminating the innovative research presented and enhancing its impact within the scientific community.

The conference provided a unique opportunity for participants to engage with leading scientists, attend keynote presentations, and collaborate across disciplines. The integration of these diverse themes enriched the dialogue and promoted innovative solutions to environmental issues.

In addition to the scientific program, participants enjoyed a rich social and cultural experience, exploring the historic sites of Cosenza in the Calabria region of southern Italy, further enhancing the collaborative spirit of the conference.

The **book of proceedings will be published in two volumes**, reflecting the diverse and multidisciplinary contributions of over 600 research papers. This two-volume collection will encompass a broad spectrum of cutting-edge research aimed at addressing environmental challenges in the Euro-Mediterranean region and beyond.

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Saint John, Canada	Ikrema Hassan
Pisa, Italy	Nicola Perilli

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This two-volume proceedings book represents a significant step forward in environmental research and cooperation, and we hope it will inspire further efforts to protect and preserve our shared environment.



5th Euro-Mediterranean Conference for Environmental Integration (EMCEI 2023), University of Calabria, Rende (Cosenza), Italy, October 2nd to 5th, 2023 (https://2023.emcei.net/)

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Ikrema Hassan	Ontario, Canada
Nicola Perilli	Pisa, Italy

About the 5th Euro-Mediterranean Conference for Environmental Integration (EMCEI—Italy 2023)



Currently, the Euro-Mediterranean region is facing not only significant political, economical, and social challenges but also an ever-growing environmental degradation that have made environmental and resource protection an increasingly critical issue. These issues have re-energized the debate on the Euro-Mediterranean integration process through concrete cooperative projects in many sectors, especially those concerned with environmental awareness, assessment, and improvement. This integration process is intended to make decision-makers from related sectors aware of the importance of integrating environmental considerations into their respective activities. To reach this goal, the development gap between the northern and southern coasts of the Mediterranean should be reduced and new and closer political, economical, social, cultural, and, most importantly, scientific ties between these two shores should be created founded on common concerns.



In this context, and with the specific aim to promote Euro-Mediterranean scientific partnership so as to develop and integrate environmental research and findings into the activities of related sectors in the region, a group of Euro-Mediterranean scientists have recently launched the *Euro-Mediterranean Journal for Environmental Integration*. This journal (published by Springer and owned by the University of Sfax, Tunisia), which started in 2016, has been now indexed in the Web of Science and Scopus. It offers a scientific platform for presenting and discussing the latest advances in research with a focus on emerging environmental issues and challenges in the region. In particular, this first regional journal from the Euro-Mediterranean, encompassing all disciplines of the earth and environmental sciences, seeks to make societies and decision-makers from related sectors aware of the importance of integrating environmental considerations into their respective activities. In this context, the journal provides a scientific forum that promotes the exchange of knowledge and fosters collaborations to improve the consistency of environmental management efforts between the countries of the northern and southern shores of the Mediterranean.



To further strengthen Euro-Mediterranean environmental integration, the journal's editorial office at the University of Sfax (Tunisia), in collaboration with other Euro-Mediterranean universities, continued the success of the 1st (EMCEI-2017), 2nd (EMCEI-2019), 3rd (EMCEI-2021), and 4th (EMCEI-2022), and organized the 5th (EMCEI-2023), in close collaboration with the University of Calabria (Rende, Italy), Springer (as publishing partner), and several partners in the region. The conference aimed to gather new research contributions from all disciplines of earth and environmental sciences by scientists from diverse backgrounds and thus makes an essential contribution toward ensuring that science and knowledge contribute to the promotion of a more sustainable environment for the Euro-Mediterranean and surrounding regions.

Conference Tracks

The 5th EMCEI invited research papers on all cross-cutting themes of the environmental sciences and engineering, with a main focus on the following 16 conference tracks:

- Track 1. Engineering applications for environmental management
- Track 2. Process control, simulations, and intensification for environmental management
- Track 3. Ecotoxicology, environmental safety, and bioremediation
- Track 4. Biotechnology for environmental management
- Track 5. Climate-change-related effects on the environment and ecological systems
- Track 6. Natural resources, agriculture, and the environment
- Track 7. Smart technologies for environmentally friendly energy production
- Track 8. Remote sensing and GIS for environmental monitoring and management
- Track 9. Environmental impacts of natural hazards and environmental risk assessment
- Track 10. Sustainable management of marine and coastal environments
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- Track 14. Other related topics
- Track 15. Special Session: Social and environmental impacts of land use changes in the Amazon
- Track 16. MUNA Satellite Event: Conservation and sustainable use of Mediterranean biodiversity

The dynamic four-day conference provided more than 600 in-person and online attendees with opportunities to share their latest unpublished findings and learn the newest environment studies. The event also allowed attendees to meet and discuss with the journal's editors and reviewers.

More than 1700 short contributing papers to the conference were submitted by authors from more than 80 countries. After a pre-conference peer review process by more than 800 reviewers, 606 papers were accepted. These papers were published as chapters in two volumes of the conference proceedings by Springer.

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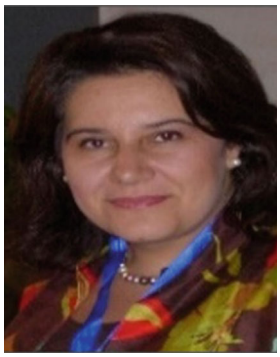
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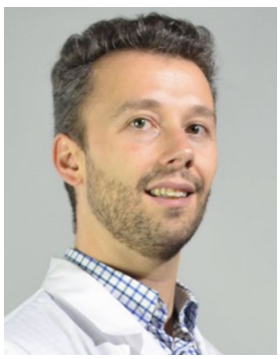
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About the Editors



Giulia Guerriero Department of Biology, University of Naples Federico II, Naples (Italy), Italy.

Giulia Guerriero, Ph.D. is Associate Professor and Advisory Board Member for the Interdepartmental Center for Environmental Research and the Inter-university "Center for Studies on Bioinspired Agro-Environmental Technology" at the University of Naples "Federico II," Italy. She has published over one hundred research studies focused on the development and validation of oxidative stress biomarkers for noninvasive biomonitoring, bioconservation, and bioremediation assessment; on the determination and monitoring of physiological fertility defenses; and on biological pollution and biodiversity control. Principal investigator in national and international projects, she has established a consolidated network of relationships in important research institutes in Europe, Africa, Asia, and in the USA. She has organized and participated in international conferences. She is currently serving as Editor in several journals and books. Since 2021 she is Coordinator of the Mediterranean and Middle East Universities Network Agreement (MUNA) on the Board of Coordinators, Co-editor of *Recent Advances in Environmental Science from the Euro-Mediterranean and Surrounding Regions* and Chief Editor (topic: Biodiversity Conservation for Ecosystem Sustainability) of the journal *Euro-Mediterranean Journal of Environmental Integration.*



Guillermo Rey-Gozalo Universidad de Extremadura, Cáceres, Spain.

Guillermo Rey-Gozalo is a lecturer and researcher with the Lambda group, Department of Applied Physics, INTERRA, Polytechnic of School, University of Extremadura (Spain). His main research focus is environmental acoustics, although he has also conducted significant studies on the characterization of materials with acoustic properties. He has carried out research in various countries, including Spain, Chile, France, Portugal, Mexico, and Ecuador, among others. Despite his young age, he has led several competitive research projects at the international, national, and regional levels. The results of these studies have been published in high-impact JCR journals and presented at various international and national conferences.



Dr. Ahmed M. El-Kenawy Mansoura University, Mansoura, Egypt.

Dr. Kenawy is an assistant professor of Climatology at Mansour University, Egypt. He has authored or co-authored more than 90 peer-reviewed contributions, 3 books, and 6 book chapters, with almost 4600 citations and a Hirsh index of 38 (Google Scholar). His research focuses on assessing, attributing, and projecting climate extremes in arid and semi-arid regions and their socioeconomic and environmental implications. The research that Dr. Kenawy and his collaborators undertake has spanned the Arabian Peninsula, Syria, Iraq, and Jordan in the Middle East, North Africa (Libya and Egypt), and Ethiopia, throughout Spain and also South America: a testament to the global reach and application of his research activity. He has also acted as a reviewer for more than 45 leading SCI journals in the area of climatology, hydrology, and environmental sciences. He acts as a member of the editorial board for a range of SCI journals (e.g., *Hydrosphere*, *Journal of Water and Climate Change*, *Scientific African*, the *Open Atmospheric Sciences Journal*).



Prof. Riheb Hadji Setif 1 University, Algeria.

Prof. Hadji is a distinguished researcher and full professor at the Department of Earth Sciences at Ferhat Abbas University, Setif 1, Algeria. Specialized in applied geology, he has made significant contributions to the fields of geology, environmental earth sciences, and geotechnical engineering. As the head of the Laboratory of Applied Research in Engineering Geology, Geotechnics, Water Sciences, and Environment, Prof. Hadji leads critical research initiatives focusing on natural hazards, groundwater studies, and environmental impact assessments. He has an extensive academic background, holding a Ph.D. in Geology from the University of Annaba. With over 160 papers, 200 international conference participations, and more than 80 contributions to HDR and doctorate dissertations, his academic influence is profound. Professor Hadji has been recognized with numerous awards, including the Scopus Award for Best Researcher in Algeria in Earth and Planetary Sciences in 2022 and 2023. His editorial roles include serving as an associate editor for EMJEI. With a strong focus on applied geology and environmental sciences, Prof. Hadji continues to contribute to the advancement of geosciences through his research, teaching, and editorial work.



Dr. Haroun Chenchouni Higher National School of Forests, Khenchela, Algeria.

Dr. Haroun Chenchouni is an accomplished ecologist, currently serving as an associate professor and a research scientist at the Higher National School of Forests in Khenchela, Algeria. With a rich academic background, he previously held the position of Associate Professor at the University of Tebessa in Algeria. Dr. Chenchouni earned his doctorate degree in Ecology and Environment from the University of Batna 2, Algeria, and holds a Master of Science (Magister) in Dryland Ecology from the University of Ouargla, Algeria. Additionally, he completed his graduate studies as an engineer specializing in Plant Ecology and Forest Ecosystems at the University of Batna, Algeria. Dr. Chenchouni's research interests span a wide range of ecological disciplines. He employs advanced statistical modeling techniques to unravel the complex relationships between natural environments, including climatic and edaphic factors, and the impact of human activities on biological interactions and biodiversity. His work sheds light on the dynamics of populations and the complexities of community diversity within arid and semi-arid ecosystems of North Africa. Beyond his research endeavors, Dr. Chenchouni is deeply committed to education. He imparts his knowledge and expertise to students across various Algerian universities, teaching courses on biostatistics, soil biology, forest ecology, and ecological modeling. Dr. Chenchouni's contributions to the field are substantial, with over 150 peer-reviewed publications and internationally recognized research papers to his name. He actively participates in both national and international research projects, demonstrating his dedication to advancing ecological understanding on a global scale. Furthermore, Dr. Chenchouni serves on the editorial boards of esteemed scientific journals, including the *Arabian Journal of Geosciences*, *Ecological Indicators*, *Frontiers in Environmental Science*, and *Discover Geoscience*, where he contributes his expertise to shaping the scientific discourse in his field.

Arturo Sousa Department of Plant Biology and Ecology, Universidad de Sevilla, Spain.

Arturo Sousa has a Ph.D. in Biology since 2004 and has worked as a faculty member for more than 20 years in the Department of Plant Biology and Ecology (Faculty of Pharmacy) at the University of Seville (Spain). He currently teaches different subjects related to pharmaceutical botany and plant biology as an associate professor. He is specialized in the temporal evolution of hygrophytic plant communities, climate change, wetlands, and malaria epidemiology. His research lines, which began with the study of diachronic changes in the hygrophytic vegetation of Doñana (Southwestern Spain), allowed him to establish multidisciplinary collaborations with specialists in limnology, climatology, and atmospheric physics. Such works eventually led him to diagnose the anthropogenic and climatic impacts on wetlands and vegetation of southwestern Europe. Due to his numerous scientific contributions, in 2006, the Iberian Association of Limnology gave him the Award for the Best Doctoral Thesis in Limnology and, in 2020, he also received recognition for his work as a reviewer for different journals, as well as the Cartography Prize of the Nico Rüpke Foundation (Germany). He is a member of the scientific committee of several international conferences, Guest Editor and Topic Editor of *Atmosphere* (MDPI), Associate Editor of *Euro-Mediterranean Journal for Environmental Integration* (Springer) and a member of the Editorial Board of *KN-Journal of Cartography and Geographic Information* (Springer). Moreover, he has co-edited two books of *Recent Advances*

in Environmental Science from the Euro-Mediterranean and Surrounding Regions (3rd Edition 2024 and 4th Edition 2024, 2 volumes). Regular reviewer of 14 indexed journals, as well as of several chapters of the latest IPCC AR6 report on Climate Change and also of the Spanish National Report on Climate Change. His studies about wetlands have led him to analyze, in the last years, the links of inland aquatic ecosystems with endemic foci of autochthonous malaria, as well as the risk of the re-emergence of this disease as a consequence of Climate Change (directing R&D projects funded by competitive public programs, specifically on this topic). He has carried out different post-doctoral stays in German universities and has also worked as Guest Professor at the Technical University of Applied Sciences Würzburg-Schweinfurt (Germany).



Paola Di Carlo PROMISE, Department, University of Palermo, IT, Italy.

Paola Di Carlo is associate professor at the Dipartimento PROMISE (Department of Health Promotion, Mother and Child Care, Internal Medicine and Medical Specialties), Università degli Studi di Palermo. Paola does research in HIV, Tuberculosis and nosocomial infection due to MDR bacteria, climate change and bile microbiota.

Disciplines: Pediatrics Infectious Diseases Skills and expertise Infection Biology Infection Infectious Disease Medicine Mycobacterium Tuberculosis Bioscience Treatment Diagnosis Science 2.0 and Open Access Immunology of Infectious Diseases Immunology Tuberculosis Science Education Antibiotics Science Communication Microbiology Pedagogy and Education Child Health Infection Control Hospital-acquired Infections Pediatric Infectious Diseases Dieli Francesco Infectious Diseases Infectious Disease Epidemiology Tropical Diseases Cross Infection.

Languages: English

Contact information paola.dicarlo@unipa.it



José Lopes Velho Aveiro University, Aveiro, Portugal.

José Lopes Velho graduated in geology from the University of Coimbra. He is an associate professor at the Department of Geosciences at the University of Aveiro in Portugal. He holds a master's degree in economics and applied geology from the University of Lisbon and a doctor's degree in geosciences, specializing in mineralogy, from the University of Aveiro. He is a member of the Industrial Minerals and Clays Research Unit. He published 23 papers in international journals (Scopus h-index 8).



Dr. Ikrema Hassan University of New Brunswick, Saint John, Canada.

Dr. Hassan is an environmental engineering professor specializing in sustainable environmental and geoenvironmental solutions. His research focuses on ground improvement and the remediation of soil and groundwater, with an emphasis on minimizing disturbance to subsurface conditions. Dr. Hassan's expertise includes experimental design, data analysis, mathematical modeling, and the use of electrokinetics for heavy metal and petroleum hydrocarbon contamination remediation. Notably, Dr. Hassan has developed an innovative technique to enhance heavy metal removal via electrokinetics, powered by solar energy. His work leverages solar power as a sustainable and cost-effective solution, particularly for remote or abandoned sites lacking electricity.



Nicola Perilli University of Pisa, Italy.

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Climate-Change-Related Effects on the Environment and Ecological Systems

Assessing of Wind and Wave Climate Changes in Iskenderun Bay (Southeastern Turkey) During 1971–2021

Egemen Ander Balas and Lale Balas

Abstract

The eastern Mediterranean region is highly vulnerable to rising sea levels due to climate change affecting adjacent areas and moderately shallow depths. Specifically, the southeastern coast of Turkey is experiencing notable impacts from climate change, including alterations in wind and wave patterns that contribute significantly to sea level rise. This study focuses on Iskenderun Bay to evaluate the influences of wind and wave climate changes on the southeastern coast of Turkey. Long-term analyses of changes in sea level, storm surges, and wind and wave climates in the bay were performed using the 50-year database between the years of 1971 and 2021 obtained from the European Centre for Medium-Range Weather Forecasts Reanalysis (ECMWF ERA-5) and shoreline meteorological stations. The three-dimensional hydrodynamic model HYDROTAM-3D, a GIS-based cloud computing system, enabled long-term statistical analysis and climate studies of wind and wave. The study modeled the percentage rises in sea level, significant wave height, storm surge, and wind speed for Iskenderun Bay, indicating increases in average and maximum wind speeds by 17% and 23%, respectively. Statistical analysis of wave data indicated a 7% reduction in yearly calmness. Hydrodynamic modeling showed a 13% rise in storm surge heights and an average sea level increase of 1.2 mm annually in Iskenderun Bay throughout the study. Modeling these impacts and mitigating rising sea levels necessitate effective local, national, and worldwide management efforts.

Keywords

Climate change · Coastal vulnerability · HYDROTAM-3D model · Sea level rise · Wind and wave climate

1 Introduction

Iskenderun Bay, situated in the eastern Mediterranean region of Turkey (Fig. 1), is known for its ecological significance with surrounding wetlands and diverse biodiversity. It is also a hub for economic activities, facilitated by Iskenderun Port, supporting trade and various industries. Due to its shallow and narrow nature, the bay is particularly susceptible to the effects of climate change, such as rising storm surge heights and sea levels caused by the increasing frequency and intensity of extreme weather events.

Several studies have assessed the potential impacts of sea level rise on the Mediterranean Sea (Calafat et al. 2022), like coastal erosion, coastal inundation, saltwater intrusion, and infrastructure vulnerability. Climate change manifests in rising temperatures, increasing heat stress in the Iskenderun Bay's ecosystem. The highest sea surface temperature change in the bay over 1982–2015 was determined in the June–July-August season in the northern part of the Bay as 1.5 °C (Gucel and Sakallı 2018). The State Meteorological Works (Demircan et al. 2014) has projected the sea level rises for the scenario of RCP8.5 in light of the increasing concerns regarding climate change impacts. This scenario accounts for global temperature rise, extensive land use changes, the absence of climate stabilization measures, high greenhouse gas emissions, and rapid population and economic growth. The results suggest a potential maximum temperature increase of up to 6 °C and a 50% decrease in summer precipitation in Southeastern Anatolia (Demircan et al. 2014).

E. A. Balas
Faculty of Engineering, Başkent University, Ankara, Türkiye

L. Balas (✉)
Sea and Aquatic Sciences Application and Research Center, Gazi University, Ankara, Türkiye
e-mail: lalebalas@gmail.com

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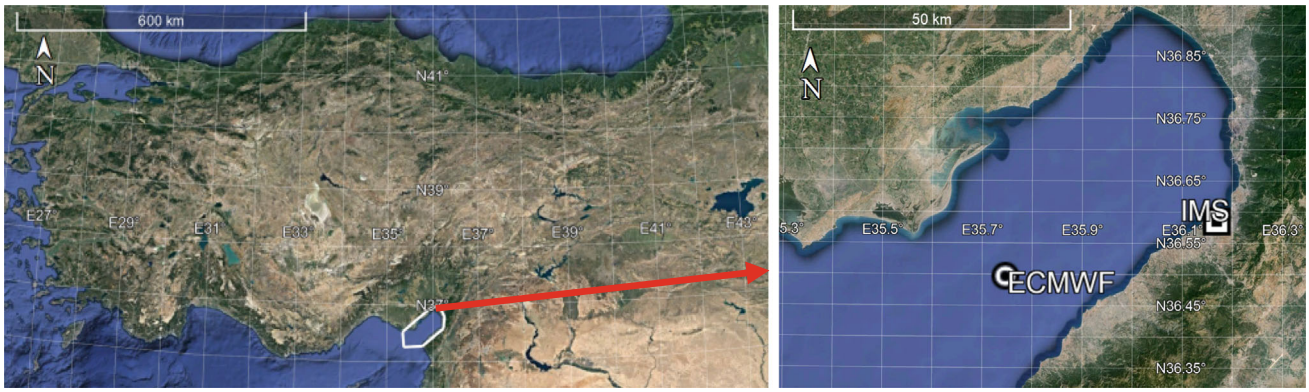


Fig. 1 Location of Iskenderun Bay, Iskenderun Meteorological Station (IMS), and European Centre for Medium-Range Weather Forecast Station (ECMWF-ERA5) (HYDROTAM-3D 2023)

2 Methodology

The wind climate, wave climate, and hydrodynamic modules of HYDROTAM-3D (DTLM Software Technologies, Gazi Technopark, Türkiye), the three-dimensional hydrodynamic transport and water quality model (Balas and Özhan 2002) were employed to determine the climate change impacts on the Iskenderun Bay. The sub-model of wind climate performs long-term log-normal and extreme gumbel statistical analyses of wind data (continuous hourly time series of wind speed, direction, and duration) for the Iskenderun Meteorological Station (IMS, at 36.588° N–36.172° E) for the years 1971–2021 and examines wind at 10 m and wave data (continuous six hourly time series of wind speed, blowing direction, and duration, and wave height, period, and propagation direction) provided by the European Centre for Medium-Range Weather Forecast Reanalysis (ERA5) database of 36.5° N–35.75° E coordinate (Fig. 1) between the years 1971–2021. ERA5 database has a 0.25° horizontal resolution (Hersbach et al. 2020). Changes in wind and wave climates have been investigated in two periods. The first period covers hourly wind measurements between 1971–1991, and the second covers hourly wind measurements between 1991–2021.

3 Results

The wind roses based on ECMWF-ERA5 data for the first (1971–1991) and second (1991–2021) periods are provided in Fig. 2a, b, respectively. The dominant wind direction is the southwest to west-southwest, averaging 4 m/s and reaching a maximum of 13 m/s wind speed in the first period. There are seasonal changes in the wind climate. It is seen that during winter and autumn periods, winds blow dominantly from the east-northeast directions. The frequency of winds blowing from the dominant southwest direction increased from 6% to 25% in the last thirty years. The maximum wind speed increased to 16 m/s, and the mean speed increased to 5 m/s, blowing from the southwest.

The ECMWF-ERA5 data analyses reveal an upward trend in wind predictions over the sea, with the second period showing a 23% increase in maximum wind speed and a 17% increase in average wind speed compared to the first period (Fig. 2). The wind roses based on the IMS measurements (on land) for the first and second periods are given in Fig. 3a, b, respectively. The long-term statistical analyses of IMS wind measurements using log-normal distribution indicate an average of 21% increase in maximum wind speed and a 14% increase in mean wind speed in the second period compared to the first. According to the long-term hydrodynamic modeling by HYDROTAM-3D, the sea level in the bay increases by an average of 1.2 mm per year during the study period, and the storm surge height increases from 0.59 m to 0.67 m, showing an increase of 13%.

The wave roses based on ECMWF-ERA5 data for the first and second periods are given in Fig. 4a, b, respectively. Log-normal wave statistics show that the annual calmness rate (significant wave height Hs < 0.5 m) in the first period decreases by 7% from 60.1% to 55.8% in the second period.

The analysis reveals seasonal decreases in the annual calmness rate (significant wave height Hs < 0.5 m) of 1.5, 4.4, 16.2, and 6.3% for winter, spring, summer, and autumn, respectively, with the most substantial increase in wave height observed during summer. The dominant wave propagation direction is west-southwest by 16% and 18% of annual occurrences in the first and second periods, respectively.

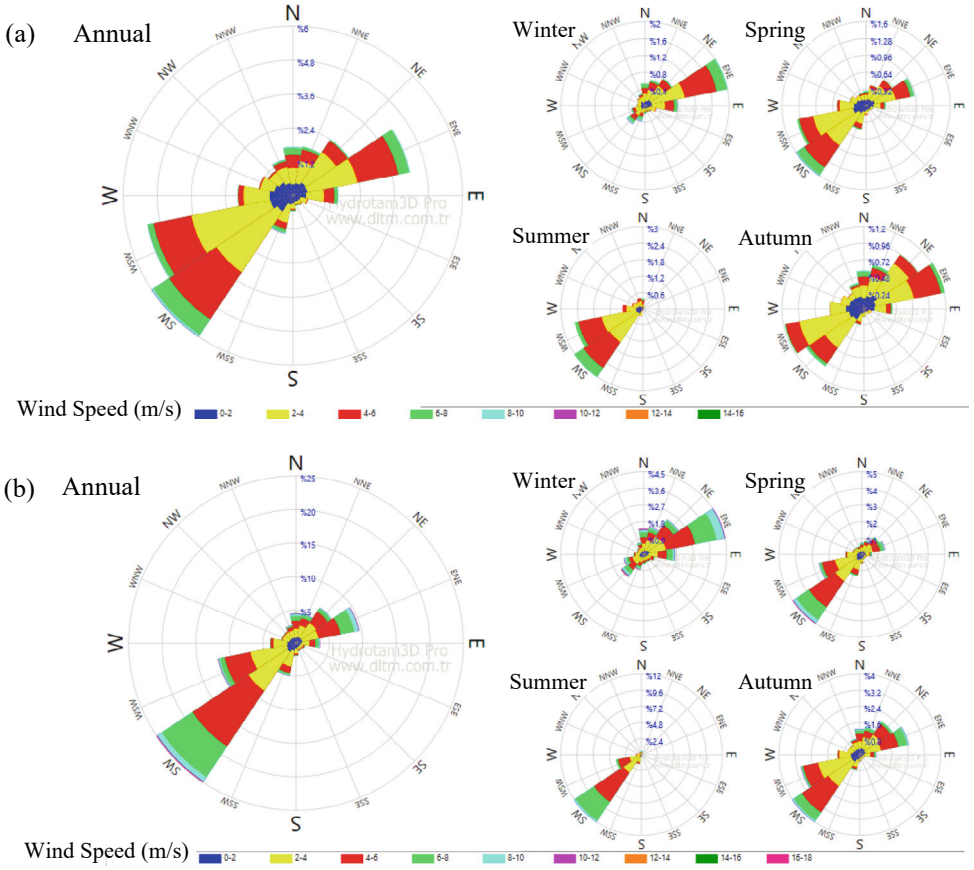


Fig. 2 Annual (left) and seasonal (right) wind roses based on the ERA5 database for **a** first period (1971–1991) and **b** second period (1991–2021) (HYDROTAM-3D 2023)

4 Discussion

The study reveals the alteration in wind and wave climate, notably a decrease in the annual calmness rate and an increase in the wind speeds and wave heights, particularly in the summer months. Similar observations in other Mediterranean regions have been linked to changing wind patterns and increased frequency and intensity of extreme weather events. The shift toward a dominant southwest wind direction and increase in wind speeds aligns with studies in the Mediterranean, indicating alterations in temperature gradients and large-scale atmospheric dynamics. The identified rise in sea level and storm surge in the bay is comparable with global trends and elevates the risk of coastal flooding, impacting urban and natural environments.

5 Conclusions

This research delivers essential insights into the localized impacts of climate change on Iskenderun Bay, emphasizing the interdependence between global and regional climate systems. The observed changes in wind and wave climates and alterations in hydrodynamics pose significant implications for Iskenderun Bay's ecosystem, coastal infrastructure, and local communities. The observed changes in wind and wave climate and hydrodynamics underline the need for adaptation measures to protect coastal areas. Integrating these findings into broader discussions on climate change impacts in the Mediterranean and globally is essential for informed policymaking and sustainable management of coastal environments.

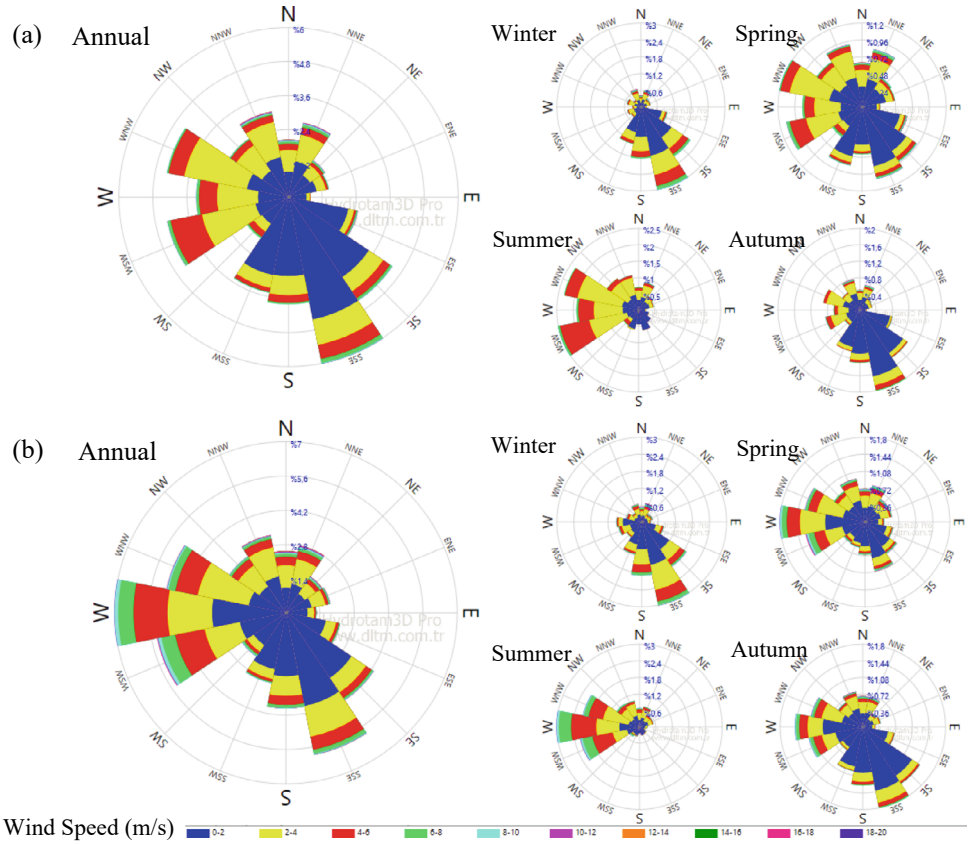


Fig. 3 Annual (left) and seasonal (right) wind roses based on the IMS measurements for **a** first period (1971–1991) and **b** second period (1991–2021) (HYDROTAM-3D 2023)

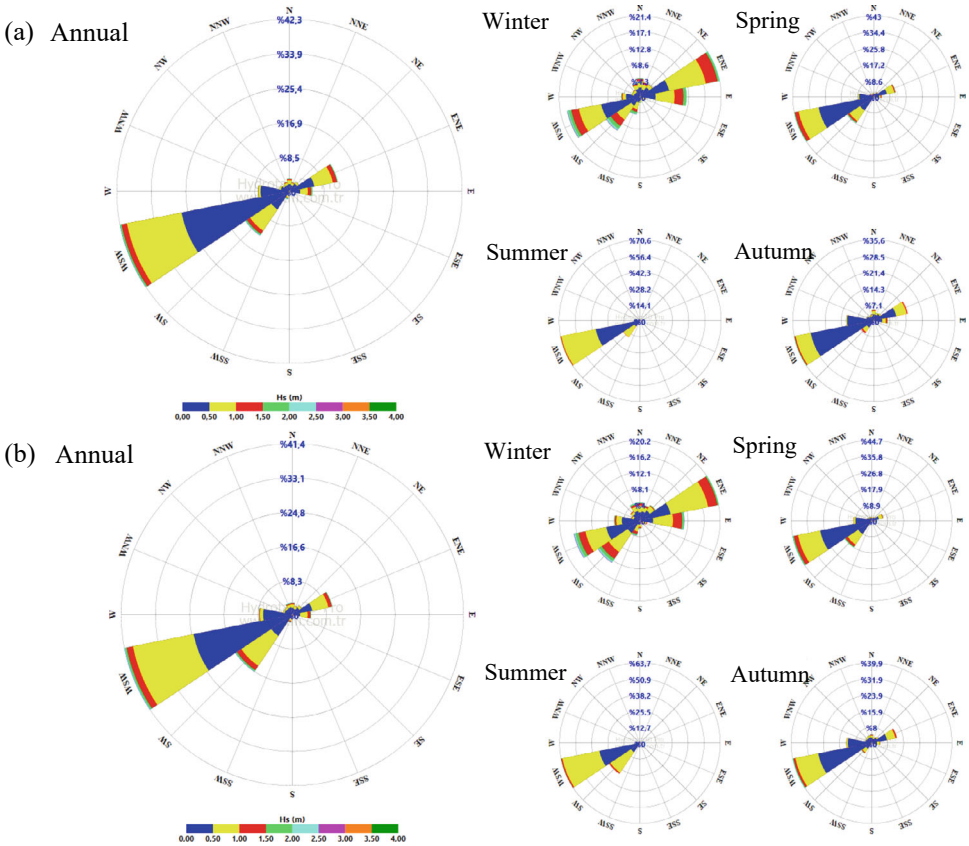


Fig. 4 Annual (left) and seasonal (right) wave roses based on the ERA5 database for **a** first period (1971–1991) and **b** second period (1991–2021) (HYDROTAM-3D 2023)

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Effect of Climate Change on Discharge Data in Tunisia's Semi-arid Region

Khaoula Khemiri and Khlifa Maalel

Abstract

The quantification of water inputs under various climatic conditions has always been the focus of scientific hydrological research. This work focuses in particular on the influence of climate change on river flow in central Tunisia, more particularly the watershed of Oued Merguellil. The tools used consist of the ITA method: "Innovative Trend Analyses", over two consecutive periods spanning approximately two decades each (P1: 1975–1995; P2: 1996–2017).The observed discharge data belonging to the two stations Skhira and Haffouz were considered and processed. The results obtained show that seasonal and annual flows increase upstream of the basin and decrease downstream. However, the winter and summer discharges of period P1 behave inversely. The discharge in period P2 showed a general downward trend. For extremely high discharges, only the Skhira station showed a significant increase in period P1. Finally, it is shown that the last twenty years clearly illustrate a reduction in water intake by up to 40%. This certainly had an effect on the wadi's flow, the water supply in the reservoirs and the water stocked in general. The real situation on the ground proves this concretely through, among other things, the content of the reports as well as the conflicts between communities and local services. In conclusion, discharge continues to serve as a critical parameter and a key indicator to inform decisions for both decision-makers and practitioners in the context of current and future climatic conditions. This approach will contribute to the sustainable management of water resources.

Keywords

Discharge · Tunisian semi-arid · Analysis of trends · Innovative trend analysis

1 Introduction

Climate change "CC" refers to a statistically significant variation in the average state of the climate or its persistent variability over an extended period of time. Usually two decades or more should be considered (PNUE/OMM 2011). One of the most important challenges for scientists today is studying the impact of CC. Indeed, the expected results can enlighten development sectors and decision-makers on the scale of threats and risks run through the twenty-first century (Jebari et al. 2017). The manifestations are interpreted by climatologists as trends continue to rise, global warming signifies an ongoing and consistent elevation in temperatures coupled with changes in precipitation regimes (Li and Fang 2017). Thus, direct or indirect hydrological effects are observed. This is seen in the abnormally low level of supply to rivers and/or surface or underground reservoirs as mentioned by Zaharia et al. (2018). We propose as a study area in this work, the central region of Tunisia. The wadi in question is the main river in the Merguellil watershed. Thus, we seek to detect the trend of long-term discharges of Oued Merguellil by looking at annual, seasonal, maximum and minimum daily discharges. The expected results could shed light on the evolution of stocks and water discharges in the Merguellil watershed. This type of information helps to better guide the development of land and strategies for conserving water, along with the sustainable governance of water resources.

K. Khemiri (✉)
National Research Institute for Rural Engineering, Water and Forestry, Tunis, Tunisia
e-mail: khemiri.khaoula@gmail.com

K. Khemiri · K. Maalel
National Engineering School of TUNIS (ENIT), University of Tunis El Manar, Tunis, Tunisia

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2 Materials and Methods

2.1 Study Area

The Merguellil watershed is situated in central Tunisia, encompassing an area spanning 1183 km^2. Constructed in 1989, the El Haouareb dam, represented by its natural outlet (Fig. 1), is the primary drainage channel for most of the basin (Bouzaiane and Laforgue 1986). The altitude within this hydrological unit ranges from 200 to 1200 m, with an average elevation of 500 m, as depicted in Fig. 1. This watershed falls within a semi-arid region. It experiences convective storms, particularly in summer and fall. This provides an illustrative example of hydrological processes affected by climate change (Kingumbi 2006; Slimani et al. 2007; Chergui et al. 2018). The observation stations installed for a long time within this hydrological unit allow the study and characterization of various climatic episodes, whether linked to flash floods or to long droughts. Annual rains are low, not exceeding 220 mm downstream and 420 mm upstream. These rains are characterized by intense events, especially in spring and autumn, leading to floods (Ogilvie et al. 2016). The maximum flow estimated during the September 1969 event reached a volume of 3000 m^3/s at the Haffouz location (Hamza 1988). In general, the flow of the wadi is characterized by extreme spatiotemporal variability. The runoff decreases from upstream to downstream, with an annual average equal to 32 mm in the Skhira station, 30 mm in Haffouz and 21 mm in the El Haouareb dam station (Kingumbi 2006). The annual siltation rate of the El Houarreb dam is on average equal to 15.61 t/ha/year (DG/BGTH 2011). This implies that the Merguellil watershed presents an area vulnerable to degradation of the agricultural landscape.

2.2 Description of Available Hydrological Data

The discharge data used come from observations made at the Skhira and Haffouz stations. They are obtained from the hydrological directories of the Directorate General of Water Resources (D.G.R.E). These two stations are selected because of their locations within the study basin and the availability

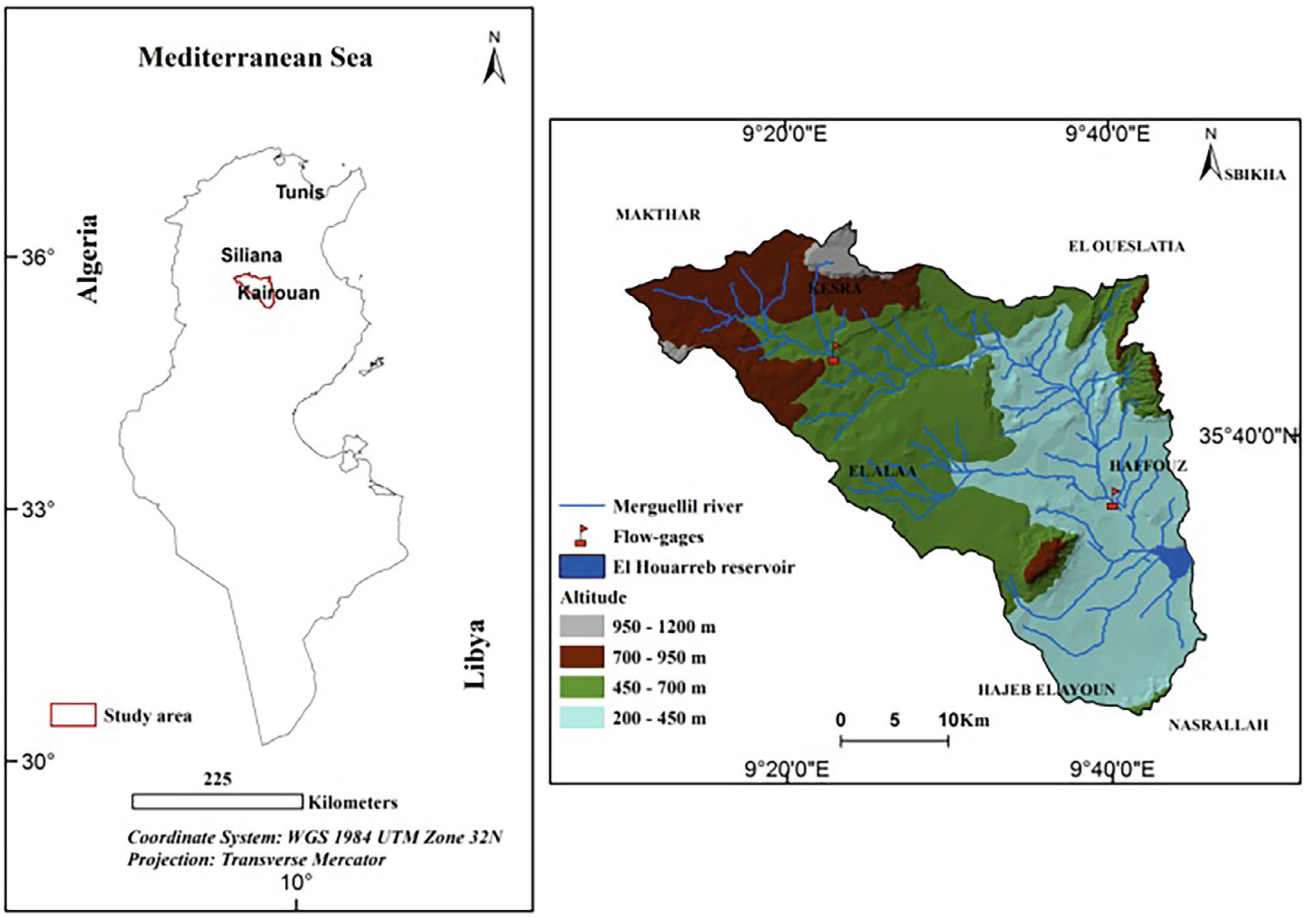


Fig. 1 Topographic of the Merguellil watershed

of their data over long periods of time (Fig. 1). Data gaps are less than 3%. Their homogeneity is controlled by the double mass curve. The missing data is filled in using the multiple regression method adopted by Roudier and Mahe (2010). The collected data is being prepared for analysis, with a specific focus on quantitatively assessing the influence of climate change on discharge. The methodology employed involves the examination of two consecutive periods, each spanning approximately two decades (P1: 1975–1995; P2: 1996–2017). This approach offers a substantial dataset for understanding the effects of climate change and enables a comparative analysis of hydrological conditions between the two study periods.

2.3 Analysis of Flow Trends

The identification of the flow trend in this study considered the ITA method: "Innovative Trend Analyses" proposed by Şen (2012, 2015). Indeed, it offers more advantages compared to traditional statistical tools. Its graphic illustration presents more details by characterizing the extreme events. The procedure involves splitting the recorded discharge data into two equal segments. These two subsets are then individually sorted in ascending order. Subsequently, the values of the first subset (x_i) are plotted along the horizontal axis, while the values of the second subset (x_j) are plotted along the vertical axis, using a two-dimensional Cartesian coordinate system (Şen 2012, 2015).

For estimating the rate of the trend, the T_{ITA} trend indicator is calculated by Eq. 1

$$T_{\mathrm{ITA}} = \frac{1}{n}\sum_{i=1}^{n}\frac{10\left(X_j - X_i\right)}{\mu} \tag{1}$$

where "n" represents the sample size, "x_i" and "x_j" denote the data series corresponding to the first and second halves of the time series, respectively. "μ" signifies the mean of the data series from the first half of the time series. To apply the ITA method in this research, an open-source "trend change" library has been developed using the R programming language. This library is accessible through the CRAN repository.

3 Results and Discussion

The results of the assessment of annual discharge trends during the two observation periods (P1: 1975–1995; P2: 1996–2017) using the ITA method at the Haffouz and Skhira stations are presented in Table 1. During P1, the Skhira station experienced a notable and upward trend in the annual mean discharge, whereas the Haffouz station exhibited a significant downward trend. In contrast, during P2, both stations displayed a significant annual decrease in discharge. On a seasonal scale, the trend is generally downward. Autumn and spring are the most affected for both period P1 and P2. The values of the extreme discharges (max & min) show an increasing trend during the period P1. During period P2, the significant trend was downward. Consequently, we are observing that we are in a progressive context of reduction of contributions. This reduction is on average equal to 40.4% over the last twenty years. This confirms certain studies undertaken previously and mentioning reductions of up to 40% in the annual balance sheet of inflows into the outlet of the basin, via the observation of the El Haouareb dam. (e.g., Bouzaiane and Laforgue 1986; Dridi 2000; Kingumbi 2006). Therefore, this work underscores the significance of discharge data in discerning the influence of climatic conditions in the Tunisian semi-arid. Moreover, this study comes to assess the importance of the continuous research, started in the Merguellil watershed since the early 1980s. The aim is to provide guidance to those responsible for rural development in crafting water management and economic models that are suitably attuned to climate change. This is intended to help pre-empt situations of water scarcity in the future.

Table 1 Analysis of trends by the ITA method of discharge series for the period (1975–2017)

Time scale/Hydrometric station	P1 (1975–1995)		P2 (1996–2017)	
	Haffouz	Skhira	Haffouz	Skhira
Annual	− 2.07	5.40	− 1.84	− 3.85
Autumn	− 3.24	0.39	− 0.53	0.07
Winter	6.36	14.38	− 6.23	− 8.28
Spring	−3.93	3.41	− 3.22	1.42
Summer	2.54	10.10	2.46	− 5.81
Minimum discharge	− 0.18	9.32	3.31	3.07
Maximum discharge	− 3.31	6.92	− 1.52	− 1.78

4 Conclusions

This study has enabled an evaluation of the influence of climate change on river discharge within the Merguellil watershed. The trend analysis results obtained through the ITA method indicate a substantial decrease in the average annual discharge at the basin's outlet, specifically at the El Houarreb dam, over the last two decades. On average, this reduction amounts to approximately 40%. These findings underscore the significance of discharge as a crucial parameter and a pivotal indicator for informing decisions made by both decision-makers and practitioners in the context of current and future climatic conditions. Ultimately, it is necessary to extend this study to larger areas and to consider more observation stations. This approach will make it possible to validate both the methodology undertaken and the results obtained. Finally, these results could be considered as inputs within management models to guide the supply, use and management of water in the near future.

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Impacts of Climate Change on Standardized Precipitation, Evapotranspiration, and Groundwater Indices: A Comprehensive Study in Semi-arid Tunisia

Emna Gargouri-Ellouze, Fairouz Slama, Hammouda Dakhlaoui, and Rachida Bouhlila

Abstract

Numerous studies indicate an escalating frequency of drought events characterized by varying intensities and durations ranging from one month to several years. Effective drought monitoring is crucial for adapting groundwater management strategies to climate change. This study focuses on three selected semi-arid regions in Tunisia (Kélibia, Kairouan, and Kasserine) and employs three key indices—SPI (Standardized Precipitation Index), SPEI (Standardized Precipitation Evapotranspiration Index), and SGI (Standardized Groundwater Index). The objectives encompass calculating these indices, assessing correlations between SPI (or SPEI) and SGI, projecting SPI and SPEI over multiple time horizons under climate change, and predicting SGI evolution based on these correlations. Projections for precipitation and evapotranspiration utilize two climate models (RCM-GCM) and two greenhouse gas emission scenarios (RCP4.5 and RCP8.5) across two temporal horizons—medium term (01/01/2040–31/12/2069) and long term (01/01/2070–31/12/2099). The calculated indices unveil a dynamic pattern of alternating wet and dry periods. Notably, SPI/SPEI and SGI computations reveal a temporal offset between these indices, with groundwater response exhibiting a phase shift. Ongoing analyses are exploring the correlations between SPI/SPEI and SGI, shedding light on drought projections for Kélibia and Kairouan.

Keywords

Drought indices · Groundwater · Climate models · Climate change · Semi-arid

E. Gargouri-Ellouze (✉) · F. Slama · H. Dakhlaoui · R. Bouhlila
University of Tunis El Manar, National Engineering School of Tunis (ENIT), LR99ES19, Laboratory of Modelling in Hydraulics and Environment (LMHE), Tunis, Tunisia
e-mail: emna.gargouri@enit.utm.tn

1 Introduction

Meteorological drought arises when an area is dominated by dry weather patterns, characterized by little to no precipitation, while hydrological drought manifests as visible water scarcity in streams, reservoirs, and groundwater, typically following prolonged meteorological drought periods. Recognizing groundwater drought as a hydrologic phenomenon has gained prominence (Uddameri et al. 2018), as it has irreversible consequences on aquifers, impacting both groundwater availability and quality. Meteorological droughts contribute to reduced recharge and heightened groundwater extraction, leading to diminished storage and discharge into springs.

Studies indicate an increasing frequency of meteorological droughts, lasting from one month to several years, necessitating vigilant monitoring for short- and medium-term groundwater management. Researchers have proposed various indices for predicting and characterizing droughts, as comprehensively reviewed by (Svoboda and Fuchs 2016).

This study focuses on three selected indices—SPI (Standardized Precipitation Index), SPEI (Standardized Precipitation Evapotranspiration Index), and SGI (Standardized Groundwater Index). Our objectives include calculating these indices in three semi-arid regions in Tunisia (Kélibia, Kairouan, and Kasserine), exploring correlations between SPI (or SPEI) and SGI, projecting SPI and SPEI over diverse time horizons under climate change, and predicting SGI evolution based on these correlations.

2 Materials and Methods

2.1 Material

In this present study, three hydrographs depicting groundwater levels were utilized, positioned in the northern, central, and southern regions of Tunisia. The selection

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of meteorological stations for gathering precipitation and temperature data was made based on their alignment with the influence zones of the designated study sites (Kélibia, Kairouan, and Kasserine). Table 1 provides the coordinates of the stations or piezometers along with the observation periods. Daily mean temperature and precipitation data were extracted from two regional climate models driven by a general circulation model (GCM-RCMs) sourced from the EURO-CORDEX project (http://www.euro-cordex.net/).

EURO-CORDEX offers the latest high-resolution climate projections for the European domain, featuring a resolution of 0.11° (horizontal grid spacing of approximately 12 km). The historical model simulation covers the period 1970–2000. Climate projections extend into future periods, namely 2040–2070 and 2070–2100, with consideration given to two radiative concentration pathways: RCP 8.5 and RCP 4.5.

2.2 Methods

The SPI (McKee et al. 1993) is a straightforward index designed for the calculation of precipitation deficits across various time scales, involving averaging over a sliding window. The computation necessitates monthly records spanning at least 20–30 years, and the index can be calculated for periods ranging from 1 to 48 months. The SPI is determined at a specific location by fitting a probability distribution to a lengthy series of observations, transforming it into a normal distribution to achieve an average SPI of zero for the studied time period (Edwards and McKee 1997). Positive SPI values denote precipitation above the median, while negative values indicate precipitation below the median. The normalization of the index enables the representation of wet and dry climates in a consistent manner (McKee et al. 1993), facilitating the definition of drought event intensity.

Table 1 Data characteristics

Site	Data	Coordinates	Observation period
Kélibia	Precipitation and temperature	Lat 36.850 N long 11.083 E	1970–2019
	Piezometer (Lebna)	Lat 36.691 N long 10.922 E	1996–2019
Kairouan	Precipitation and temperature	Lat 35.569 N long 9.750 E	1968–2010
	Piezometer (Haouareb)	Lat 35.574 N long 9.764 E	1968–2010
Kasserine	Precipitation and temperature	Lat 35.167 N long 8783 E	1976–2005
	Piezometer	On going	–

Similar to the SPI, the SPEI is a drought index developed by (Vicente-Serrano et al. 2010). It incorporates potential evapotranspiration and implicitly considers temperature in its assessment of the water deficit gap, computed as the difference between precipitation and potential evapotranspiration. The calculation methodology aligns with that of the SPI. The SGI, derived from the SPI concept, accommodates variations in the form and characteristics of groundwater level time series. SGI estimation involves a nonparametric normal score transform of groundwater level data for each calendar month (Bloomfield and Marchant 2013). We adopted the 12-month SPI (SPEI), comparing 12 consecutive months with the same period in all previous years of available data. These timescales are typically associated with groundwater levels (Svoboda and Fuchs 2016).

Projections for precipitation and evapotranspiration utilized two climate models (RCM-GCM), namely ICHEC-EC-EARTH_SMHI-RCA4 and MPI-M-MPI-ESM-LR_SMHI-RCA4, alongside two greenhouse gas emission scenarios (RCP4.5 and RCP8.5) over two-time horizons (medium term: 01/01/2040–31/12/2069, and long term: 01/01/2070–31/12/2099). Quantile mapping (QM) was employed for the bias correction of daily precipitation and temperature from the GCM-RCMs. QM aims to align the distribution of climate model data with that of observational data.

3 Results and Discussion

3.1 SPI/SPEI/SGI

The comparison of SPEI and SPI for the same period of observation (see Fig. 1) shows that the duration of wet and dry periods are longer for SPEI. However, the amplitude seems to be equivalent. This is due to the insertion of temperature. The comparison of SPEI12 and SGI12 in Kairouan shows a shift, in the occurrence, due to the lag time of reaction of groundwater (see Fig. 2).

3.2 SPEI Projections

The preliminary analysis shows the two models give similar projections. RCP 8.5 shows longer wet/dry episodes than RCP 4.5. For long-term horizon, RCP 8.5 shows a severe drought which will remain about 15 consecutive years and RCP4.5 reveals rather a longer wet/dry alternance period than medium-term horizon (Fig. 3).

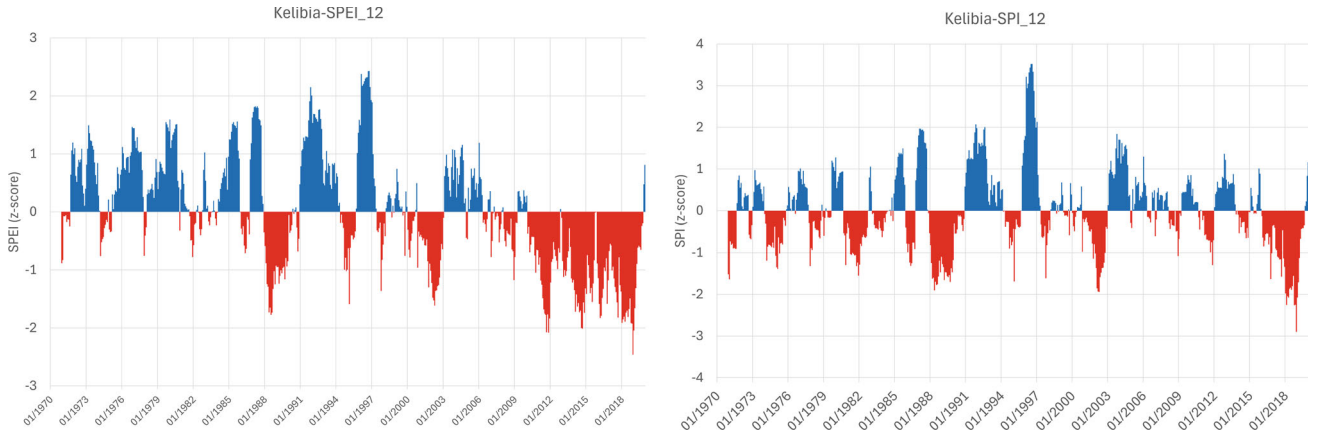


Fig. 1 SPEI and SPI Kélibia station for historical period

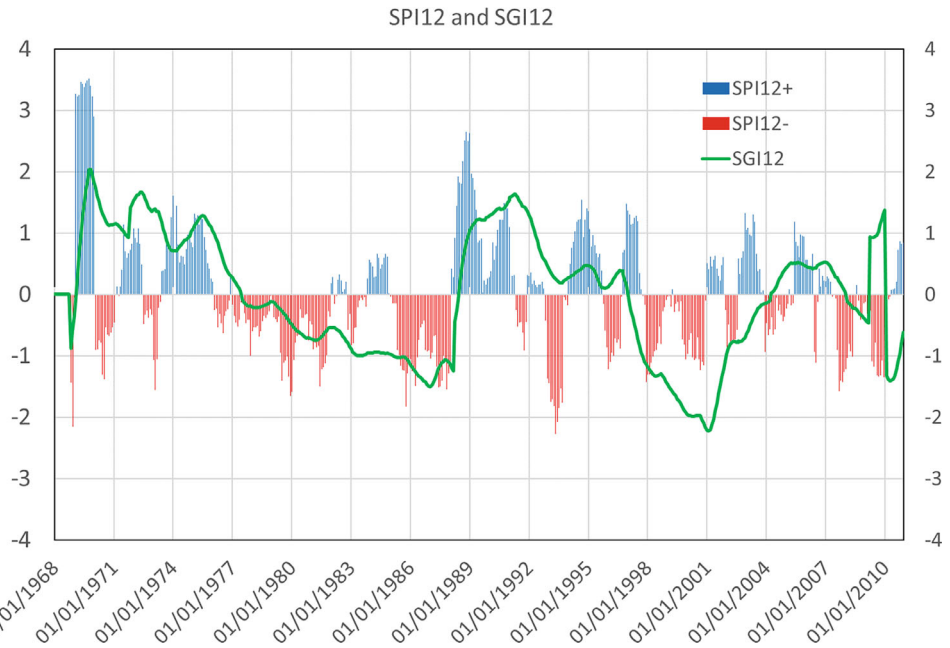


Fig. 2 SPEI and SGI Kairouan station for historical period

4 Conclusions

The SPI/SPEI calculations for Kélibia revealed a pattern of alternating wet and dry periods. An assessment of the relationship between SPEI and SGI unveiled a discernible time shift between the two. This temporal discrepancy is reflected in the groundwater's response, which exhibits a phase shift. To quantify the lag time between SPEI and SGI, a shifting time window will be employed, and their interdependence levels will be calculated using copulas. The approximate estimation of the delay time will be determined by aligning the shifting window with the maximum Kendall's τ between SPEI and SGI.

Furthermore, a comparative analysis of RCP 4.5 and RCP 8.5 for both horizons indicates that RCP 8.5 projects more severe drought conditions than RCP 4.5. Ongoing efforts are directed toward projecting drought under climate change for various regions.

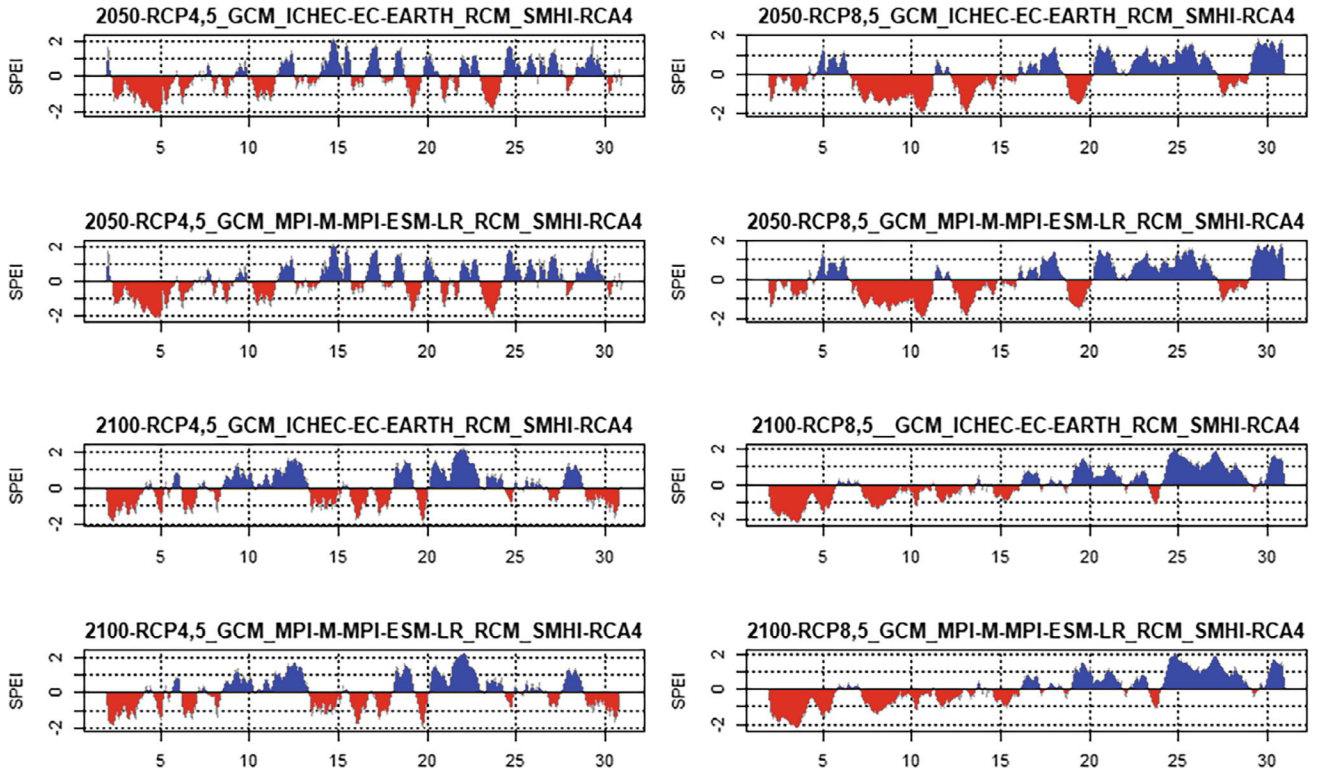


Fig. 3 SPEI projections under two GCM-RCM models ICHEC-EC-EARTH_SMHI-RCA4 and MPI-M-MPI-ESM-LR_SMHI-RCA4 and two scenarios RCP4.5 and RCP8.5 with two times horizons (medium term 2050, and long term 2100)

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Inland Waterway Transport Contribution Reducing Environmental Impact: Case of Neman River in Lithuania

Elena Plotnikova and Milita Vienažindienė

Abstract

- The transport sector is a serious environmental polluter. In connection with the European Union's policy to achieve the aim to be a climate-neutral economy by 2050, much research is being done on the possibility of reducing pollution for road transport. Much less attention is paid to inland waterway transport, although this mode of transport has great potential.
- In this study, we consider a specific positive impact on the environment on the example of Lithuania in the case of a modal shift and move part of the cargo flow from the congested Kaunas-Klaipeda highway to Neman River (part of the E41 TEN-T core network). Using modelling and detailed comparison methods, it was calculated that the amount of external costs could be saved for Lithuanian citizens if inland waterway transport is used instead of heavy vehicles.
- Calculations have shown that an increase in the carrying capacity of the barge, as well as the replacement of diesel fuel with natural gas, can further reduce the external costs. The maximum effect is got due to a significant reduction in external costs of noise, congestion and safety. The positive effect can be increased using alternative energy sources, such as electric vessels.
- In Lithuania, inland waterway transport has experienced difficult times over the past decades, which has led to the almost disappearance of the cargo fleet. In case that electric vessels appear on the Neman, Lithuania can become a unique example of the use of this modern technology. For reliable operation, it is necessary to ensure good navigation conditions on Neman River. In this regard, the article analyzes a number of projects that are currently being implemented by the Lithuanian Ministry of Transport with the financial support of the European Union to achieve navigation conditions that meet international standards.
- In accordance with the fulfilled studies, it can be inferred that rivers should be used more actively as natural transport routes. They can sustainably complement the transportation of goods by other modes of transport. Modern technologies, such as electric vessels, will help make inland waterway transport even more environmentally friendly.

Keywords

Inland waterway transport · Environmental impact · Electric vessels

1 Introduction

Currently, society devotes more attention to environmental problems, which have become more serious. EU has set out the European Green Deal which sets the ambition making Europe the first climate-neutral continent in the world (European Consilium 2023).

Transport activity is one of the world's largest sources of pollution. At the same time, road transport accounts for the highest proportion of emissions—almost 70% of transport pollution. The active use of more eco-friendly types of transport may be one of the future answers to this problem in the face of an inevitable increase in freight turnover (Mako et al. 2021; de Barros et al. 2022). The presence of the underutilized potential of the carrying capacity of rivers is a big reserve for the development of freight transportation by this type of transport (Havinga 2020). More active participation of water transport in the future is advisable. The purpose of this paper is to confirm the benefit of the contribution of inland navigation to reduce environmental impact: case of Neman River in Lithuania.

E. Plotnikova (✉) · M. Vienažindienė
Vytautas Magnus University, Kaunas, Lithuania
e-mail: elena.plotnikova@vdu.lt

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2 Materials and Methods

The external transport costs estimating method was chosen to substantiate the environmental as well as economic benefits of the development of river transport in the Republic of Lithuania. External costs mean the difference between social costs and private transport costs (European Commission 2020). In this paper, we will adopt data from the Handbook on External Costs of Transport compiled by the European Commission in 2019 and carry out our own calculations in the case of the Neman, if the use of river transport in Lithuania will reach the European average.

Detailed calculations of external costs were carried out in comparison with the crowded highway A1 (part Kaunas-Klaipeda) and the inland waterway route along the Neman (the E41 TEN-T core network), provided that created prime conditions for regular navigation on Neman River. This river has the greatest potential for cargo transportation in Lithuania. It belongs to the TEN-T network and passes through two important centres in the country: Kaunas—former capital of Lithuania, the logistics and industrial centre of the region and Klaipeda—one of the largest European ports by tonnage in the Baltic. Therefore, more active use of river transport on this route has significant potential.

3 Results

Comparative calculations of the external transport costs of trucks and river vessels on the section Kaunas-Klaipeda show that the external costs of cargo transport by river are lower, which makes possible to save almost 0.7 €-cents/tkm. Detailed analysis revealed that the essential effect is observed because of very low vessels' noise levels, significantly less air pollution and safety of river transport. For modelling, 3 different variants of possible volumes of cargo transportation for the case of the Neman were considered. Table 1 further assumes a traffic volume scenario of two million tonnes per year (the most realistic volume forecast for the start of traffic).

Presented in Table 1 calculations helped to find out that due to switching to river transport, savings are observed in most categories of external costs (even though in our considering particular case, the distance along the highway is 211 km or along the river is longer—almost 300 km).

Comparison of river and highway external costs for climate change and air pollution proves advantages when using inland waterway transport. Environmental impact calculations show that increasing the tonnage of a vessel from 1000 to 1800 tonnes can reduce greenhouse gas emissions by a quarter. Replacing diesel with gas fuel can do the climate change external costs by up to 25% less. Environmental pollution is minimized using electric vessels.

4 Discussion

An innovation of this article is that we have analyzed and calculated positive effect of using alternative fuels and other energy sources for river transport, which is a very real prospect due to the rapid growth of technologies. These studies were carried out for Lithuania, where inland waterway transport has experienced difficult times in recent decades, which has led to almost complete disappearance of the cargo fleet.

Before 1990 between up to one million tonnes of freight was transported via the Neman from Klaipeda to Kaunas and vice versa. After 1990, river transport started to decline and now almost all cargo is transported by road. However, the situation is changing, there is an increasing

Table 1 Calculations of the reduction of external costs after freight modal shift from the highway to inland waterways for section Kaunas-Klaipeda, €

External cost	Highway A1	Inland waterway E41	Reduction of external costs, €/t	Decrease in external costs
				Realistic scenario of 2 mln. t per year (€/year)
Accidents (safety)	0.004 * 221 = 0.884	0.00031 * 300 = 0.093	0.791	1,582,000
Air pollution	0.00675 * 221 = 1.492	0.00204 * 300 = 0.612	0.87975	1,759,500
Climate change	0.00528 * 221 = 1.1669	0.00292 * 300 = 0.876	0.29088	581,760
Habitat damage	0.002 * 221 = 0.442	0.002 * 300 = 0.6	− 0.158	− 316,000
Noise	0.00465 * 221 = 1.027	Is considered insignificant	1.02765	2,055,300
Congestion	0.0005 * 221 = 0.111		0.1105	221,000
Total	5.12278	2.181	2.94178	5,883,560

Table 2 Important projects to improve navigation conditions on Neman River (Lithuanian Inland Waterways Authority Homepage 2023)

Project	Financing and timeline	Description
TEN-T network road E41 modernization	By the European Union, allocated funding—23 mln. EUR. The start is 2020, IV quarter, end—2023 IV quarter. By 2024, it is planned to adapt this way for intensive freight, pleasure and passenger traffic	The goal is to modernize the TEN-T network road E41, improve navigation conditions, ensure compliance with guaranteed dimensions, reduce erosion of the banks and the riverbed. To achieve the goal at least 500 new groynes will be built or renovated
Concession project. Kaunas Marvele port	European Regional Development Fund, State budget Kaunas Marvele cargo berth is built in 2015 in a convenient geographical location near highway via Baltica. Several more stages are planned to expand the port	It was used when oversized cargo was delivered from Kaunas to Klaipeda and vice versa. Pilot trips upstream and downstream on the Neman have been conducted in the context of the EU co-funded EMMA project and revealed the first interest of entrepreneurs in exploiting the potential of inland navigation

pressure in Lithuania to reduce road freight transport for less externalities in emissions, congestion, and road safety and to comply with EU decarbonization regulations. This moment may become an important impetus for the development and modernization of river transport in the country.

Currently a number of important projects (Table 2) is already implementing in the Republic of Lithuania that will offer the potential to shift part of the freight transported by road to inland waterway transport.

The implemented projects make it possible to use the river for regular cargo transportation. In case of appearance on the Neman electric ships Lithuania may become a unique example and start cargo transportation by inland waterway between two ports with zero emission vessels, which is fully consistent with the goals, the European Green Deal, the implementation of which is planned for 2050 and will be achieved with a two-step approach designed to reduce CO_2 emissions by 55% by no later than 2030. In practice, this means:

1. Adopt measures for significantly reducing the current dependence on fossil fuels;
2. Take decisive action for active shifting towards more sustainable transport types;
3. Create the right incentives for switching.

5 Conclusion

Based on the calculations carried out (on the example of Lithuania), it can be concluded that inland waterway transport is a sustainable mode of transport, more active use of which can make a significant contribution to reducing environmental impact. Safety, low emissions, economic efficiency, carrying capacity in comparison with road transport are serious benefits in favour of river transport development. Modern technologies, such as electric vessels, will help make inland waterway transport even more environmentally friendly.

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Impact of Environmental Stress on the Endemic Draa Barbel *Luciobarbus lepineyi* (Pellegrin, 1939) (Teleostei: Cyprinidae) of Permanent and Intermittent Rivers in the Draa Basin, Morocco

Mohamed Naimi, Fayçal Ait Boumallassa, Souhaib Hanfouri, Abdelghani Guechchani, Elisabeth Berger, Miguel Clavero, and Mohammed Znari

Abstract

Context/Purpose The endemic Draa barbel, *Luciobarbus lepineyi* is the only species found in the Draa basin from the Cyprinid genus. Besides eight other fish species, they are faced with a set of environmental stressors (intermittency, water salinity, temperature, and hypoxia) in the arid Draa basin. This study aimed to evaluate the impacts of these stressors on body condition and growth. *Methods* Samples were collected from three localities that present a salinity gradient (Iriri 0.4 ppt, Mghimima 10.3 ppt and Sidi Mokhtar 17.4 ppt) by electrofishing, cast net, and a seine net. Then were weighed, aged, and other morphometric measurements were made. Scaled mass index (SMi) was calculated for evaluating the growth, also mortality/longevity, and the Von Bertalanffy model were used to assess the relative growth. The physicochemical parameters of the water were measured during field trips. *Results* The obtained result showed that the environmental and anthropic impacts were accentuated. The calculated scaled mass index decreases from Iriri to Sid El Moukhtar, (16.87, 10.26, 9.54 in Iriri, Mghimima and Sid El Moukhtar, respectively). Longevity decreases from Iriri to Sid El Moukhtar, (23.73, 18.18, and 11.2 years, in Iriri Mghimima and Sid El Moukhtar, respectively), natural mortality rate increases from 0.44, 0.52, and 0.62 in Irir, Mghimima, and Sid El Moukhtar, respectively. Von Bertalanffy growth parameters were respectively 0.079, 0.110, and 0.150 for the growth constant K, and 477.19, 260.45, and 126.37 for the ultimate length L∞ (mm), and 4.26, 3.87, and 2.95 for the growth performance Φ, respectively for the three populations. *Conclusion* The findings show that the environmental stressor accentuated by human activities in the region affect negatively the population parameters, for that fisheries management and conservation plan for the endemic Draa barbel can be established based on these results.

Keywords

Luciobarbus lepineyi · Environmental stress · Salinization · Drought · Draa basin

M. Naimi (✉) · F. A. Boumallassa
Polyvalent Team On Research and Development, Polydisciplinary Faculty of Beni-Mellal, Sultan Moulay Slimane University, Beni-Mellal, Morocco
e-mail: mohamed.naimi@usms.ma

M. Naimi · F. A. Boumallassa · S. Hanfouri · A. Guechchani · M. Znari
The Natural History Museum of Marrakech, Cadi Ayyad University, Marrakech, Morocco

S. Hanfouri · A. Guechchani · M. Znari
Laboratory "Water, Biodiversity and Climate Change", Faculty of Sciences Semlalia, Cadi Ayyad University, Marrakech, Morocco

E. Berger
Institute for Environmental Sciences, University of Kaiserslautern-Landau, Landau, Germany

M. Clavero
Estación Biológica de Doñana, Consejo Superior de Investigaciones Científicas (EBD-CSIC), Americo Vespucio s.n., Seville, Spain

1 Introduction

Covering half the world's river network, intermittent rivers and ephemeral streams (IRES) span different climates and biomes, dominating arid, semi-arid, and dry-sub-humid regions (Tooth 2000). IRES fish communities, while less diverse than perennial systems, may still harbor species with varied environmental preferences and endemics. Fish community structures in the IRES are mainly shaped by temporal changes in aquatic habitat availability (Cid et al. 2017; Kerezsy et al. 2017).

Salinity stress is an important factor governing fish activity and distribution, with most species adapted to specific salinity ranges. North Africa experiences variable river dynamics due to aridity gradients, which has an impact on biodiver-

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sity patterns and human occupation. Fish species coexist in some desert rivers, responding to environmental changes such as global warming and dam construction (Brito et al. 2014; Drake et al. 2011).

The Draa Valley is one of the ten most important arid river catchments on the planet, and is the longest river in Morocco. The arid Draa basin contains nine fish species that are facing enormous natural and anthropogenic disturbance. *Luciobarbus lepineyi* is the only species of the Cyprinidae genus found in the Draa basin (Clavero et al. 2017).

Mediterranean barbels are known for their tolerance of salinity (Kraiem 1986), and in the Draa basin in southern Morocco, researchers hypothesized that environmental stress, such as unpredictability, increased salinity, and hypoxia, would affect the body condition, growth, and developmental stability of endemic Draa barbels. The research aims to assess differences in body condition, longevity/mortality, and growth among populations from permanent and intermittent rivers with different salinity levels in the arid Draa River basin during the 2021 spring season.

2 Materials and Methods

Samples of *L. lepineyi* were obtained from three distinct localities in the Draa basin, SE Morocco, during April–May 2021. Barbels were captured by means of electrofishing and throwing fishing net. The studied localities are chosen following a salinization gradient and intermittency, i.e., Iriri: Permanent stream low salinity (0.4 ppt), Mghimima: Isolated Daya medium salinity (4.2 ppt), and Sid El Moukhtar: Intermittent stream high salinity (10.2 ppt). The body weight (W) and the total length (T_L) were taken, using a precision balance (0.1 g) and a digital caliper (0.1 mm), respectively. We estimated the somatic condition of individual barbels using the scaled mass index, following Maceda-Veiga:

$$\mathrm{SMI}_i = W_i[L_0/L_i]b/\mathrm{SMA}$$

where W_i and L_i are the fresh body weight and standard length, respectively, of individual i, L_0 is a constant length used to standardize body condition values estimated by the arithmetic mean of total lengths of all individuals captured, and b/SMA is the scaling component, which was obtained by dividing the slope of the least squares regression of weight on length (both of them ln-transformed) divided by the Pearson's correlation coefficient of that relationship.

The relative condition factor (K_n) was established to assess the condition of different fish species under study. K_n is defined as:

$$K_n = W_o/W_c$$

where W_o is the observed weight, and W_c is the calculated weight. Good growth condition of the fish is deduced when $K_n = 1$, while the organism is in poor growth condition compared to an average individual with the same length when $K_n < 1$.

Growth was expressed in terms of the von Bertalanffy equation:

$$L_t = L_\infty(1 - e - K(t - t_o))$$

where L_t is the total length of the fish at age t, L_∞ is the ultimate length average fish could achieve, K is the growth constant which determines how fast the fish approaches L_∞ and t_0 is the hypothetical time at which the length of the fish is zero. The index of growth performance (Φ) of the species was calculated with the equation of Pauly and Munro:

$$\Phi = \log k + 2\log L_\infty$$

where K and L_∞ are the von Bertalanffy parameters.

The longevity ($t_{\max}$) was obtained using the expression:

$$t_{\max} = t_o + 3/K$$

Estimation of natural mortality rate (M) was obtained by Pauly's 1980, (Tooth 2000) empirical equation as the mean annual water temperature of the river waters ($T = 26.3$ °C):

$$\log_{10}M = -0.0066 - 0.279\log_{10}L_\infty + 0.6543\log_{10}K + 0.463\log_{10}T.$$

All data were analyzed using the software program SPSS Statistics 26.0.0. and Statgraphics centrion 19.2.01.

3 Results

3.1 Body Condition

The SMi calculated for male shows a slight decrease for Iriri, Mghimima, and Sid El Moukhtar, contrary to that calculated for females, which strongly decreases in the 3 stations (Table 1).

For the body condition of Draa barbels, which is expressed by Le Cren's relative condition factor K_n, was similar and normal (close to 1; fish were neither lean nor heavy) for the three studied populations. On the other hand, SMi was very significantly lower in Sidi El Moukhtar (Table 2).

3.2 Growth

L_∞ in Iriri is higher than Mghimima and then Sid El Moukhtar (477.19, 260.45, and 126.37 respectively). On the other hand, the growth constant rate k is more than two times higher in

Table 1 Body condition expressed as scaled mass index (SMi) in the *L. lepineyi* from three environmental streams of the arid Draa basin, SE Morocco

Locality	N male	SMi ± SD	Range	*P*value
Iriri	14	13.88 ± 1.25	12.11–16.06	0.0163
Mghimima	33	13.41 ± 1.95	9.34–18.40	
Sid El Moukhtar	24	12.01 ± 1.62	7.77–16.83	
Locality	N female	SMi ± SD	Range	*P* value
Iriri	15	21.25 ± 2.03	18.48–25.92	0.0001
Mghimima	22	15.88 ± 1.38	13.95–19.33	
Sid El Moukhtar	27	9.85 ± 1.17	7.85–11.94	

Table 2 Relative condition factor (K_n) in *L. lepineyi* from three environmental streams of the arid Draa basin, SE Morocco

Locality	N	Kn ± SD	Range	*P* value
Iriri	58	1.02 ± 0.12	0.61–1.33	0.3149
Mghimima	59	1.03 ± 0.14	0.69–1.51	
Sid El Moukhtar	55	1.00 ± 0.12	0.67–1.26	

Sidi El Mokhtar (Ir:0.079, Mgh:0.110, and Sm:0.150 year^{-1}). The corresponding calculated growth performance indexes (Ø) were 4.26, 3.87, and 2.95 for Iriri, Mghimima, and Sid El Moukhtar, respectively.

3.3 Longevity and Mortality

Calculated longevity (t_{max}) was 23.73, 18.18, and 11.2 years, respectively for Iriri, Mghimima, and Sid El Moukhtar, respectively. The estimated natural mortality rate (M) was 0.62 (100%) for Sid El Moukhtar population, which is higher of that in Iriri (0.44) and Mghimima (0.52).

4 Discussion

The present study and that of Clavero et al. (2017) reported the presence of *L. lepineyi* in freshwater (salinity < 2 g/L) upstream and in brackish water up to 13.6 ppt (39% seawater), but not at 16 ppt (46% seawater) in the desert zone of the Draa River. The closely related species *L. pallaryi* occurs at salinities below 7 ppt (20% seawater) in the Ziz valley.

The identification and assessment of the impact of environmental stress on Draa Barbel in periodic vs. intermittent rivers are important aspects that have not received sufficient attention to date, as there is little information on most fish species in (IRES) (Abdoli and Naderi Jolodar 2008). In the present study, SMi of Draa barbels decreased along an increasing salinity gradient. This is in agreement the obtained data on *L. capito* from Aral Sea in Uzbekistan, because of the change in the water's salinity causes salinity stress, if it is not compensated, it interferes with physiological homeostasis and routine biological processes (Jolodar 2017).

The relative growth calculation for *L. lepineyi* shows a significant allometry (ED, HL, and SnL). This is similar to results reported by Chaouachi and Ben Hassine (1998), (ChaouaChi 1998) for Algerian barbels living in the lagoon of Ichkeul, Tunisia. Also, the length-weight relationship in *L. mascarensis* is allometrically positive in wadi El-hammam (Ahmed 2020). Jolodar (Jolodar 2017) reported that *L. capito* showed positive and negative allometric growth patterns, respectively, in males and females.

Growth rate of the Draa barbel is comparable to those obtained ($k = 0.100$) for *L. labiosa* from Allal EL Fassi dam, Morocco and *L. capito* from Shahid Rajaei Reservoir, Iran (Jolodar 2017). On the other hand, a part from the very low value ($k = 0.035$) in *L. esocinus* from Keban reservoir, Turkey, growth rate in *L. lepiney* is lower than those reported for *L. callensis* algeria (Berrouk et al. 2020; Morsi et al. 2015) and *L. xanthopterus* Iraq (0.200–0.230) (Kraiem 1986), and the exceptionally high value ($k = 0.760$) in *L. esocinus* from Gamasiab River, Kermanshah, Iran (Hajiahmadian et al. 2018).

5 Conclusions

The present thesis provides for the first time basic biological and ecological information on the Draa barbel, from permanent and intermittent streams with different salinities in the arid Draa River. In light of the obtained results on the length-weight relationship, body condition, population age-structure, and growth parameters, we can identify the following main facts: (i) The Draa barbel adapts to a wide range of salinity from freshwater to brackish water of up to10 ppt, in permanent and intermittent streams of the arid Draa river basin. (ii) However, the environmental stress, with the increase of water salinity and the intermittence of the streams, leads to a clear decrease of the body condition with fish getting leaner, and a lower growth performance which results in a reduced asymptotic body size.

The Draa barbel could therefore be a good biological indicator of the state of fish populations and environmental conditions in the desert hydrosystems in which they occur.

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Downscaling for Fine Spatial Resolution of Current and Future Precipitation in the Context of Climate Change: The Case of the Rheris Watershed: Morocco

Abdelmoumen Benchattou, Mohamed El Ghachi, and Atika Kasmi

Abstract

Climate change is now widely acknowledged within the scientific community, but its impact on hydrological extremes remains a significant concern. Floods account for half of the world's natural disasters, and over the past decade, these hydrological hazards have become a major risk, especially in areas located at the foot of mountains. This research integrates various types of meteorological data, combining both historical and climate model data to capture the complexity of precipitation patterns. The data is carefully validated to ensure its accuracy. The methodology applied in the study uses statistical downscaling techniques to refine the spatial resolution of precipitation data and generate accurate projections. The Rheris basin, located in southeastern Morocco, spans 12,702 km^2 and is characterized by a semi-arid climate. The focus on downscaled precipitation modeling in the Rheris watershed is particularly relevant due to the high degree of climatic variability in the region. The study aims to assess the functioning of the river system in response to climate change through high-resolution rainfall projections. The results show significant changes in the rainfall regime of the Rheris basin for the projected future periods, including variations in intensity and seasonality. This abstract emphasizes the importance of fine-scale precipitation data for understanding evolving hydrological patterns and informing effective water resource management strategies. It also recommends the consideration of high-resolution precipitation projections in future water resource planning and management.

Keywords

Climate change · Rheris basin · Precipitation downscaling · Climate simulations · Hydrological effects

1 Introduction

In recent years, the global scientific community has been deeply concerned about the profound impact of climate change on various hydrological phenomena (Smith et al. 2020; Johnson et al. 2020; Chen 2022). The years 2020–2023 have witnessed a surge in research findings that illuminate the complex interplay between climate shifts and hydrological systems, providing crucial insights into the evolving dynamics of our environment (Smith et al. 2020; Johnson et al. 2020). While our understanding of these intricate connections continues to evolve, one pressing issue stands out: the escalating threat posed by floods, which account for nearly half of all-natural disasters worldwide (Chen 2022). This danger is particularly evident in regions with proximity to mountainous terrain, where the interactions between climate change and hydrological processes are most pronounced (Lee et al. 2022).

As we delve into this critical field of study, the Rheris basin emerges as a focal point of investigation. Nestled in the southeastern region of Morocco and spanning an impressive 12,702 km^2, the Rheris basin showcases the unique challenges posed by a semi-arid climate (Garcia 2021). It is within this distinct environment that our research endeavors to make a meaningful contribution. This study's primary objective is to refine our understanding of the influence of climate change on hydrological extremes through fine-scale precipitation modeling within the Rheris basin (Davis et al. 2023).

The choice of the Rheris basin as our research area is justified not only by its geographical significance but also by its pronounced climatic variability. The region's suscep-

A. Benchattou (✉) · M. El Ghachi
Laboratory "DPRP" USMS, Beni Mellal, Morocco
e-mail: benchattouabdelmomen@gmail.com

A. Kasmi
Regional Meteorological Office Central East, Beni-Mellal, Morocco

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tibility to hydrological risks, particularly floods, underscores the urgency of our investigation. In this regard, we draw upon the insights from a diverse array of sources, published over the last four years, to guide our research and build upon the existing body of knowledge (Wilson et al. 2023; Turner 2023; Martinez et al. 2023; Adams et al. 2023). These sources collectively contribute to the contextualization of our research within the current scientific landscape, providing a robust foundation for our exploration of the intricate relationships between climate change and hydrological processes in the Rheris basin.

2 Methods and Materials

This scientific study used a methodology based on advanced modeling techniques and measured data from rainfall stations. Daily precipitation data from three stations, located at different altitudes, were used for the period from 1982 to 2022. Following a comparison between the measured data and the downscaling tool's predictors, we found that the predictor's ncpp500gl.dat and nceptempql.dat were the closest to the measured data. Consequently, they were chosen to represent future contexts. Statistical and dynamical downscaling techniques were used to refine global climate model results, improving future precipitation projections' spatial resolution and accuracy. These data were specifically adapted to the Rheris basin to capture the subtleties of local climatic variations.

2.1 Methodology

In this study, we devised a comprehensive methodology to successfully undertake the climate downscaling exercise. Initially, we gathered raw climatic data from diverse sources, including global climate models and meteorological station records. Subsequently, we embarked on a rigorous selection of pluviometric stations, favoring sites at various altitudes within the region of interest. Meticulous attention was given to data preprocessing, encompassing removing outliers and formatting information to ensure consistency in comparisons. At the core of our methodology, the downscaling tool was deployed to anticipate future precipitation based on global climate models. Through a meticulous process of comparison, we evaluated the accuracy of these predictors against observed data in pluviometric stations. The predictors "ncpp500gl.dat" and "nceptempql.dat" stood out by exhibiting the best fit with the measured data, justifying their selection to represent forthcoming conditions.

Subsequently, an array of sophisticated downscaling techniques, ranging from statistical to dynamic approaches, was employed to refine the results generated by global climate models. This approach enhanced the spatial resolution of future precipitation projections, thereby augmenting their precision levels. A specific adaptation step was undertaken to ensure local relevance, adjusting the data based on topographical peculiarities and regional climate nuances. To corroborate the soundness of our approaches, a cross-validation step was undertaken, segmenting the data into training and testing sets, enabling us to assess the downscaling models' ability to generalize their results. In conclusion, our methodology yielded informative future precipitation projections, encompassing a range of seasonal, inter-annual, and long-term parameters. All these steps were exhaustively documented in a scientific report that will serve as a reference for interpreting the implications of predictions in the local context.

2.2 Materials Used

1. Global climate model results (IPCC global scenarios and predictors).
2. Daily precipitation measured at stations in the Rheris watershed.
3. Geospatial data (altitude, land use) for the Rheris watershed.
4. Downscaling SDSM software (for downscaling and data analysis).
5. By following this comprehensive methodology and using the specified materials, the study aimed to provide valuable information on the possible effects of climate variation on hydrological functioning within the Rheris basin.

3 Results and Discussion

3.1 Regression Models for the Periods 2022–2060 and 2080–2100

In the Rheris watershed, innovative regression models have been developed using ALADIN-Climat outputs for future periods. These models show adjustment coefficients closely comparable to those observed during the 1980–2000 reference period. This innovative approach has enabled us to identify new regression equations, effectively addressing concerns about the stationarity of the process. Unlike other statistical downscaling methods, this technique offers a significant advantage by merging the relationships between observed climate variables, including daily precipitation (Pj), and simulated variables. By integrating the evolving dynamics between the environment and daily precipitation, these recent models, based on ALADIN-Climat's Pj precipitation pixel data for the periods 2022–2060 and 2080–2100, provide a reliable, context-sensitive solution for the Rheris watershed. This approach considerably reduces concerns

Table 1 Adjusted determination coefficients of precipitation statistical models for 2080–2100

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PJ R^2	0.89	0.98	0.97	0.98	0.99	0.99	0.98	0.99	0.98	0.97	0.99	0.98
PJ erreur-type	0.31	0.37	0.35	0.39	0.33	0.32	0.38	0.32	0.25	0.34	0.36	0.31
PJ RMCE	0.37	0.48	0.37	0.39	0.36	0.35	0.40	0.36	0.32	0.31	0.27	0.35

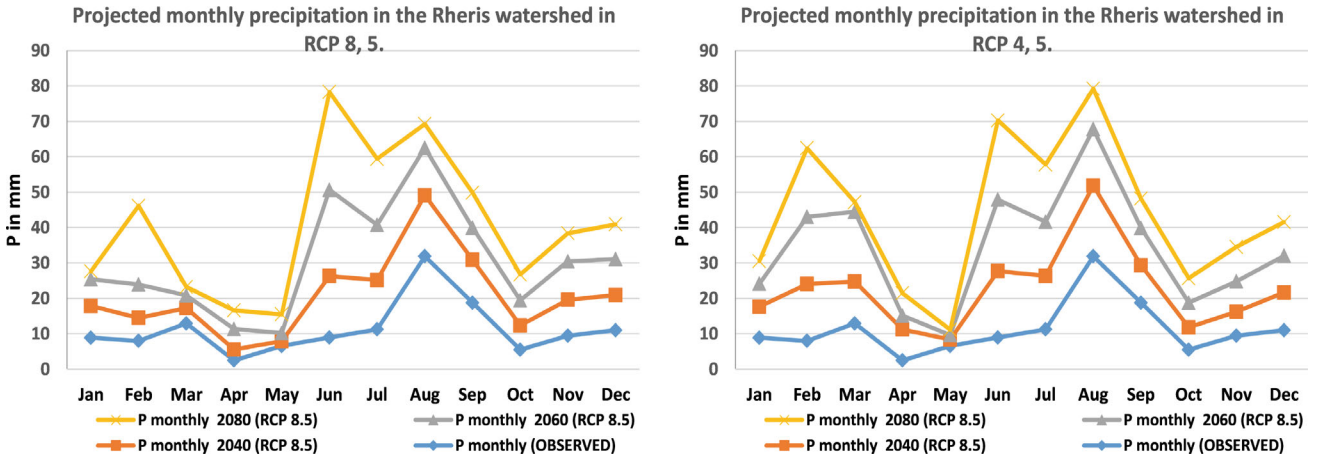


Fig. 1 Projected monthly precipitation in the Rheris watershed in RCP 4.5 and RCP 8.5

about the stationarity of the process, distinguishing it from methods based on unchanged equations for future projections (Table 1).

3.2 Equation Resolution for Different Periods and Scenarios

The data provided in the table reveal crucial information about future precipitation scenarios in the Rheris watershed. These projected variations in precipitation intensity and seasonality are key factors that could influence the occurrence of floods in this region (Fig. 1).

It is clear that the climate scenarios for 2080 and 2050 show significant variations in precipitation patterns. In particular, the month of June shows a trend toward increased precipitation under the RCP 4.5 and RCP 8.5 scenarios, which could contribute to higher river flows. This increase in precipitation, especially during the spring and summer months, could increase the risk of flooding, as soils have less capacity to absorb excess water, leading to increased runoff into rivers and streams.

On the other hand, seasonal and inter-scenario variation in months like August raises concerns about water resource management. For example, in the 2080 RCP 4.5 scenario, the month of August shows a significant increase in precipitation (80 mm), which could lead to rapid accumulation of water in catchments and potentially to flooding, particularly in the lower areas of the catchment.

In addition, the autumn and winter months also show notable differences between the scenarios, suggesting that periods of more intense precipitation could be associated with higher risks of flooding during these seasons, when precipitation coincides with already saturated soils.

According to the figures depicting the temporal projection of precipitation in the Rheris watershed, it can be observed that in recent years, the Rheris watershed has been receiving precipitation (both rainfall and snowfall), primarily in the upstream part of the basin. Additionally, it is noticeable that the majority of the rainfall occurs during the summer months in the form of thunderstorm-related precipitation. This type of precipitation contributes to the occurrence of floods and inundations, leading to material damage and sometimes even human casualties each time. Furthermore, it is evident that the Rheris watershed has experienced climatic disturbances over the past years. This semi-arid climatic zone, characterized by snowfall, is depicted in the following images.

4 Discussion

Overall, the results of this study highlight the need for proactive flood risk management in the Rheris catchment. Planners and water managers should consider these rainfall



Fig. 2 Photo documentation from fieldwork on January 27, 2022, in the upstream area of the Rheris watershed

projections in their adaptation strategies. This could involve measures such as strengthening flood management infrastructure, setting up early warning systems, promoting soil and water conservation practices, and planning land use to take account of the increased risks associated with climate change (Fig. 2).

5 Conclusions

In sum, this investigation underscores critical apprehensions regarding climate change and its consequences on hydrological extremes within the Rheris watershed, Morocco. The forthcoming precipitation projections unveil substantial variations, with notable seasonal increases in certain scenarios, heightening the vulnerability to flooding. Effectively addressing these impacts necessitates proactive planning. This involves the incorporation of projections into water management decisions, as articulated in Conclusion 192, and the execution of adaptive measures. Simultaneously, there is a pressing need to enhance the resilience of local communities and ecosystems.

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Systematic Atmospheric Observations Greenhouse Gases (CO_2, CH_4, and CO) at a Coastal Site in the South Italy

Luana Malacaria, Domenico Parise, Claudia Roberta Calidonna, Daniel Gulli, Ivano Ammoscato, Paolo Cristofanelli, Teresa Lo Feudo, Elenio Avolio, Mariafrancesca De Pino, and Salvatore Sinopoli

Abstract

Carbon dioxide, CO_2, and methane, CH_4, variability in the atmosphere is important because it is the major driver of anthropogenic climate change, while carbon monoxide (CO) is an effective tracer for the combustion process. Knowing the atmospheric transport involved in the land-atmosphere-sea exchange can help to understand the sources of these gases. Measurements were made by a G2401 Picarro analyzer, at the permanent World Meteorological Organization/Global Atmosphere Watch (WMO/GAW) observatory in Southern Italy: Lamezia Terme—LMT. This work presents a preliminary characterization of CO_2, CH_4, and CO variability in the central Mediterranean basin. The period of investigation includes eight years, i.e., 2015–2022, and has produced an important long-term dataset. A set of 3 primary standards of calibration from NOAA-GML is available at the LMT station: CB10928, CB11039, CB11164; also, secondary standards were used to calibrate the amount of greenhouse gases. Routine calibrations were performed using the observatory's working standards to assess the possibility of drift and the calibration factors stability. Specifically, for each gas, two working standards with CH_4, CO_2, and CO mole fractions representing the lower and upper ranges of the expected ambient variability were used. Under the sea breeze regime, air masses more representative of the background atmospheric conditions could be observed, whereas the mole fraction of greenhouse gases was influenced by anthropogenic emissions when air masses flowed in from the interior of the land. This work would contribute significantly to a better understanding of tropospheric chemistry in the central Mediterranean region, which is known as a climate "hotspot."

Keywords

Atmospheric greenhouse gases · Quality control · Calibration · Anthropogenic emissions · Mediterranean basin

1 Introduction

Atmospheric data of sufficient duration and quality, have the potential to significantly improve understanding of the processes that control the budgets of CH_4, CO, CO_2, and other greenhouse gases on decades to centuries timescales (Cristofanelli et al. 2017). In the present work, we describe a consistent, automated, and highly accurate analytical system for routine unattended monitoring of CH_4, CO, and CO_2 from the Lamezia Terme observatory, 38.87630° N 16.23220° E; 6 m.a.s.l., Calabria (Fig. 1). Atmosphere variables are monitored non-stop to examine natural and human-caused sources at the measurement site. Some results on monthly greenhouse gas variations are presented. CO_2 is the main anthropogenic greenhouse gas, and mixing ratio measurements of its abundance are sensitive to upwind fluxes, including uptake by and emissions from soils and vegetation as well as fossil fuel emissions. CH_4 has significant anthropogenic sources from fossil fuel exploitation, agriculture, wastewater treatment, and landfills. CO measurements are useful for analyzing CO_2 data by helping to quantify and identify pollution episodes and biomass burning (Andrews et al. 2014). The observatory of Lamezia Terme is located at 600 m from the coastline of the Tyrrhe-

L. Malacaria (✉) · D. Parise · C. R. Calidonna · D. Gulli · I. Ammoscato · T. L. Feudo · E. Avolio · M. De Pino · S. Sinopoli
CNR–ISAC, Institute of Atmospheric Sciences and Climate of National Research Council, Lamezia Terme, Italy
e-mail: malacarialuana@mail.com

P. Cristofanelli
CNR–ISAC, Institute of Atmospheric Sciences and Climate of National Research Council, Bologna, Italy

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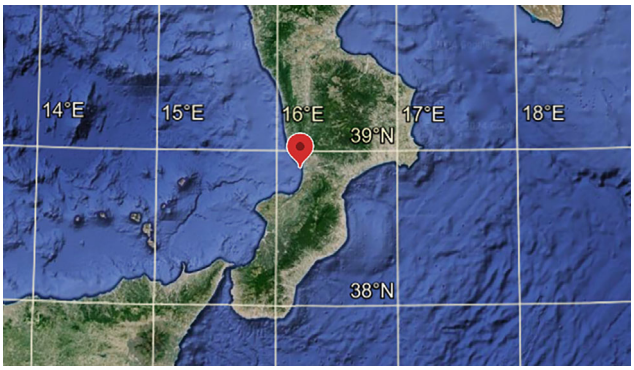


Fig. 1 Lamezia Terme, location of the WMO/GAW regional site

nian Sea. It is known that at 5.5 km and 6.7 km northward with respect to the experimental site, there are Lamezia Terme International Airport and the city of S. Eufemia, respectively. The purpose of this paper is to monitor the amount of greenhouse gases in the atmosphere from 2015 to 2022 at LMT observatory.

2 Materials and Methods

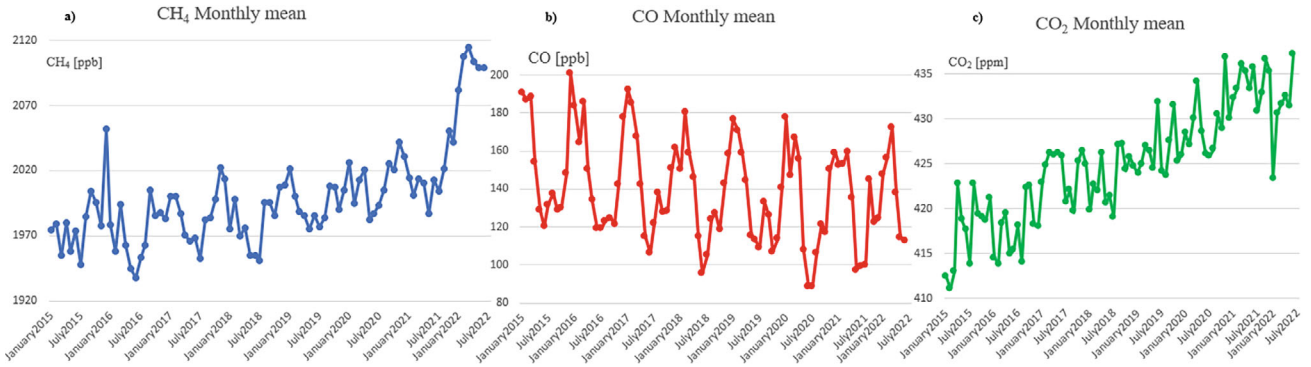
A cavity ring-down spectrometer, Picarro model G2401 analyzer, was used to measure concentrations of greenhouse gases in the atmosphere. The instrument, online with sampling, measures continuously every 5 s. It is possible to aggregate high frequency (second) data to obtain the hourly mean of amount of CO, CO_2, and CH_4, concentrations. The hourly mean datasets are stored and corrected using the calibration coefficients. For CO and CH_4, to define calibration coefficients, we used primary standards of calibration from NOAA-GMDL and secondary standards. Whereas, for CO_2 gas the new scale identified as WMO-CO2-X2019 (Hall et al. 2021), was adopted.

3 Results and Discussion

The Lamezia Terme station consents to examine the variability of atmospheric CH_4, CO_2, and CO concentrations at the regional scale. Use of the ICOS European infrastructure process for the calibration and accuracy of our datasets, the data quality control matches the international GAW-WMO recommendations. Starting from hourly mean datasets of the greenhouse gases of the investigated years, we designed the monthly mean. Fig. 2 shows the CH_4 (a), CO (b), and CO_2 (c) monthly mean time series at the LMT site from 2015 to 2022 by considering the complete datasets. The CH_4 and CO seasonal variations over the years are evident, with maxima in the first months of each year and minima during summer season, in accordance with the interpretations at the ICOS stations in Europe. CO showed an overall decreasing trend in line with the levels of reduction since 2000 driven structured to reduce anthropogenic emissions in Europe, the USA, and China, intended to help reduce pollution (Gialesakis et al. 2023). For CO_2 in (c), there is the multi-year increasing tendency, in accordance with literature (Trisolino et al. 2021). The seasonal CO_2 cycle was a mixture of diverse influences, i.e., removal processes, anthropogenic and biosphere emissions, atmospheric transport, and fires from agricultural residues at multiple scales of time and space. Over the study period, we derived an average annual growth rate of 2.1 ppm/year for CO_2 and 16.2 ppb/year for CH_4, while no significant annual increase in CO. When air masses are flowing from the land interior the mole fraction of greenhouse gases was affected by anthropogenic emissions, whereas under sea breeze conditions, air masses more representative of background atmospheric conditions were observed (Lo Feudo et al. 2020).

4 Conclusions

We monitored the concentrations of CH_4, CO, and CO_2 in the atmosphere for a period of eight years, i.e., from 2015 to 2022, at the CNR regional WMO/GAW LMT station located in a characteristic area of the western coast of southern Italy (region of Calabria)—Mediterranean Basin. Observations were carried out by Picarro G2401 analyzer for CO_2/CO/CH_4/H_2O. The monthly variation of the greenhouse gases was determined. Analysis of greenhouse gas amounts allowed us to see how local sources were affecting concentrations. We conclude that the amount of CO_2 in the atmosphere is increasing by about 2.1 ppm/year and by about 16.2 ppb/year for CH_4. Regarding the CO trend, we observe a recognizable seasonality.



		January		February		March		April		May		June		July		August		September		October		November		December	
		Monthly mean	SD	Monthly mean	SD	Monthly mean	SD	Monthly mean	SD	Monthly mean	SD	Monthly mean	SD	Monthly mean	SD	Monthly mean	SD	Monthly mean	SD	Monthly mean	SD	Monthly mean	SD	Monthly mean	SD
CH_4 [ppb]	2015	1974.3	136.8	1979.2	137.5	1955.0	96.9	1980.0	132.5	1958.1	119.1	1973.9	133.5	1948.0	112.9	1984.6	148.9	2004.0	151.9	1995.8	135.2	1977.3	118.1	2051.8	171.5
	2016	1978.8	113.8	1958.3	111.7	1994.3	127.9	1963.0	116.0	1945.0	72.8	1937.3	82.5	1953.1	113.5	1963.2	106.9	2005.4	122.1	1985.7	117.2	1988.0	109.8	1983.4	91.9
	2017	2000.7	119.3	2000.6	122.5	1986.9	121.3	1970.8	107.7	1966.6	106.1	1967.9	126.3	1962.4	111.2	1982.5	126.2	1984.2	117.4	1998.2	112.3	2022.6	141.3	2013.7	138.2
	2018	1975.2	121.6	1998.3	117.5	1969.6	91.6	1976.2	97.5	1954.6	77.7	1954.7	90.4	1960.7	87.9	1995.5	105.4	1995.5	109.4	1985.5	91.6	2007.8	107.5	2008.8	116.5
	2019	2021.3	118.6	2000.3	107.0	1989.0	92.8	1955.4	86.0	1975.2	76.4	1985.7	107.1	1977.2	102.1	1984.1	97.6	2008.2	101.9	2007.2	105.1	1990.5	82.7	2004.8	104.2
	2020	2026.0	114.5	1995.0	93.5	2013.1	78.9	2020.6	97.6	1982.3	78.6	1986.7	95.7	1993.4	95.9	2005.1	95.5	2025.4	88.5	2020.6	80.7	2041.6	86.8	2031.0	82.6
	2021	2014.2	82.7	2001.2	76.0	2014.0	76.5	2010.9	76.0	1986.8	75.2	2012.9	94.1	2004.0	102.2	2021.9	122.0	2050.4	118.2	2041.8	101.8				
	2022	2052.1	96.0	2107.8	97.8	2114.6	88.8	2103.7	81.1	2098.8	89.7	2099.5	93.8												
CO [ppb]	2015	190.4	55.3	186.8	47.4	188.4	40.7	153.9	25.7	129.0	17.9	119.9	17.0	131.8	19.4	137.7	32.2	128.4	20.5	130.0	32.5	147.9	41.1	200.4	56.3
	2016	183.4	58.7	163.9	42.2	186.6	42.1	160.0	27.3	134.1	19.8	119.2	28.1	119.2	28.1	128.2	26.6	124.7	23.7	121.7	27.9	141.9	34.8	177.4	45.4
	2017	191.9	54.4	154.9	46.8	167.7	42.1	142.1	29.8	115.1	16.7	106.1	26.8	122.1	49.0	138.3	43.8	127.4	26.2	127.9	25.6	150.4	45.6	161.8	62.0
	2018	160.2	54.2	180.7	50.6	159.1	45.1	145.9	26.4	115.0	15.0	95.8	18.6	104.9	30.1	124.3	29.8	127.1	26.3	118.7	31.1	142.4	49.4	158.2	54.9
	2019	176.4	57.4	170.8	45.2	159.3	44.0	144.4	33.6	115.8	23.1	113.1	26.3	108.9	32.6	132.9	38.3	126.0	31.4	107.0	22.8	113.8	35.2	140.7	50.6
	2020	177.4	58.3	147.3	47.5	167.1	35.7	165.5	39.2	108.3	13.0	88.8	14.0	88.8	13.2	105.9	25.6	121.6	33.7	117.1	23.3	160.1	38.5	169.0	45.0
	2021	152.6	47.1	153.0	42.3	159.4	38.6	135.0	21.9	97.3	11.3	99.6	19.7	99.9	35.5	145.0	44.4	122.4	19.3	124.5	22.3				
	2022	147.7	48.8	156.1	45.9	172.2	38.6	138.1	24.8	114.6	16.0	112.5	22.9												
CO_2 [ppm]	2015	412.6	9.1	411.1	7.3	413.0	9.4	422.7	24.9	418.8	22.7	417.6	24.9	413.9	22.6	422.8	28.0	419.3	24.0	419.0	19.6	418.8	19.6	421.2	14.1
	2016	414.6	10.6	413.9	11.0	418.4	13.2	419.4	18.9	414.9	15.3	416.4	17.7	418.0	23.9	414.0	21.9	422.3	23.4	422.6	20.1	419.2	13.0	418.0	8.9
	2017	422.9	8.0	424.9	10.5	426.3	14.2	426.0	16.3	426.3	19.3	425.8	22.3	420.7	21.2	422.1	20.5	419.6	17.8	425.3	17.6	426.5	14.1	424.9	10.9
	2018	419.8	10.8	422.7	10.8	422.0	13.4	426.2	18.5	420.6	14.8	421.4	19.7	419.1	19.3	427.1	26.1	427.2	24.8	424.3	16.6	425.7	14.4	424.7	13.6
	2019	424.0	8.5	425.0	10.3	427.0	15.2	426.4	15.1	424.5	15.8	431.8	21.2	424.1	22.4	423.7	19.5	427.5	23.2	431.6	20.9	425.2	13.5	426.0	11.5
	2020	428.5	12.0	427.1	13.4	430.0	13.1	434.2	19.1	428.6	18.2	426.2	20.1	425.8	20.9	426.6	22.6	430.5	21.1	428.9	17.6	436.9	17.1	430.0	10.4
	2021	432.3	10.2	433.3	12.4	436.1	14.3	435.2	15.0	433.4	16.0	438.8	20.1	430.9	18.5	433.0	20.8	436.7	20.2	435.2	15.0				
	2022	423.4	11.7	430.6	15.5	431.7	12.7	432.6	17.7	431.4	18.0	437.2	21.7												

Fig. 2 Time series of monthly mean (in the table, concentrations and SD Standard Deviation) of **a** CH_4 blue line, **b** CO red line, and **c** CO_2 green line for LMT. The spots in the graphs represent monthly means of every year

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Inventory of Characeae of Eastern Numidia (Northeastern Algeria), Characterization of Biotopes and Identification of Ecological Niches

Hanene Zouaidia, Gerard de Bélair, and Ingeborg Soulié-Marshe

Abstract

Information on the ecological requirements of Characeae in the literature varies greatly between geographical areas and also according to the methodological approach (laboratory, field, etc.). The bibliography on European Characeae is abundant, particularly in France and Switzerland. Bibliographic material on research carried out on Characeae in Algeria is very rare. References to the Characeae of Numidia are limited to two sources: Works of Mrs. Feldman who cites and describes all the species of Characeae of Numidia (Feldmann in Bull Soc Hist Nat Afr Nord 37:64–118, 1946) and Mr. de Bélair's collections as part of his missions to study the vegetation of the ponds of Numidia (De Bélair in Ecol Medit 31:1–18, 2005). The aim of this study is to carry out a representative inventory of Characeae in northeastern Algeria. Secondarily, it also aims to characterize and identify the habitats where they are found. To achieve this objective, Charophytes were sampled in 33 water bodies of different types, with monthly sampling during a study period of four years (2007–2011) in eastern Numidia (Algeria). In parallel, measurements were taken of the physico-chemical conditions of the sampled water bodies and the sexual reproduction of the Characeae was monitored. The results obtained allow us firstly to identify 12 species of Characeae including a new taxon (*Nitella confervacea*) cited for the first time for Algeria and Africa. Secondly, to estimate the spatio-temporal variability of the environmental conditions affecting the distribution of the different charophytes. The Outlier Mean Index (OMI) analysis made it possible to define the ecological niche of all the taxa inventoried, as well as the dispersion of their abundance in the 33 sites studied according to environmental variables. The ecological niche of *Chara aspera* Willd., and *C. galioides* DC., for example, is linked to clear brackish to salty waters that settle on sandy substrate. *Nitella gracilis* (Sm.) C. Agardh would occupy clear waters with a moderately neutral pH and more or less mineralized. This species has been observed in the form of isolated clumps in the herbarium with other species, including *Nitella hyalina* (DC.) C. Agardh. Other species are dependent on large bodies of water; etc. Our results show significant susceptibility of most species, including *Nitella.* Some of these species are rare and endangered and deserve good management for the conservation of their habitats.

Keywords

Characeae · Numidia · OMI analysis · Physiochemical · Water ponds · Algeria

1 Introduction

Characeae of Numidia (eastern Algeria) are still globally and insufficiently known and studied. Although they have often been reported at the genus level, they have never been the subject of a specific study. The pioneer character of these species makes them play an important role in the dynamics of Numidian wetlands, which closely follows the precipitation regime. Bibliographic material on research carried out on Characeae in Algeria is very rare, restricting to Works of Mrs. Feldman who cites and describes all the species of Characeae of Numidia (Feldmann 1946) and Mr. de Bélair's

H. Zouaidia (✉)
Higher school in food sciences and agro-food industries, Algiers, Algeria
e-mail: zouaidia@essaia.dz

G. de Bélair
Badji Mokhtar University, Annaba, Algeria

I. Soulié-Marshe
Montpellier-2 University, CNRS/IRD, Institute of Evolutionary Sciences (ISE-M), Montpellier, France

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collections as part of his missions to study the vegetation of the ponds of Numidia (De Bélair 2005). On the other hand, the bibliography on European Characeae is more abundant, particularly in France (Corillon 1975; Soulié-Märsche 2008; Bailly and Schaefer 2010) and Switzerland (Auderset-Joye 1992).

The present work aims to identify the habitats of Characeae of eastern Numidia from previous data as well as samples collected following field surveys (phytosociological surveys during a long period of study which extends from 2007 to 2011) as well as the characterization of the environments of their habitat for three consecutive years 2009, 2010 and 2011. This makes it possible to assess the heritage value of the charophytic assemblages of Numidia due to the rarity of some species and the important role they play in the stabilization of many aquatic ecosystems both fresh and brackish environments.

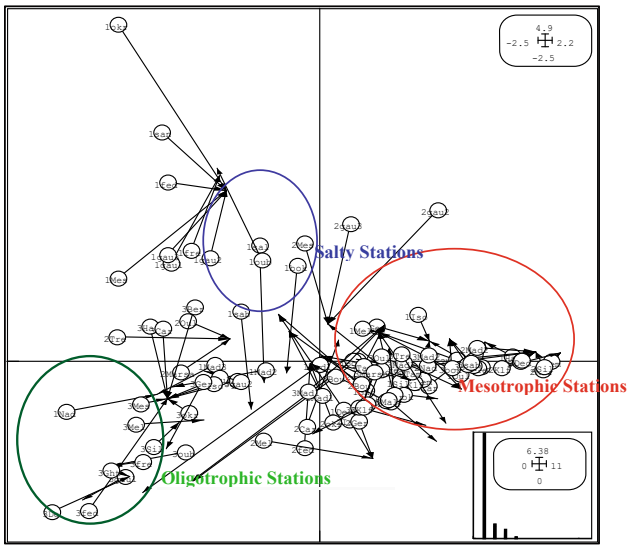


Fig. 1 1 × 2 plan of the co-inertia carried out on 33 stations × 25 environmental parameters × 12 species of Characeae × 3 years

2 Materials and Methods

The fieldwork took place from January 2007 to July 2011. During these years, Characeae surveys were carried out on a monthly basis, except when the temporary ponds dried up. Systematic phyto-sociological and ecological surveys of the aquatic vegetation present with the charophytes in 33 station have been accompanied by a series of data such as the situation of the site (altitude, geology, topography, landscaped environment); the physiognomy of the body of water (type, size, shape, bottom texture, depth); hydrological conditions (turbidity, pH, conductivity, percentage of dissolved oxygen, main source of supply, etc.) and human environment (accessibility to livestock, degradation, threats.

Water samples were taken for each station to carry out physico-chemical analyzes in addition to certain parameters already measured in the field (water depth, temperature and pH for each station and at each survey).

The multivariate statistical analysis was carried out using the ADE4 (Chessel and Thioulouse 1996). Aiming at the notions of ecological profiles and with the aim of defining the ecological profile of each species of Characeae, analyzes of co-inertia, Discriminant analysis and ecological niche (Outlier Mean Index Analysis) were carried out on all the phytosociological surveys combined with the ecological factors of each study station.

3 Results

The 1 × 2 co-inertia factorial plan carried out on 33 stations, 12 species and 25 environmental variables for 3 years highlights that the different bodies of water disperse according to a first eutrophication gradient on which eutrophic, mesotrophic and oligotrophic stations can be distinguished (Fig. 1).

A second gradient, that of salinity, groups brackish to salt water stations in relation to other freshwater bodies of water. This shows the variation of the factors of axes 1 and 2 of the co-inertia through the different bodies of water during the 3 years of study (2009, 2010, and 2011).

We note that for eutrophic stations, the degree of eutrophication increases from one year to another. Some stations considered as oligotrophic keep the same status for 3 years; on the other hand, other water bodies show mesotrophic characteristics for the first and second year and are found in the group of eutrophic stations in the last year.

The salinity factor shows a slight variation for the same station over the 3 years, which is certainly due to the different measurement periods each year and also the variation in climatic factors, especially rainfall.

The dispersion of different species of Characeae in the 33 sites studied according to environmental variables. Each species has an ecological niche which is represented according to its affinities to the different physico-chemical factors of water and other abiotic factors such as the nature of the substrate, the air temperature, and the surface of the water body and also the biotic factors represented by accompanying species identified in the field. The latter all therefore determine the position of the ecological niche of each species of Characeae as well as the ecological tolerance of the species. We can also identify on the IMO graph. The variations in the abundance of Characeae species in the different sites studied, which is represented by the diameter of each ball. The larger diameter represents the

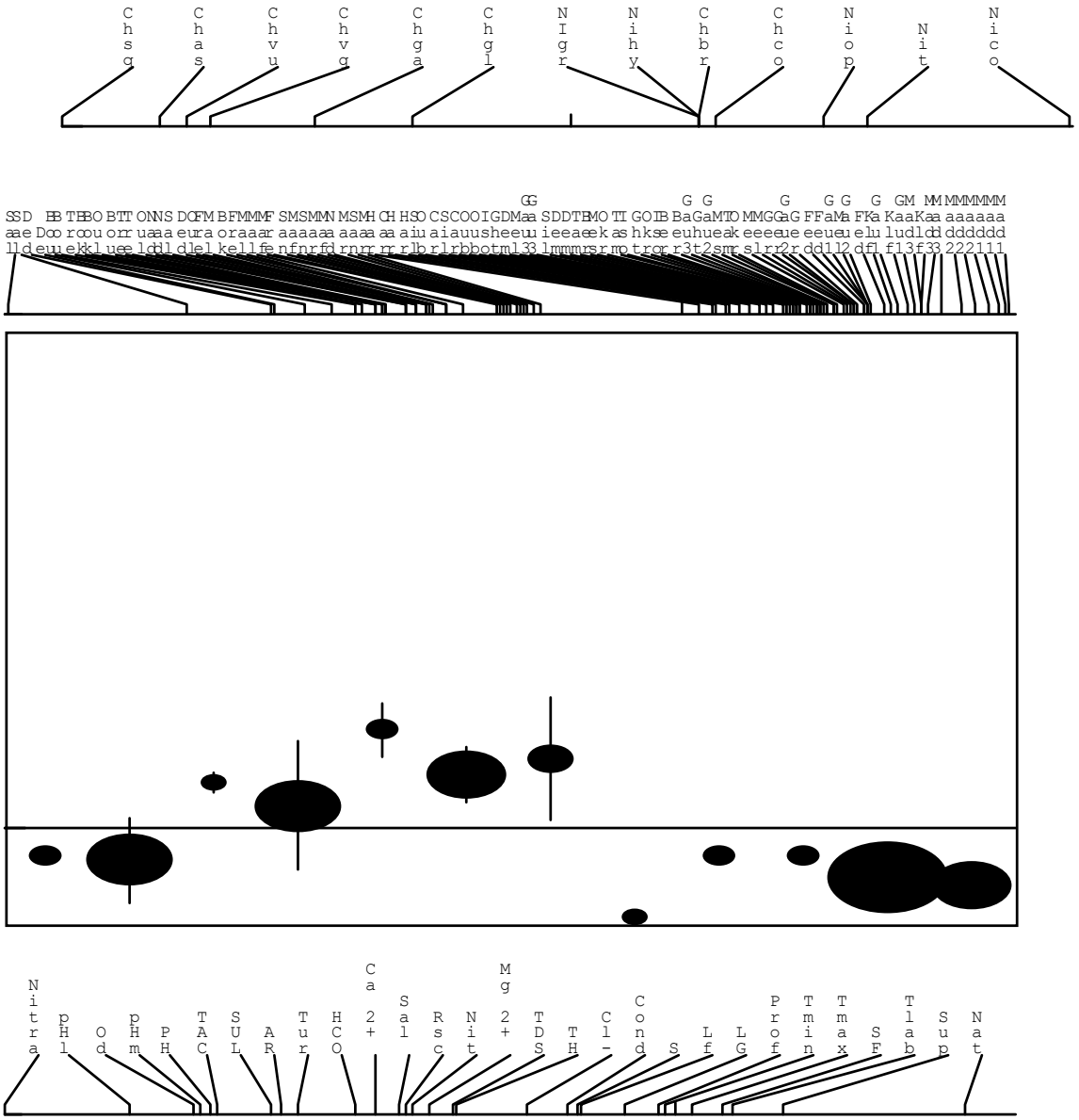


Fig. 2 Ecological niche of the 12 species based on IMO analyzes of 29 variables and 99 records

greater abundance. The figure of the ecological niche indicates that the niche of *Nitella translucens* (Pers.) C. Agardh, is linked to bodies of water with a large surface area and great depth, with a low pH (acid) and whose middle bottom is sandy, generally consisting of fine sand. This is also the case of *Nitella confervacea* (Bréb.) A. Braun ex Leonh., for these parameters frequenting oligotrophic environments. *Nitella opaca* (C. Agardh ex Bruzelius) C. Agardh, is found at different depths, at medium conductivity rates and including weakly mineralized waters. *Nitella gracilis* (Sm.) C. Agardh, would occupy clear waters with a moderately neutral pH and more or less mineralized. This species has been observed in the form of isolated clumps in the herbarium with other species, including *Nitella hyalina* (DC.) C. Agardh. Thus, the same types of observations have been reported for this species. *Chara braunii* Gmelin grows in neutral, weakly acidic (calcareous) waters and at shallow depths. *Chara connivens* P. Salzmann ex A. Braun, would frequent environments with clear waters that are weakly acidic and not turbid (Fig. 2).

Chara globularis Thuill. would be associated with moderately turbid and mesotrophic environments, with basic or neutral or weakly acidic pH. *Chara vulgaris* L. lives in disturbed environments at basic or neutral pH quite strongly mineralized and even resists in eutrophic environments. *Chara gymnophylla* (A. Braun) A. Braun, is attached to small bodies of warm water at very shallow depths. It tolerates high levels of phosphates and nitrates.

The ecological niche of *Chara aspera* Willd. and *C. galioides* DC is linked to clear brackish to saline waters that settle on sandy substrate. The bodies of water colonized by these two species are generally calm.

4 Discussion

Various studies have shown the varied impacts of Characeae carpets on the physico-chemical parameters of water (Guerlesquin 1992; Kufel and Kufel 2002) and their possible role as bio-species. Indicators of water quality. This is how the maximum depths of colonization by Characeae are retained as one of the quality criteria in various programs on bodies of water. Characeae meadows are sometimes very stable; even constitute the climax of certain environments (Feldmann 1946). This is particularly the case for seagrass beds in deeper areas where Tracheophytes do not penetrate and therefore do not compete. This type of deep seagrass bed has been encountered in the Demnet Attaoua station where a large population of *Nitella translucens* has existed for a long time in a constant seagrass bed. In terms of specific richness, there has been an impoverishment and trivialization of the flora in Characeae in recent years.

This study revealed the first record of a new species for Algeria, and for Africa (*Nitella confervacea*). Indeed, the latter has never been cited in previous works in the region. Following the monitoring of the seasonal evolution of the Characeae, we find that these species follow one another in time following a seasonal gradient in relation to important factors such as temperature, luminosity and depth; limiting certain stages of development such as fruiting.

5 Conclusions

The study of the species of Characeae of Numidia has made it possible to determine the ecological niche of the species of the region. Following the monitoring of the seasonal evolution of the Characeae, we find that species follow a seasonal gradient in relation to important factors such as temperature, luminosity and depth, limiting certain stages of development such as fruiting variations in the specific assemblages in the water bodies of the region have been recorded between the years of study, this may be due to climate changes from one year to another, in particular variations in temperature and rainfall which favors certain physico-chemical parameters over others, which consequently favors one species over others on the one hand; on the other hand, it causes the regression of certain meadows by affecting the abundance of species and can even lead to their disappearance over time.

In terms of abundance, some taxa such as *Nitella opaca* are frequent while almost all others are declining. In terms of specific richness, there has been an impoverishment and trivialization of the flora in Characeae in recent years. This study revealed the first record of a new species for Algeria (*Nitella confervacea*). Indeed, the latter has never been cited in previous works in the region.

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Management of Urban Water Security under the Challenge of Climate Change; Palestinian Territory as a Case Study

Samah Jabari and Isam Shahrour

Abstract

This article provides a new model for managing water security at urban level under the challenge of climate change. Because of the global warming, urban areas are facing challenges related to reasonable amounts of water, depletion of resources, low water security, and frequent extreme weather events. The research methodology uses the risk-based approach by determining the risk drivers and creating an indicators framework where each indicator has a severity, likelihood (probability), and score, then the urban water security is expressed in a quantitative value (index). The research results show that successful management of urban water security under critical challenges should follow, respectively, a series of steps: (1) conducting an integrated and periodic assessment based on coherent scientific approach, (2) defining the risk drivers, (3) translating risk drivers into indicators, (4) creating a numerical value to express water security in urban areas, and finally (5) adopting a set of creative strategies to form a new model of management that will be more adaptive with the accelerated challenges especially the climate change. The research concludes that climate change is the biggest challenge facing the urban water security (an alarming risk driver). Management of urban water security is a very complicated process since it combines environmental, technical, management, governance, and social issues. The summary of the research shows that the use of quantitative and qualitative indicators combined with a risk-based approach can support urban areas with a good way to manage water security under the challenge of climate change.

S. Jabari (✉)
Palestine Polytechnic University, West Bank, Palestine
e-mail: samahj@ppu.edu

I. Shahrour
University of Lille, Lille, France

Keywords

Water security · Urban level · Climate change · Risk · Indicator · Management · Palestinian territory

1 Introduction

Water challenges, climate change problems, the large increase in population, the large expansion of urban areas, weak infrastructure, pollution of sources, and the increase in uncontrolled industrial and agricultural activities are all factors that affect the management of water security in urban areas and are making it a complex process. In addition to that, urban water security is a subject that is related to governance, social systems, and environmental aspects, this is what makes the subject very complicated (OECD 2013; ITU 2014; OECD 2016; Nazemi and Madani 2017; Silva et al. 2018). Water issues constitute a global challenge, as the weakness in the provision of integrated water services affects all aspects of life (health, economic, and social life). Over time, these challenges have turned into conflicts between countries at the regional and global levels and have become a concern for scientists and politicians.

Water scientists have resorted to relying on the concept of risk in analyzing and evaluating water security (Nazemi and Madani 2017). The process was used to simplify the complexity of the water security issue (OECD 2013; Garrick and Hall 2014; Hall and Borgomeo 2013). They were clarifying that understanding the water security issue and creating policies and strategies are more inclusive when using the risk concept (Garrick and Hall 2014; Zio 2018; Rovins et al. 2015). This paper shows a new method in assessing urban water security based on the risk concept by using a novel framework of indicators and with the SWARA method for ranking and weighting.

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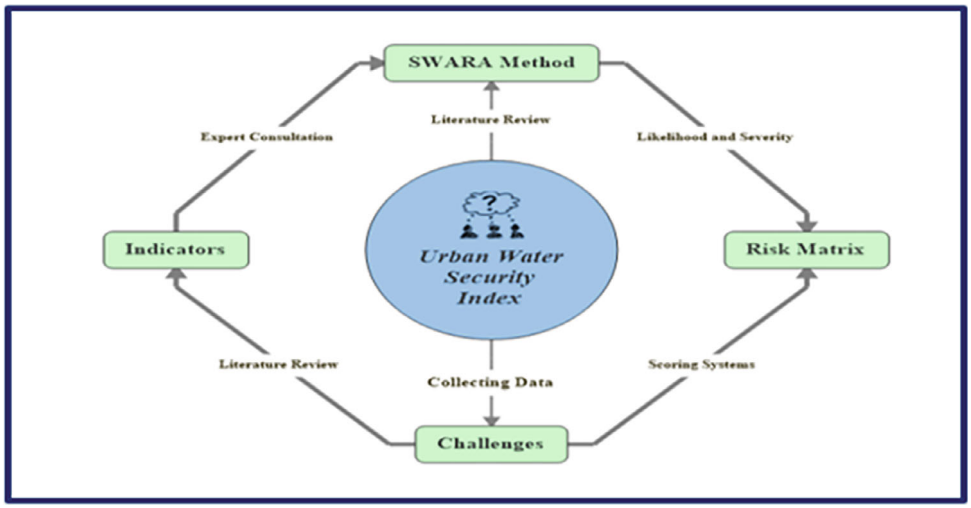


Fig. 1 Urban water security assessment circle

2 Methods

The methodology is based on the risk concept. Data for evaluating water security were collected about: 1—water services, 2—water resources, and 3—water governance. A framework of risk indicators was created where each indicator had a weight, severity, probability, and score, each of these criteria were determined based on previous studies, scientists view, the use of SWARA, and the risk matrix (Fig. 1). A number of steps were followed to apply the methodology: 1—defining water challenges, 2—determining the risk indicators and sub-indicators, 3—creating a criterion, 4—indicator ranking and weighting, 5—assessment of risks, and 6—management of risks.

A semi-quantitate matrix was used for assessing the water security (Fig. 2), the matrix based on a combination of quantitative and qualitative procedures. Evidences were monitored for making assessment and prediction; indicator framework was created; and a large quantity of qualitative and quantitative data were collected and analyzed.

The next and important step was to convert the (risk) scores and levels to (water security) scores and level. This step was done by using a proposed model (Table 1). In this table, (Good) = risks are in a low level in water services, resources, and governance; the management system of water security in the city is good. (Challenging) = risks are in medium level; some gaps in managing water services, resources, and governance; some improvements are needed to be good.

Fig. 2 Semi-quantitative risk matrix (WHO & IWA, 2001)

Risk Matrix			SEVERITY				
			insignificant	Minor	Moderate	Major	Catastrophic
Score			1	2	3	4	5
LIKELIHOOD	Almost Certain	5	5	10	15	20	25
	Likely	4	4	8	12	16	20
	Moderate	3	3	6	9	12	15
	Unlikely	2	2	4	6	8	10
	Rare	1	1	2	3	4	5
Risk Score				1-5	6-9	10-15	16-25
Risk Level				Low	Medium	High	Extreme

Table 1 Proposed urban water security scoring system

Risk score	Risk level	Urban water security score	Urban water security level
(RS)	(RL)	(UWSS)	(UWSL)
$1 \leq RS < 6$	Low	4	Good
$6 \leq RS < 10$	Medium	3	Challenging
$10 \leq RS < 16$	High	2	Poor
$RS \geq 16$	Extreme	1	Alarming

Table 2 Risk drivers and indicators

Risk driver	Indicators
Water resources	Water resources availability
	Annual precipitation
	Ratio of treated wastewater
Waters	Water coverage
	Water losses
	Continuity of supply
Water governance	Clear roles and responsibilities
	Access to data and information
	Stakeholders engagement

(Poor) = risks are in high level; management system is weak. (Alarming) = risks are in extreme level; the management system is failure.

3 Results

Palestinian territory was chosen to apply the methodology as Palestine is considered as a complex example; water challenges in Palestine are many, tangled, and complicated. Those challenges are conflicts and wars, climate change, population growth, civilization, high water losses, weak water governance, low quality of water, and weak water infrastructure. Accordingly, a large quantity of data was collected about water services, resources, and governance (Table 2); then an indicator framework was applied and scores for the severity and probability were calculated for each indicator using the risk matrix. Ranking and weighting for indicators were conducted by using SWARA method. While scores and levels of risks in the Palestinian cities were calculated by using the risk matrix (Tables 3 and 4), then it converted to water security scores and levels (Index) by using the model (Table 5).

4 Discussions

As shown in the results, water security at urban areas in the Palestinian territories is between poor to alarming, basically the challenge is coming from the water resources which is directly affected by the climate change, and then from the water governance. They are in bad conditions. According to risk analysis, the risk score for water resources is between 17 and 23 and between 6 and 20 in water services, while it was 16 for water governance. These scores were converted to water security index using the proposed model to be 1 (alarming) in almost all Palestinian cities and 2 (poor) for some others.

Table 3 Scores and levels for risk indicators in the Palestinian cities

Risks	WRA	AP	WWC	SoS	TL	RTWW	WC	WL	CWS
Jenin	25	15	10	20	10	13	10	25	25
Tubas	25	20	25	25	25	25	1	15	1
Tulkarm	25	15	15	25	25	21	1	20	1
Qalqilya	25	15	1	20	25	14	1	15	1
Salfit	25	15	25	15	25	21	1	10	10
Nablus	25	15	1	15	10	8	1	15	25
Ramallah and Al-Bireh	25	15	10	15	10	11	1	15	20
Jericho	25	25	25	1	10	13	15	10	15
Bethlehem	25	15	20	15	25	20	1	15	20
Hebron	25	15	20	15	25	20	15	15	25

Table 4 Overall risk scores and levels in the Palestinian cities

Risk driver	W.R	W.S	W.G	Overall cose
Driver weigh	0.39	0.28	0.33	
Jenin	18.5	20.8	16.4	18.5
Tubas	23.4	6.4	16.4	16
Tulkarm	20.7	8.3	16.4	15.8
Qalqilya	18.8	6.4	16.4	14.5
Salfit	20.7	7.5	16.4	15.6
Nablus	17.2	14.4	16.4	16
Ramallah and Al-Bireh	18	12.7	16.4	16
Jericho	21.8	13.1	16.4	17.6
Bethlehem	20.4	12.7	16.4	17
Hebron	20.4	18.3	16.4	18.5

Table 5 Water security index in the Palestinian cities

City	Overall score of risk	Urban water security index
Jenin	18.5	1
Tubas	16	1
Tulkarm	15.8	2
Qalqilya	14.5	2
Salfit	15.6	2
Nablus	16	1
Ramallah and Al-Bireh	16	1
Jericho	17.6	1
Bethlehem	16.73	1
Hebron	18.27	1

5 Conclusions

This paper presented a new understanding for the urban water security under the challenge of climate change using the risk concept. The methodology used was following a number of steps: 1—defining water challenges, 2—determining the risk indicators and sub-indicators, 3—creating a criterion, 4—indicators ranking and weighting, 5—assessment of risks, and 6—management of risks. Indicators framework and the SWARA method were used in the study. Methodology was applied to the Palestinian territories as a complex example for areas subjected to water stresses and climate change challenges. The results show that the water security in the Palestinian urban areas is in bad situation. In such places new strategies must be taken to deal with the risk; risk prevention, risk mitigation, risk adaptation, and risk sharing could present a good solution to be proactive when dealing with risks and to build a successful management system for dealing with the water security at urban level.

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Geological Environment and Djorf Torba Dam Effect on Turonian Aquifer of the Cretaceous Sedimentary Basin of Bechar (Southwest Algeria)

Sarra Ameri, Abderrahmane Mekkaoui, and Abdeljalil Belkendil

Abstract

This study investigates the geological environment and water infiltration from the Djorf Torba dam into the underlying Turonian aquifer. It is a multidisciplinary experimental study, which is based on geological, hydrogeological, hydraulic, statistical, and hydrochemical approaches. This dam, a remarkable hydraulic structure, is located in the southwest of Algeria. It is of the reinforced concrete weight type, with a conventional profile. It is implanted (melted) in different sections of marine limestones, fissured Turonian, which circumscribe the Cretaceous basin of Bechar structured in asymmetric syncline. These limestones have the advantage of supporting the weight of the dam, but they have the disadvantage of waterproofing. Therefore, the phenomenon of infiltration remains a concern for both the technician and the manager. The piezometric fluctuations recorded in the "auscultation piezometers" of the dam, indicate that 72.2% are consistent with the variations in the water rating in the lake whose correlations are strong to very strong correlations (r: 0.75 to 0.94). Piezometry shows the presence of two recharge domes under the location of the Oued Guir and under the Wadi Meridja. This foundation rock is predisposed to infiltration, supported by a permeability k: 1.5×10^{-3} to 3×10^{-4} m.s^{-1}, of a transmissivity that varies from 10–3 to 10^{-4} m^2/s. It is affected by karstification and sinkholes. In addition, the outcrops exhibit three families of cracks with spacing from 10 to 100 cm and opening from 0.5 to 2.5 cm. The rock quality designation (RQD) indicates values ranging from 35 to 65%. Hydrochemical comparisons of surface water (lake) and groundwater (Turonian aquifer (pH; RS; Ca^{++}; Mg^{++}; Na+; Cl^{-}; $SO_4^{—}$; HCO_3^{-}; TH) show that the levels are higher in groundwater due to leaching. The volume infiltrated to the underlying Turonian aquifer is calculated by the balance equation of this structure and it is estimated at 22.57 Hm^3/year.

Keywords

Djorf Torba dam · Aquifer · Infiltration · Turonian

1 Introduction

Dams are works of art constructed across rivers and Wadis, aim to control floods, regulate water flows, and store water for different uses (Carrere A., 1994). To choose and adopt the right type of dam, the techniques of their construction require detailed studies in topography, hydrology, geology, and hydrogeology (Rolley R et al 1977). The Djorf Torba dam is an imposing hydraulic structure located in the southwest of Algeria (Fig. 1). It is built on the Guir Wadi, known as the Sahara Nile (Deleau 1951), by draining the upper Guir watershed of 22,068 km^2 (Ameri et al 2015). This dam, of the reinforced concrete gravity type, is founded in sections of Turonian limestone, which circumscribe the sedimentary Cretaceous basin of Bechar (Benchabane N.I, 2015; Alazard M., 2013), perfectly circumscribed by Turonian limestone.

S. Ameri (✉)
Department of Civil Engineering and Hydraulics, Faculty of Technology, NOUR Bachir University Centre El Bayadh, El Bayadh, Algeria
e-mail: s.ameri@cu-elbayadh.dz

A. Mekkaoui
Department of Civil Engineering and Hydraulics, Laboratory FIMAS, University TAHRI Mohamed, Bechar, Algeria

A. Belkendil
Center for Research in Territory Planning (CRAT), Zouaghi Slimane Campus, Route de Ain el Bey, Constantine, Algeria, Université, 25000 Costantine, Algeria

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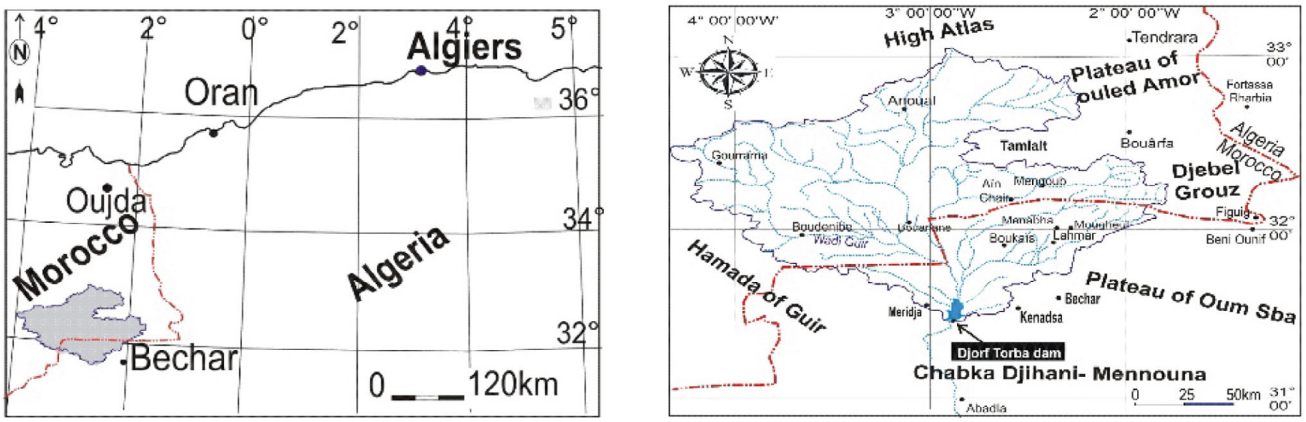


Fig. 1 Location of high Guir Watershed and Djorf Torba dam (Ameri et al 2015)

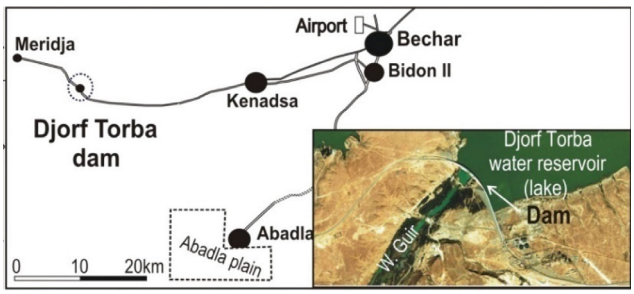


Fig. 2 Location of Djorf Torba dam

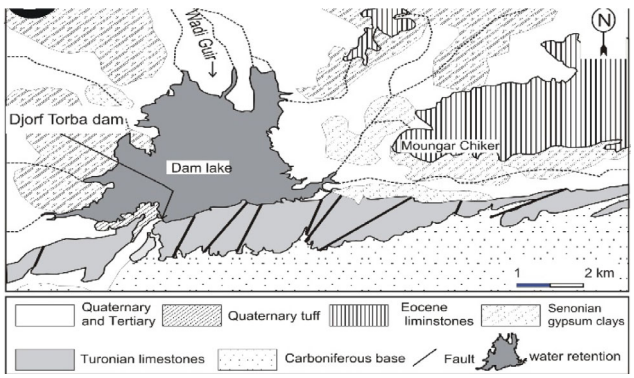


Fig. 3 Photogeological map of dam area

2 Settings and Methods or Materials and Methods

This dam is located about 60 km west of Chief Bechar and 37 km west of Kenadsa then, proceed 20km east of the village of Meridja and 70km south of the Algerian-Moroccan border (Fig. 2).

The geological formations encountered at the site boundaries are the Cretaceous, discordant to the Carboniferous, the Tertiary, and the Quaternary (Fig. 3).

This study focuses on studying the geological environment of this dam based on a multidisciplinary approach and quantifying the volume infiltrated toward the underlying Turonian aquifer. It is based on geological surveys, databases from the ANBT's operating notebooks, and a hydrochemical sampling campaign.

3 Results

3.1 Geology Prone to Infiltration

- Turonian limestones, which serve as foundation rocks, correspond to a regional aquifer. This formation has a thickness of 40 m, with permeability ranging from 3 10^{-4} to 1.5 10^{-3} and transmissivity (T) between 10^{-4} to 10^{-3} (Idrotechnico 1976 and Sadat 2020).
- Turonian limestone affected by karstification and present in sinkholes.
- Fractured limestones with four directions of fracturing (Table 1).
- RQD is calculated in the reconnaissance drilling, oscillates from 35 to 65%, and attests to significant fracturing (Deere 1964).

3.2 Statistics

The piezometric correlation matrix (Table 2) shows that the majority of the piezometers correlate positively with the water level of the reservoir (r: 0.57 to 0.90). In addition, the piezometers correlate with each other to different degrees, probably inducing either the effect of the sealing veil or their distance from the dam. Due to its position distal to the dam,

Table 1 Turonian limestone fracturing system

Family	Spacing (cm)	Opening (cm)	Length (m)	Observation
Stratification plan	10 à 100	0.5	Important	../..
N010°	50 à 60	0.5 à 2	0.5	Frequent
N045°	15 à 25	1 à 2	> 1	More common
N110°	25 à 40	2 à 3	0.3	Frequent
N150°	40 à 50	1 à 3	0.6	Less frequent

Table 2 Matrix of piezometric correlations

The variables	Lake	D209	D303	D206	D401	D407	D410	D502	D11	D105	D113	D1	D3	D10	D13	D14	D20	D28
Lake	**1**																	
D209	**0.87**	**1**																
D303	**0.90**	**0.93**	**1**															
D206	0.36	0.34	0.32	**1**														
D401	**0.77**	**0.87**	**0.82**	0.21	**1**													
D407	**0.73**	**0.87**	**0.83**	0.29	**0.66**	**1**												
D410	0.30	0.31	0.22	0.15	0.22	0.28	**1**											
D502	**0.77**	**0.80**	**0.92**	0.25	**0.72**	**0.75**	0.23	**1**										
D11	0.25	0.27	0.29	0.06	0.21	0.22	0.01	0.17	**1**									
D105	0.40	0.51	0.45	0.07	0.39	0.39	0.35	0.36	0.04	**1**								
D113	– 0.26	– 0.12	– 0.24	– 0.03	– 0.12	– 0.16	– 0.25	– 0.35	– 0.03	0.07	**1**							
D1	**0.62**	**0.78**	**0.76**	0.20	**0.82**	**0.63**	– 0.01	**0.64**	0.28	0.57	0.01	**1**						
D3	**0.83**	**0.80**	**0.82**	0.22	**0.84**	**0.63**	0.07	**0.67**	0.33	0.47	– 0.18	0.84	**1**					
D10	**0.61**	0.45	0.48	**0.77**	0.28	0.42	0.51	0.44	0.01	0.16	– 0.32	0.11	0.35	**1**				
D13	0.57	0.50	0.51	0.15	0.45	0.40	0.07	0.39	0.15	0.23	– 0.04	0.29	0.56	0.34	**1**			
D14	0.59	0.52	0.53	0.15	0.47	0.41	0.15	0.40	0.17	0.21	– 0.02	0.45	0.59	0.35	0.34	**1**		
D20	0.22	0.10	0.17	– 0.06	0.09	0.12	0.14	0.14	0.01	– 0.04	**– 0.86**	0.01	0.15	0.19	0.05	0.03	**1**	
D28	**0.89**	**0.93**	**0.92**	0.31	**0.89**	**0.75**	0.16	**0.77**	0.32	0.52	– 0.13	**0.86**	**0.94**	0.40	0.56	0.59	0.11	**1**

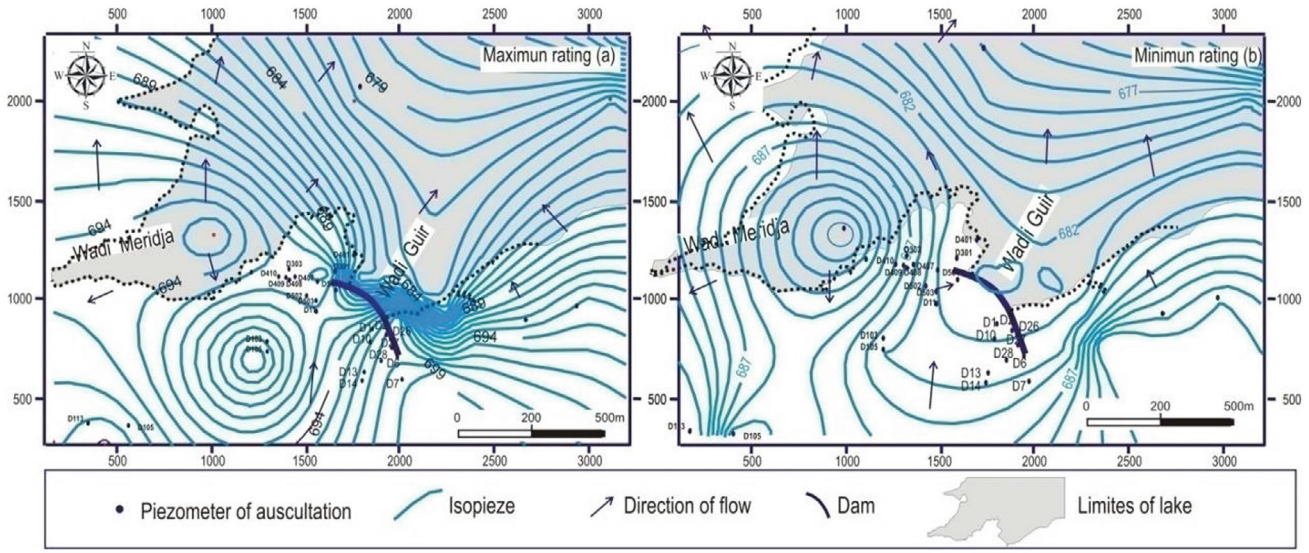


Fig. 4 Isopiestic maps of the dam site, **a** under a maximal hydraulic gradient of the lake (March, 2012) and **b** under a minimal hydraulic gradient of the lake (August, 2012)

the D113 piezometer is distinguished by low and often negative values (r: − 0.03 to 0.35). This leads to say that it is outside the influence of the effect of water seepage from the reservoir.

3.3 Hydraulic Aspect

33 auscultation piezometers are of interest to this work (Coyne and Bellier, 1985), located around the dam in a radius of more than 500 m, and spaced from a few tens of meters to more than 400 m. They are divided into groups.

3.3.1 Fluctuations of Piezometric Levels and Water Height in the Dam Reservoir

- Monitoring piezometers are sensitive to variations of the lake water level, 72,8% of auscultation piezometers are consistent with water variations in the dam reservoir.
- Piezometers not very sensitive to variations in water level in the lake (15.15%).
- Piezometers insensitive to variations in water level in the lake (12.10%).

3.3.2 Piezometry

Infiltration of lake water into the Turonian aquifer is a process that depends on the hydrodynamic properties of the aquifer (hydraulic conductivity, storage coefficient, and transmissivity), the hydraulic head generated by the lake water plan and the lake surface. The isopiestic maps drawn up for the maximum water body (697.67 m) as well as for the minimum level (693 m) (Fig. 4a and b) indicate the existence of two recharge domes; the first stand is at the lake location, while the second is imposed by the branch connected to the Meridja Wadi. These domes express a year-round supply of the Turonian groundwater from the dam lake.

3.4 Hydrochemical Aspect

The infiltration of water from the lake to the Turonian water table underlying the dam is attested by an increase in some parameters (RS, TH, and pH) and chemical elements (Ca^{++}, Mg^{++}, Na^{+}, and HCO_3^{-}).

3.5 Inflow Estimation

The balance of water inflow and outflow into and out of the reservoir for a given period allows estimating the infiltration rate. The following equation can be applied as follows:

$$V_{\text{infiltrated}} = \Delta V + V_{\text{rain}} + V_{\text{inflow}} - V_{\text{evaporation}} - V_{\text{used}} \quad (1)$$

This equation consists of a simple arithmetic operation between the element's variation in inflow and outflow at the dam and the remaining volume. The different terms of the balance were determined for over 5 years, based on ANBT operating documents. It should be noted that the average annual infiltration is 22.57 Hm^3/year.

4 Conclusion and Discussions

The present study investigated the water infiltration from the Djorf Torba dam into underlying Turonian aquifer, contained in fissured limestone. Djorf Torba dam is located in southwest Algeria. This investigation was based on four approaches: geological, hydrodynamic, statistical, and hydrochemical. It is important to note that infiltration depends on the hydrodynamic properties of the Turonian aquifer, the water height, and the lake surface. Geological analysis confirms that the foundations of the Djorf Torba dam are fissured Turonian limestones, implying a predisposition to infiltration of surface water. This latter receives the infiltrations of the lake waters, as shown by the temporal responses of the auscultation piezometers which are concordant to lake water variations and lake water dimension. This is supported by correlation coefficients that vary from moderately high to very high (r: 0.75 to 0.94) in piezometers that are very sensible to variations in lake water level and are average in others that are less sensitive (r: 0.5 to 0.57). These infiltration phenomena increase the lake size to 695 m, due to the direct contact between the surface water and the faults affecting the Turonian limestone. The infiltrated flow was treated by the water balance of this dam, over a 5 year interval, and was recorded with an annual average of 22.57 Hm^3. The hydrochemistry of the lake water showed temporal variations of chemical elements concentrations, which depend on the stored volume. Similarly, the underlying water table showed analogous fluctuations, with tenors always higher than those of the lake, attesting to the connectivity and dissolutions of the carbonate rocks in the aquifer. The Djorf Torba dam has a positive impact on the underlying Turonian aquifer, reflecting an artificial recharge, which will be valid for all similar situations.

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The Effect of Climate Risk on Sovereign Debt: Empirical Evidences from Developed Economies

Andrea Comandé, Carmelo Arena, Stefania Basiglio, and Diego Mazzitelli

Abstract

Context/Purpose: Since this is a very large and unprecedented phenomenon, research has long been studying the effects of climate change under various profiles. This study is part of a broad debate with a rich literature and aims to verify the existence of a relationship between the interest rates of long-term sovereign bonds and the climate risk deriving from climate change. *Methods* The analysis is based on panel data of 33 countries over a period ranging from 2001 to 2020, assembled from the IMF's and the Organization for Economic Co-operation and Development (OECD) databases. Since the theoretical framework of this study heavily relies on market determined prices as an indicator of economic agents' expectations, the sample meets certain criteria inherent in homogeneity in terms of economic development of the issuing countries, to ensure that the interactions between supply and demand, which then determines bond prices, make the latter more reliable. *Results* Our analysis shows the presence of a statistically significant negative relation between climate change resilience and interest rates on government debt. Although the magnitude is relatively small, its existence is particularly relevant because the intensity of the relation should become, in the long run, deeper. In fact, even if the trajectory is difficult to predict, the climate change is a phenomenon inevitably destined to worsen. *Interpretation* The initial hypothesis is confirmed by our analysis and is consistent with the prevailing literature: investors consider climate risk in their investment choices. *Conclusion* The research has several important policy implications, mainly concerning the methods of financing and allocation of government spending. In fact, the implementation of mitigation policies would have the advantage of containing the negative physical damage inherent in climate change and would allow borrowing at lower rates. This last aspect, in turn, results in an increase in current and future spending capacity, which is a key element in mitigating climate change.

Keywords

Climate change · Government Bond · Climate risk · Sustainability · Interest rates · Financial markets · Climate shocks

1 Introduction

Climate change poses significant risks to the global economic system and likely represents the greatest challenge facing current and future generations. The United Nations Intergovernmental Panel on Climate Change has released an alarming new report saying that climate change is "unequivocally" due to human activity and that timely and coordinated action by world governments is essential and at the same time will constitute a potential factor of instability for the world economy (IPCC Report 2021). Preventive management of this risk is necessary to preserve financial stability in the medium and long term. In an increasingly interconnected economy like the modern one, damage to one component of the value chain has the potential to spread its effects beyond a limited economic area, with upward pressure on prices and effects on the potential GDP of states. This work is positioned in a field of research that aims to understand how climate change materializes its effects on investment decisions. Financial operators, in fact, should take into consideration the possibility that the occurrence of events linked to both physical risk (weather events and/

A. Comandé (✉) · C. Arena · D. Mazzitelli
University of Calabria, Rende, Cosenza, Italy
e-mail: andrea.comande@unical.it

S. Basiglio
University of Bari Aldo Moro, Bari, Bari, Italy

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Table 1 Correlation between the variables

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) IR	1.0000						
(2) AdjCR	0.1852*	1.0000					
	(0.0000)						
(3) DP	− 0.1316*	− 0.0843	1.0000				
	(0.0008)	(0.0304)					
(4) pil_growth	− 0.0340	− 0.0065	− 0.3233*	1.0000			
	(0.3860)	(0.8678)	(0.0000)				
(5) infl	0.4588*	0.0444	− 0.3296*	0.1554*	1.0000		
	(0.0000)	(0.2552)	(0.0000)	(0.0001)			
(6) GDPpercapita	− 0.4520*	− 0.3520*	− 0.0292	− 0.0919	− 0.2957*	1.0000	
	(0.0000)	(0.0000)	(0.4540)	(0.0182)	(0.0000)		
(7) GHG	0.4456*	0.3170*	− 0.1717*	0.1829*	0.2717*	− 0.3994*	1.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
Source our elaboration

Table 2 Climate risk vulnerability and interest rates

Variables	(1)	(2)	(3)
CR	− 0.00167**	− 0.00123**	− 0.0012271***
GDPpc	− 2.29e-07		− 3.56e-07***
DP	0.0346995***	0.0361777***	0.0138439**
PG	− 0.2622646***	− 0.2611039***	− 0.2597457***
Infl	0.0512401		0.0549778
GHG	0.0631436*	0.0613212***	0.0633695***
Cons	0.0461283***	0.0370258***	0.0524605***
R-squared	0.3364	0.5195	0.5378
Fixed effects	Yes	Yes	No
Time fixed effects	Yes	Yes	Yes

Source our elaboration
Note *** p < 0.01, ** p < 0.05, * p < 0.1

or environmental disasters) and transitory risk (changes in environmental legislation, technology or consumer and investor sentiment) may lead to an unexpected and large-scale revaluation, resulting in a general increase in market volatility. The study by (Kruttli et al. 2021) observed an increase in the implied volatility of options written on stocks of American companies located in areas potentially affected by hurricanes. Another study (Painter 2020) highlighted how US countries who are more exposed to the effects of climate change tend to pay higher underwriting fees and initial interest for issuing long-term municipal bonds. The increase in sovereign risk appears to be greater in emerging countries (Cevik and Jalles 2021). Faccini et al. (2023) highlighted, in this regard, how non-financial companies established in "vulnerable" countries seem to show greater difficulty in accessing bank credit even after paying higher interest.

The aim of this research is to identify the existence of a relationship between public debt interest rates and the issuing country's exposure to climate risk. If investors incorporated climate risk into their expectations, this should influence their investment choices to some extent.

2 Methodology

The research will have a quantitative approach. Following the above, we formulated the following research questions:

RQ1: Is there a statistically significant relationship between climate risk and public debt interest rates?

RQ2: If it exists, what is the relationship sign?

To find an answer we use a regression model with c.d. "data panel," widely used in economic literature (Mitić et al. 2023). To verify the existence of the report sought, data from 33 countries were taken into account over a period from 2001 to 2020, using the public databases of the International Monetary Fund (IMF) and the Organization for Economic Co-operation and Development (OECD). Concerning the sample selection, we based our choice on two criteria: the first is of a practical nature, as there is generally a large availability of data for the more developed countries; the second is theoretical, since a more liquid secondary sovereign debt market is generally associated for developed countries, then the increased intensity of the interactions between supply and demand that then determine prices, should theoretically make the latter more reliable. Within the proposed empirical analysis, this research follows an approach similar to that already used in other work (Cevik and Jalles 2020; Reghezza et al. 2021). In particular, the econometric model used is as follows:

$$Y_{it} = \alpha_i + \delta_t + \beta_1 \mathrm{CR}_{it} + \beta_2 W_{it} + \varepsilon_{it}$$

The different countries are indicated with the subscript i and the time t. Y is the dependent variable, in this case the observations of 10-year government bond yields for the i-th country in period t (IR). CR is the explanatory variable of the model, built using the ND-GAIN index, an indicator of a country's exposure to the effects of climate change and its willingness to address them (Chen et al. 2023). W is a vector with country-specific control variables, inserted to control for omitted variable bias issues; these variables should not be interpreted in terms of causality. α and δ are the fixed and time effects. ε is an idiosyncratic error term. To consider the presence of heteroscedasticity in a longitudinal data context, we use standard errors clustered at the country level. In particular, the historical series of interest rates contains data on the rates of 10-year sovereign bonds, derived from the prices at which the government bonds were traded on the secondary market and not at the time of issue. As regards the explanatory variable, the ND-GAIN indicator was used which summarizes a country's exposure to climate change phenomena. The value associated with each country will therefore depends on factors external to the country. To address the issue of high correlation between the ND-Gain indicator and a country's level of economic development, a version of the indicator corrected for the country's GDP will be used.

3 Results

The results of the empirical analysis show evidence that there is a relationship between climate risk and the level of interest rates: at higher scores in the ND-GAIN (CR) score there is a decrease in the IR variable, by supporting the hypothesis that a higher climate risk also corresponds to a higher interest rate. With regard to statistical confidence, the coefficients associated with CR in its original specification are significant at the level of 5% and as regards standard errors, the table below shows the correlations between the variables used in the model. As a result, there is no correlation that would raise the question of whether there may be problems of collinearity.

4 Discussion

The results obtained confirm the hypothesis and are in line with the economic literature produced in recent years. Furthermore, they provide evidence of how climate change also affects the decision-making process of investors, who will only be willing to lend their money if the higher risk they face is rewarded. Furthermore, this research has implications for the way in which states finance their economic policies and bear budget costs: if debt were used, ceteris paribus, the costs associated with climate risk would erode spending capacity since new emissions would be more expensive and would also increase the risk on aspects not specifically linked to climate risk. For example, the same ND-GAIN indicator used as an independent variable is also influenced by the potential ability of states to cope with climate change events using budgetary resources. An increased burden of interest on public debt on the budget therefore affects the ability to react to adverse events. At the same time, it is also true that this type of policy involves transition costs that must be adequately managed and which at the same time represent one of the major resistances to the action undertaken in this sense. An increase in interest rates on sovereign bonds also has various consequences on the banking system and the real economy, since it is closely linked to that of the country in which it is based.

5 Conclusions

Research has several limitations, which will be discussed here in the hope that future research will fill them. Some of these are due to the lack of granularity of the data available. The use of data on a monthly or more quarterly timeframe would allow a higher level of detail and thus capture movements that, with annual data, are difficult to observe. Moreover, from a statistical point of view, there would be undoubted benefits from the possibility of using a greater amount of data. The countries studied are sufficiently homogeneous and the possibility of expanding research to other countries could help to make the research carried out more general. Moreover, the model as constructed is not able to capture the dynamic effects attributable to changes in microeconomic variables, namely, in this case, the intertemporal preferences of investors. From a conceptual point of view, it might be interesting to study the level of interest rates at the occurrence of events that are believed to significantly influence climate change sentiment. The observation of systematically higher interest rates for the "treaty group" (the vulnerable countries) following this event would be further evidence not only that interest rates are actually impacted by climate change but also that such a relationship could become more marked with the passage of time.

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Life Satisfaction, Social Environment and Health Behaviours in Adolescents Across Mediterranean Countries

Tania Gaspar, Conception Maldonado, Carmen Moreno-Rodriguez, Anatasios Fotiou, Charlene Vassallo, Christiana Nicolaou, Kalina Sotiroska Ivanoska, Riki Tesler, Lorena Charrier, Michaela Bersia, Paola Nardone, Silvia Ciardullo, and Margarida Gaspar Matos

Abstract

During adolescence, social relationships have a major influence on adolescents' life satisfaction and health behaviours. These relationships can be influenced by individual and cultural factors. We aim to study life satisfaction, social relationships and health behaviours among adolescents from Mediterranean countries, identifying similarities and distinctions between countries. The Health Behaviour in School-aged Children (HBSC) is a World Health Organization collaborative cross-national study conducted every 4 years in 52 countries and regions across Europe and North America (http://www.hbsc.org). The sample included 25,687 students from seven (7) Mediterranean countries (Greece, Italy, Israel, Malta, North Macedonia, Portugal and Spain). The mean age of the participants was 13.6 years (*SD* 1.6), and 51.5% were females. Indicators of health and well-being—life satisfaction, health-related behaviours, physical activity and eating habits—and developmental contexts were selected from the HBSC questionnaire from 2018 survey. Statistically significant differences were found for all the variables under study. For each of the variables we identified countries with approximate average values and countries that differ. North Macedonia is the country where adolescents showed a higher life satisfaction, more positive relationship with their parents and peers and also who showed a healthier eating behaviour, having breakfast and eating more fruits and vegetables than their counterparts in other Mediterranean countries. In relation to physical exercise, Portugal is the country with the best indicators. Regarding school pressure Greece is the country where adolescents feel the least pressure. The results are discussed from the perspective of cultural and geographical differences and the level of public health strategies. In all countries there is a statistically significant correlation between the variables under study, highlighting the correlation between life satisfaction and perception of health, the relationship with friends, liking school and communication with the father and mother. In order to improve the health of the adolescent population, there is a need for more sustainable multisectoral public policies to take into account developmental life challenges, aiming to promote health behaviours, positive social relations, prevent and reduce unhealthy behaviours and reduce health inequalities, during adolescence and in later life.

T. Gaspar (✉)
Group Coordinator, HBSC/WHO Mediterranean Countries Zone, Lisbon, Portugal
e-mail: tania.gaspar.barra@gmail.com

Digital Human-Environment Interaction Labs, University Lusofóna/HEI-Lab, Lisbon, Portugal

T. Gaspar · M. G. Matos
University of Lisbon/ISAMB, Lisbon, Portugal

C. Maldonado · C. Moreno-Rodriguez
University Seville, Seville, Spain

A. Fotiou
University Mental Health, Neurosciences & Precision Medicine Research Institute (UMHRI), Athens, Greece

C. Vassallo
Health Promotion and Disease Prevention Department for Health Regulation, Health Ministry, Valletta, Malta

C. Nicolaou
Center of Educational Research and Evaluation, Pedagogical Institute, Ministry of Education, Sports and Youth, Nicosia, Cyprus

K. Sotiroska Ivanoska
Faculty of Philosophy, Skopje, Republic of Macedonia

R. Tesler
Ariel University, Jerusalem, Israel

L. Charrier · M. Bersia
University of Turin, Turin, Italy

P. Nardone · S. Ciardullo
National Centre for Disease Prevention and Health Promotion, Italian National Institute of Health, Turin, Italy

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Keywords

Adolescents · Life satisfaction · Social environmental · Health behaviour · Eating behaviour · Cross-cultural

1 Introduction

Current changes of the modern societies, including Mediterranean societies, are affecting adolescents' well-being (Bolton and Bhugra 2021). Adolescence is referred to the transition period between childhood and adulthood also known to be a critical phase in determining a person's well-being. Paying attention to a person's well-being during this phase will probably contribute in positive ways to social relationships, life satisfaction and health behaviour of adolescents. In addition, during this phase, adolescents face challenges attributed to various body changes, like growth and biological development, physical changes as well as shifts in their moods. These three determinants (social relationships, life satisfaction and health behaviour) are not well studied and therefore there is a need to be set as a priority, if a better quality of life is to be achieved (Gaspar et al. 2022; Botelho Guedes et al. 2022; Kleszczewska et al. 2022; Fabris et al. 2023).

To conduct this study a large representative school-based survey of adolescents residing in the Mediterranean countries aged 11, 13 and 15 were investigated. The aim was to identify similarities and differences in social relationships, life satisfaction and health among adolescents to contribute to their well-being across the Mediterranean countries.

2 Methods

The HBSC cross-national study has taken place every 4 years since 1982 (for more information about the study, see http://www.hbsc.org). Data collection procedures in all participant countries and regions (currently 52 across Europe and North America) are developed in accordance with a standardized international protocol which is produced by the HBSC research network (available from the study website). Each country obtains ethical approval through the competent bodies and follows the specific procedures required to conduct the survey, adhering to the criteria that participation must be voluntary, and anonymity guaranteed. Data are collected from a nationally representative random cluster sample of 11-, 13-, and 15-year-old in each country by self-completion of questionnaires in the classroom. The primary sampling units are classes or schools. More detailed information about methodology of the HBSC study can be found elsewhere (Inchley et al. 2018). The present study data were collected in the survey year 2017/2018 and includes 25,346 students from seven Mediterranean countries (Greece, Israel, Italy, North Macedonia, Malta, Portugal and Spain). The mean age was 13.6 years (standard deviation 1.6), ranging between 10 and 16 years old and 51.5% were girls.

3 Results

The correlation analysis between life satisfaction and other health and social relationship variables reveals that life satisfaction is statistically and significantly correlated with all the variables under study. The highest correlations ($r > 0.25$) with "perceived health" ($r = 0.39$); "relationship with Friends at school" ($r = 0.30$), "communication with father" ($r = 0.27$), "communication with mother" ($r = 0.26$), "liking school" ($r = 0.27$) are highlighted (Table 1).

4 Discussion

The results allowed to characterize similarities and differences in social relationships, life satisfaction and health among adolescents across the Mediterranean countries. Adolescents encounter challenging moments, which, in combination with their sensitive nature, lead to a roller coaster of emotions. This situation leads to negative outcomes when support is not provided by social relationships with family, friends or other close people (Bolton and Bhugra 2021; Gaspar et al. 2022; Botelho Guedes et al. 2022; Kleszczewska et al. 2022).

The comparison between Mediterranean countries reveals statistically significant differences for all variables under study. North Macedonia emerges as the country that shows better indicators in the different variables related to health, health behaviours and social relations. We can conclude that the school's attractiveness for North Macedonian students is not of academic nature, but much more social, which is more often the case with boys than with girls. In North Macedonian schools, children socialize, more than they learn or are aimed at academic achievements. However, for years these conditions have been changing, so adhering to the school has a strong trend of decline in recent research (Kostarova 2020).

North Macedonia is a traditional country and has more than 260 sunny days in the year, thus providing rich vegetation and agricultural products. In addition, North Macedonia is a small economy, and vegetables and fruits are equally accessible to children, regardless of their family property. Children use that convenience and eat fruits and vegetables, unlike soft drinks and fast food, which they do not have the means to buy.

North Macedonian culture is very family oriented. Members of the extended family are involved in making

Table 1 Table captions should be placed above the tables

		N	Mean	Standard deviation	Error	*Z*/sig
Life satisfaction	Greece	3821	7.54	1934	0.031	176.42***
	Italy	4107	7.58	1812	0.028	
	Malta	2490	**7.33**	2076	0.042	
	Portugal	6048	7.73	1794	0.023	
	Spain	4313	8.09	1742	0.027	
	North Macedonia	4511	**8.43**	2080	0.031	
	Total	25,290	7.82	1925	0.012	
Difficult relation with friends at school	Greece	3827	**7.15**	2359	0.038	218.58***
	Italy	4099	6.22	2378	0.037	
	Malta	2470	6.06	2416	0.049	
	Portugal	5825	6.08	2389	0.031	
	Spain	4285	6.19	2661	0.041	
	North Macedonia	4489	**5.39**	2417	0.036	
	Total	24,995	6.16	2492	0.016	
Disliking school	Greece	3824	**2.36**	0.873	0.014	197.94***
	Italy	4121	2.32	0.812	0.013	
	Malta	2510	2.02	0.968	0.019	
	Portugal	5827	2.21	0.826	0.011	
	Spain	4299	2.21	0.967	0.015	
	North Macedonia	4613	**1.84**	0.953	0.014	
	Total	25,194	2.17	0.912	0.006	
Pressured by schoolwork	Greece	3823	**2.18**	0.858	0.014	279.33***
	Italy	4133	2.71	0.890	0.014	
	Malta	2501	**2.87**	1012	0.020	
	Portugal	5827	2.33	0.989	0.013	
	Spain	4305	2.70	0.948	0.014	
	North Macedonia	4614	2.48	0.969	0.014	
	Total	25,203	2.51	0.972	0.006	
Exercise—times a week	Greece	3824	**2.70**	1490	0.024	129.30***
	Italy	4130	3.32	1624	0.025	
	Malta	2540	3.10	1681	0.033	
	Portugal	5897	**3.47**	1819	0.024	
	Spain	4301	3.06	1579	0.024	
	North Macedonia	4614	2.92	1673	0.025	
	Total	25,306	3.12	1681	0.011	
Breakfast	Greece	3770	**4.00**	2183	0.036	264.23***
	Italy	4055	4.36	2147	0.034	
	Malta	2531	4.15	2140	0.043	
	Portugal	5906	**5.13**	1617	0.021	
	Spain	4314	4.77	1874	0.029	
	North Macedonia	4556	**5.06**	1600	0.024	
	Total	25,132	4.66	1947	0.012	
Eat fruits	Greece	3846	**4.60**	1482	0.024	51.46***
	Italy	4130	**4.62**	1700	0.026	
	Malta	2571	4.66	1778	0.035	

(continued)

Table 1 (continued)

		N	Mean	Standard deviation	Error	*Z*/sig
	Portugal	5905	4.94	1765	0.023	
	Spain	4320	4.72	1703	0.026	
	North Macedonia	4585	**5.03**	1648	0.024	
	Total	25,357	4.79	1692	0.011	
Eat sweets	Greece	3839	3.91	1458	0.024	318.47***
	Italy	4131	4.32	1641	0.026	
	Malta	2570	**4.69**	1681	0.033	
	Portugal	5904	**3.68**	1527	0.020	
	Spain	4318	**3.63**	1574	0.024	
	North Macedonia	4535	4.54	1761	0.026	
	Total	25,297	4.07	1653	0.010	
Eat vegetables	Greece	3839	4.63	1560	0.025	122.78***
	Italy	4127	4.33	1716	0.027	
	Malta	2569	**4.12**	1845	0.036	
	Portugal	5904	4.42	1823	0.024	
	Spain	4317	4.53	1596	0.024	
	North Macedonia	4544	**5.02**	1707	0.025	
	Total	25,300	4.53	1732	0.011	
Difficulty in communication with father	Greece	3809	2.22	1117	0.018	185.68***
	Italy	4082	2.32	1116	0.017	
	Malta	1396	2.42	1081	0.029	
	Portugal	5652	2.16	1231	0.016	
	Spain	4244	**2.60**	1235	0.019	
	North Macedonia	4456	**1.88**	1038	0.016	
	Total	23,639	2.24	1173	0.008	
Difficulty in communication with mother	Greece	3785	1.70	0.892	0.014	242.38***
	Italy	4075	1.85	0.943	0.015	
	Malta	2498	1.69	0.932	0.019	
	Portugal	5651	1.62	0.922	0.012	
	Spain	4237	**2.10**	0.894	0.014	
	North Macedonia	4418	**1.49**	0.837	0.013	
	Total	24,664	1.74	0.924	0.006	
Negative health perception	Greece	3849	1.59	0.667	0.011	408.25***
	Italy	4121	1.76	0.639	0.010	
	Malta	2514	**1.87**	0.649	0.013	
	Portugal	6049	1.78	0.661	0.009	
	Spain	4308	1.73	0.665	0.010	
	North Macedonia	4634	**1.32**	0.552	0.008	
	Total	25,475	1.67	0.665	0.004	

Note The values considered highest and lowest in the Duncan post hoc analysis are marked in bold

decisions for children and the whole family is likely to be consulted, associated with the most minor pronounced difficulties in communicating adolescents with parents.

Relative to other countries, students in Greece felt lower school pressure but liked school less and had a less positive social relationship with their peers at school. In terms of health behaviours, students in Greece also reported less physical activity and less consumption of breakfast and fruits. There are marked decreases in school satisfaction in Greece in the past 20 years (Löfstedt et al. 2020). These may reflect increases in academic expectations, parental pressure combined with lack of support at home or in the school as

well as adverse school experiences (e.g., bullying or peer pressure). For example, a recent small study in children aged 9–12 in Greece showed that poor quality of friendships at school is associated with low school liking (Antonopoulou et al. 2019). The relatively high prevalence of skipping breakfast among adolescents in Greece, too, has been highlighted in different studies, but the longitudinally contributing factors are rather unexplored (Benetou et al. 2020). One large cross-sectional study found that skipping breakfast among adolescents in Greece (mean age 9.9; SD = 2.8) was independently associated with inter alia poor food choices, including low consumption of fruits and low physical exercise, suggesting that all these characteristics likely cluster around the same adolescents. Greece is also the country in the Mediterranean region of Europe where the economic crisis was the deepest and longest effects on inequality and poverty, and as studies have shown, also weaker socioeconomic conditions (e.g., employment of only one parent and lower educational level of parents) can increase the risk of skipping breakfast in children.

The results in Malta reveal adolescents with lower life satisfaction, less positive health perception, higher consumption of sweets and lower consumption of vegetables. According to the results when compared to the Mediterranean countries, it illustrated that Maltese adolescents are experiencing several worrying trends towards lower life satisfaction, less positive health perception, high pressured by schoolwork, higher consumption of sweets and lower consumption of vegetables (Velez-Toral et al. 2021).

In Spain, adolescents reported more difficulties in communicating with their fathers and mothers compared to the other countries under review. The study conducted by Ramos, Cano and Meneses (Ramos et al. 2022) with Spanish adolescents concludes that positive communication with both parents is associated with health behaviours, and compared to other countries Spanish parents use less dialogue (Lorence et al. 2020).

5 Conclusions

The study concludes that life satisfaction among adolescents in Mediterranean countries should be understood from a biopsychosocial and environmental perspective. Social and contextual factors appear to have a stronger association with life satisfaction than health behaviours. Social relationships among adolescents need to be placed high on the agenda as they affect their well-being**.** Creating early interventions such as psychological and educational awareness and offering immediate support are essential to improve and to protect the adolescent's life satisfaction, social environment and health behaviours in the long term. Life satisfaction, social environment and health behaviours in adolescents across Mediterranean countries should be also based on a wider reflection on the societal needs to change urban environments. The environments in which adolescents live, especially urban environments, should be designed and adapted so that they are perceived by adolescents as safe and pleasant places to be, to carry out activities and where they feel safe (Fabris et al. 2023; Oscilowicz et al. 2020).

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Analysis of Thermal Comfort in a Construction Element Based on Earth and Agave Bagasse (*Agave tequilana*)

Iván Vera-Romero, Saúl Leonardo Hernández Trujillo, Berenice Farfán Heredia, Roberto Briones Flores, and Luis Bernardo López Sosa

Abstract

The maguey in Mexico, better known as Agave, is mainly used to make alcoholic beverages, such as Mezcal or Tequila. The process involves six main steps: (1) selection of the agave, (2) jimado of the agave, (3) cooking of the agave, (4) grinding, (5) fermentation, and (6) distillation. In this process, a very abundant residue is produced, which is known as maguey bagasse. The maguey bagasse is commonly dumped on nearby farms without any prior bioremediation treatment. The accumulation of this residue is generating local environmental problems. In this work, the residual bagasse used as an aggregate for the creation of a constructive element is analyzed, mixing it with soil, *portland* cement, and lime. To simulate heat transfer and determine the time required to reach thermal equilibrium inside a home, the conductivity of the materials was evaluated. The thermal conductivity of the maguey bagasse (0.369 W/mK), the construction element proposed in this work (Agave brick; 0.975 W/mK), adobe (soil brick; 0.550 W/mK), red brick (0.618 W/mK) and concrete brick (0.654 W/mK) were obtained. The time in which thermal equilibrium was reached was also measured for each of the construction elements analyzed: agave brick (3.32 h), soil (adobe; 5.11 h), red brick (5.5 h), and concrete brick (4.40 h). Observing that the bagasse provides an acceptable thermal comfort in the constructive element.

Keywords

Agave · Mezcal · Maguey · Thermal equilibrium · Heat conductivity

1 Introduction

The alcoholic beverage production industry in Mexico is growing day by day. Beer is the main best-selling product, followed by drinks made from grapes and drinks obtained from agave (Maguey). Different drinks are obtained from agaves: mead and pulque (*Agave salmiana, A. atrovirens, or A. mapisaga*), Bacanora (*A. angustifolia: Agave yaquiana*), mezcal (various types of agave) and Tequila (*Agave tequilana*). These last two being the most produced. The word mezcal is of Nahuatl origin, and it means cooked maguey. So, being practical, the drinks known as mezcal, bacanora, and tequila are themselves a mezcal. The general production process of these beverages is the same and consists in six main steps (modified from standard artisanal mezcal production (Vera et al., 2009): (1) selection of mature agaves, (2) jimado (leaf removal from the agave), (3) cooking the piña (stem/head), (4) macerating, (5) fermenting, and (6) distilling (Neri Vega et al. 2017) (refer Table 1).

Of the Mexican alcoholic beverages, the production of tequila is the most important. In recent years, the national production of tequila agave in 2020 was one million 519 thousand tons. The value of the total production of tequila agave in the country, in the same year, was 31 thousand 339 million pesos. Approximately 111,000 hectares were planted, of which about 20,000 hectares were harvested, which generated a yield of 77.6 tons per hectare. Throughout this year, Mexico produced 385.8 million liters, exporting 308.6 million, thus indicating that eight out of every ten liters

I. Vera-Romero · S. L. H. Trujillo · B. F. Heredia · L. B. L. Sosa
Universidad Intercultural Indígena de Michoacán, Pátzcuaro, Michoacán, México

I. Vera-Romero (✉)
Universidad de la Ciénega del Estado de Michoacán de Ocampo. Universidad 3000. Lomas de la Universidad, Sahuayo, Michoacán, Mexico
e-mail: ivan.vera@uiim.edu.mx; ivera@ucemich.edu.mx

R. B. Flores
Instituto Tecnológico Superior de Uruapan, Uruapan, Michoacán, Mexico

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Table 1 General characteristics of the artisanal process of obtaining tequila

Step	Process	Description	Machines or equipments, inputs	Tools
1	Selection	Detection of agave maturity (visual inspection to determine when the plant is ready for harvest)	–	Visual recognition
2	*Jimado* (cut leaves)	Removal of the agave leaves (cutting the leaves to expose the piña)	–	Machete, shovels, scythes, special shovels
3	Cooking	Cooking of the agave piña to convert starches into fermentable sugars	Boiler or autoclave; electricity; fuel: gas, gasoline, diesel, wood or biomass	–
4	Grinding	Grinding or maceration of the cooked agave piñas to extract the juices	Mechanical mill; fuel: gasoline, diesel or electricity	–
5	Fermenting	Spontaneous fermentation of the agave juice; conversion of sugars into alcohol	Fermentation tanks (wood, stainless steel, clay pots, plastic)	–
6	Distilling	Simple or double distillation to obtain tequila	Distillation tower, craft distiller, copper still, etc	–

produced are consumed in other nations. It has a presence in more than 101 countries, however, around 90 percent of the exports made went to the US market, which acquired 277.8 million liters. Profits from the international sale of this drink reached 2 thousand 355 million dollars (SEGOB 2022).

In 2023, according to the Tequila Regulatory Council (CRT, for its acronym in Spanish), 214.1 million liters per year were generated on average, of 40 degree tequila, they gained 1070.5 million kilograms of bagasse residue per year. This production is generated in 181 municipalities that are found in five states that have a designation of origin for tequila (designation of origin is a term used to legally protect tequila and mezcal that is produced in a certain area), these being: Jalisco with 125 municipalities, contributing 74% to the generation of bagasse; Guanajuato with 7, contributing 17.38%; Tamaulipas with 11, contributing 1%; Nayarit with 8, contributing 2.39%; and Michoacán with 30, contributing 4.8% (Conociendo la Industria del Tequila y Mezcal Online 2019).

As can be seen, the development of this industry has been important for the growth of the Mexican economy, but at the same time, it has caused an excessive generation of waste. Contributing to a large extent to an over-exploitation of resources and the generation of an environmental impact, which until now have not been able to be fully solved. The main environmental problem is related to its produced effluents, such as vinasse and solid waste (bagasse). Vinasse is liquid waste with a high content of contaminants, sugars, alcohols, metals, an acid pH (4.5), a high Chemical Oxygen Demand (52 g/L) and is usually dumped at an average temperature of 85 °C. Bagasse, on the other hand, is typically dumped untreated on adjacent lands, where it undergoes in situ degradation. This process generates leachates that contaminate surface and groundwater bodies as well as soils; both residues also exhibit an acidic pH (4.5). Collectively, these liquid and solid wastes represent a major source of pollution. Although various management strategies have been attempted, none have proven entirely successful. For instance, vinasse has been used for irrigation, but its application forms an impermeable layer that hinders plant nutrient uptake. It has also been employed in composting and in the production of second-generation biofuels, elbeit with limited efficiency (Sherrer 2013).

On the other hand, when the bagasse decomposes it produces leachates, which when filtered contribute to soil degradation and contamination of water bodies, changing their properties. Due to the large amounts of discarded bagasse, it reaches the point of implementing its burning since it is in a limited space, causing emissions of polluting gases. Compost is also produced; however, it takes an average of approximately 3 months to obtain, and due to its slow production speed, land extensions must be large, making this option impractical or partial. Data collected in the field, in the town of Jiquilpan, Michoacán, Mexico.

In this research work, an alternative for the use of bagasse as an aggregate construction material is proposed and that is applied in the elaboration of a constructive element, which manages to provide better thermal comfort in houses. For this purpose, the thermal conductivity of the bagasse is evaluated, as well as the thermal conductivity of a mixture of bagasse, soil, and *portland* cement, corresponding to a proposed constructive element. The objective of evaluating thermal conductivity and thermal balance is to, in the future, compare energy consumption from heating, as well as energy consumption from air conditioning, both of which are consumed in a house to guarantee thermal comfort in the studied region (Cedano et al., 2021; Oropeza-Perez et al., 2017).

2 Materials and Methods

The thermal conductivity and thermal equilibrium of the maguey bagasse and the proposed construction element (samples) were evaluated using a P.A. Hilton Ltd. linear heat conduction unid (model H111A, serial no. H111A/

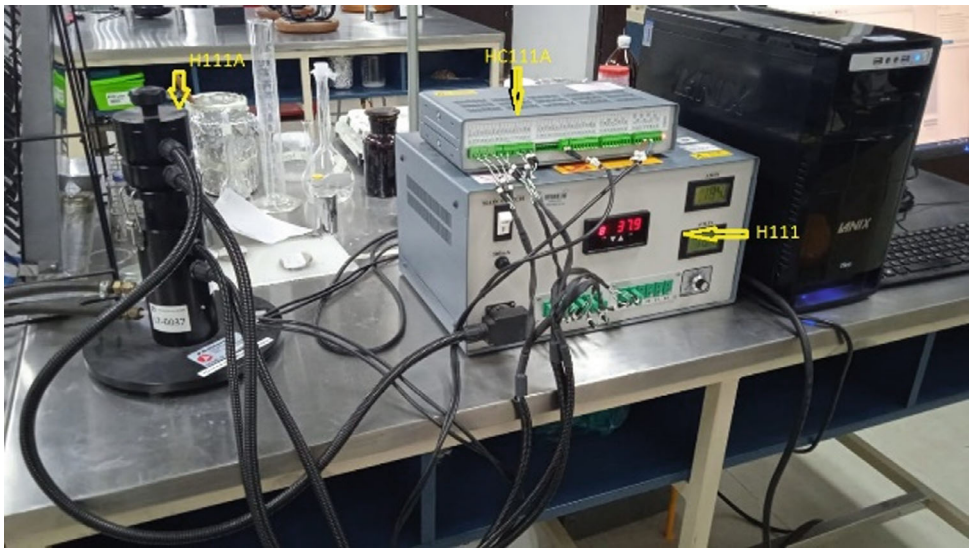


Fig. 1 Linear heat conduction H111A/10346

10346 Fig. 1). The samples must be inserted into the apparatus and must have a thickness of 4.5 mm and a diameter of 45 mm. The equipment is equipped with eight thermocouples for temperatures measurement (Fig. 1). A constant voltage is applied to heat the sample ultil thermal equilibrium is reached. The thermal conductivity is then clculated from the recorded upper (T3) and lower (T6) sample temperatures, the applied voltage and current, and the sample thickness, according to the following equation (Eq. 1). For the elaboration of the proposed construction element, the following was mixed (% volume): water (9.7%), soil (51.5%), dry maguey bagasse (25.8%), *portland* cement (6.5%), and lime (6.5%). And this was left to dry for approximately 30 days at room temperature (approximately 19 °C).

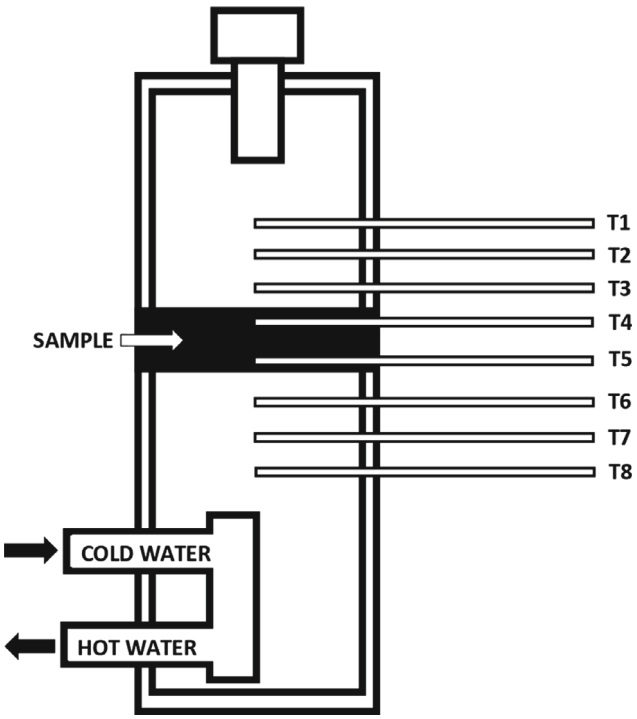


Fig. 2 General schemematic of the H111A linear heat conduction appartus showing the position of the eeight thermocouples and sample insertion

$$Q = Ak\left(\frac{\Delta T}{\Delta x}\right) \tag{1}$$

where

Q is the obtained heat transferred by the resistance (I*V);
I, amperage;
V, voltage;
ΔT, temperature difference between sample surfaces;
Δx, sample thickness;
A, axial area of the sample;
k, thermal conductivity of the sample.

To evaluate the time in which thermal equilibrium is reached, the same equipment was used, but this time, the test was stopped when the temperatures at the ends of the sample stopped having variations. In this way it is defined that thermal equilibrium has been reached and, therefore, the time in which it has been reached is recorded.

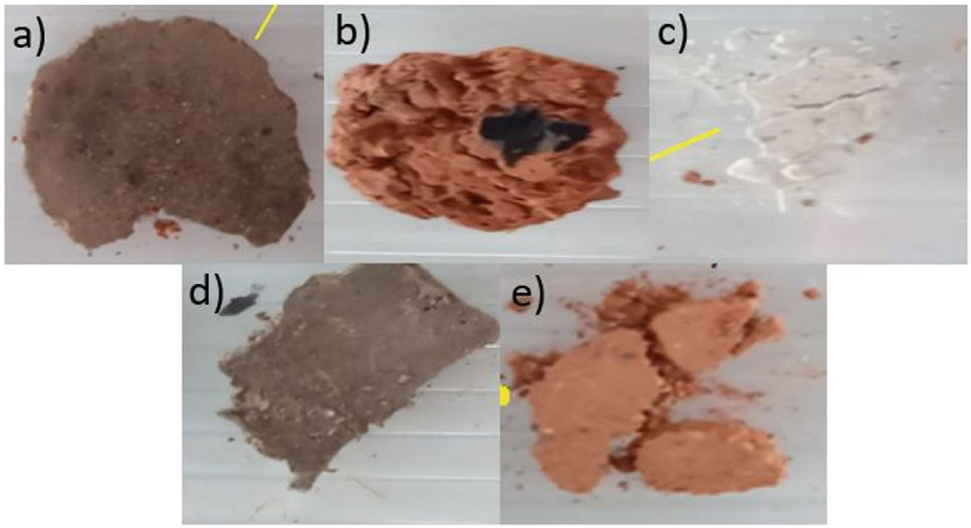


Fig. 3 Samples of materials (after testing): **a** soil (adobe), **b** red brick, **c** concrete brick, **d** agave brick, and **e** discarded sample

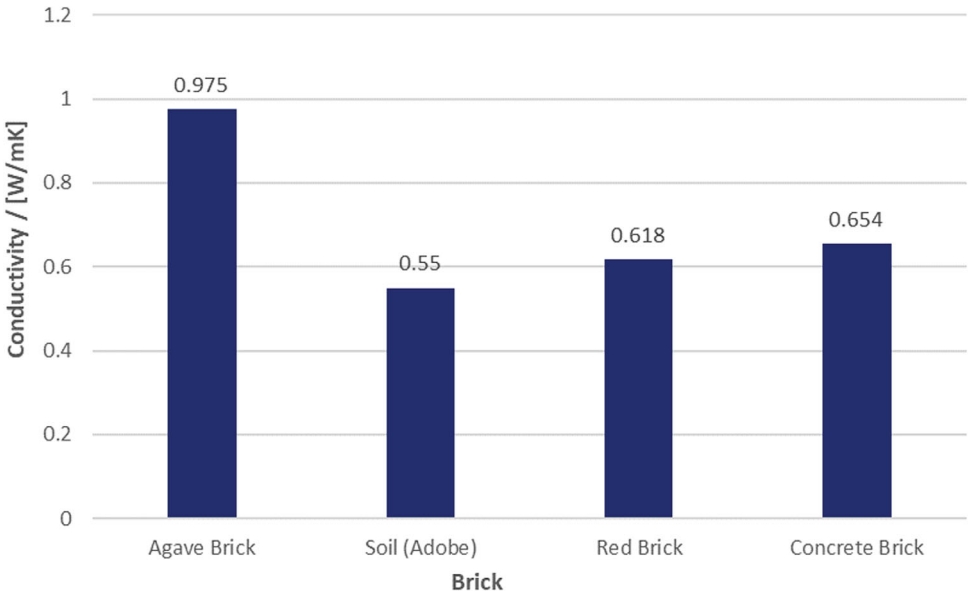


Fig. 4 Experimental thermal conductivity

3 Results

In these preliminary results, thermal comfort is not evaluated as such, since this requires further investigation. Therefore, only the thermal conductivities and the time in which thermal equilibrium is reached between bricks are compared.

According to the data obtained, the average thermal conductivity of the maguey bagasse turned out to be 0.369 W/mK. Six measurements were made at two different compression pressures of the samples: 8000 and 10,000 kg of force. On the other hand, both the conductivities of the different samples (Fig. 3), as well as the time for obtaining thermal equilibrium, are observed in the following figures (Figs. 4 and 5).

4 Discussion

Results indicate that maguey bagasse alone has an average thermal conductivity of 0.369 W/mK, a low value comparable to insulators susch as certain polymers, wood, and clays. Thus, maguey bagasse can be classified as a natural insulating raw material. Conversely, when mixed with soil, Portland cement and lime, the conductivity increases significantly to 0.975 W/mK. Although this value is higher than that of traditional adobe or brick, it remains relatively low for a structural composite. However, the proposed element reached thermal equilibrium faster (3.32 h) than the reference materials, suggesting lower thermal inertia wich could impact indoor thermal comfort. Consequently, further research is

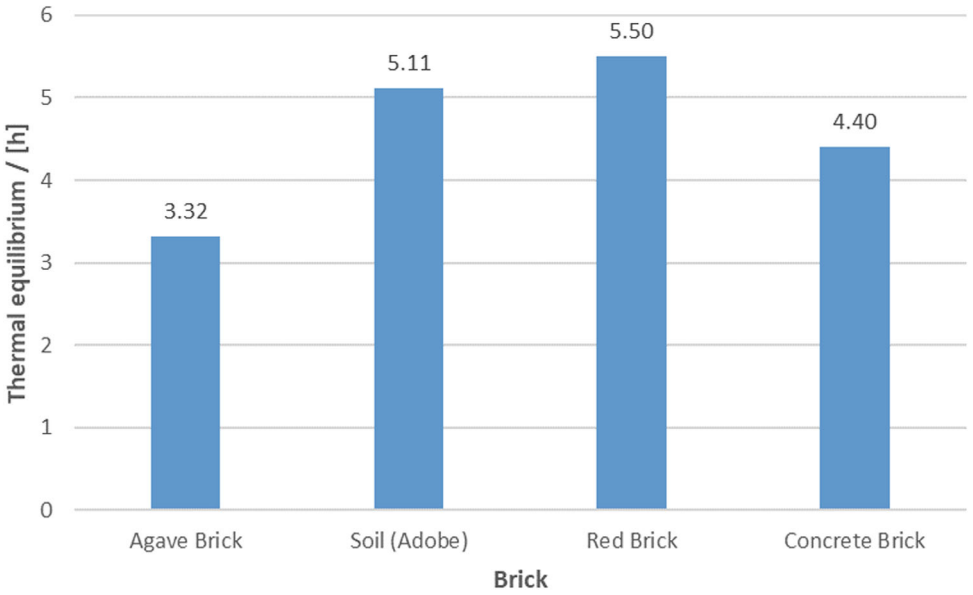


Fig. 5 Experimental thermal equilibrium

needed to optimize the mixtures and bagasse concentration to enhance its insulating performance.

5 Conclusions

The constructive element analyzed in this study provides acceptable thermal comfort and can therfore be considered a viable alternative for the safe management of tequila industry waste in Mexico. However, further research is required, particularly regarding compressive strength, to determine whether it meets the minimum requirements established in Mexican official standards.

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The Origin of the Shoal Islands in Khor Abdullah Waterbody Using Sedimentary Analyzes and Sub Bottom Profiler Survey

Zainab A. Al-Humaidan, Wala′a M. Al-Mosawi, and Mohanad H. Al-Jaberi

Abstract

Shoal islands are sandy barrier islands that extend parallel to the coastline and are located in the Khor Abdullah waterbody northwest of the Persian/Arabian Gulf, a shallowing coastal creek or lagoon. The shoals are noticed at the lowest low water period yet submerged during high tide. There are 11 shoals in Khor Abdullah, with 7 are on the Kuwaiti seawater side, while the rest of them, 4, in the Iraqi side. The main aim of the present research is to identify the origins of these shallow areas, commonly referred to as shoals. The study has utilized the SBP (Sub bottom profiler) technique, along with sedimentary testing of sediments including grain size and mineralogical tests, primarily to accomplish its objectives. Four locations, namely, Athan Shoal (St.1), Small island (St.2), Atlassi Shoal (St.3), and an island near Fasht Ayk (St.4), were identified. The SBP technique, however, did not show distinctive features with an increase in the depth under the seabed. This suggests that the source of these shoals is not from deep area, but rather from the recent sediments of the seabed. The results of the grain size analysis show muddy sand, sand, and sand white shell fragments of sediments for St.1, St.2, and St.4, while for St.3, it is characterized by hard rocks where corals have grown. The fauna was much diversified, especially in St.4 with the dominance of Mollusca. Regarding the mineralogical analysis, the results of the *X*-Ray Diffraction (XRD) testing showed high percentages of quartz and calcite, with the presence of primary and secondary dolomite as well as low percentage of clay minerals. The findings revealed that many geologic factors including the sedimentary, tectonic and morphological aspects having combined action contribute to forming of these shoals. The shoal islands are subject to erosion rather than growth (sedimentation). Atlassi Shoal does not often appear above the water surface even in the lowest tide phases. It is therefore considered one of the remains of the ancient coast, as a result of the sea level fluctuations due to climate changes and tectonic movements in the Quaternary period.

Keywords

Shoal islands · Sub bottom profiles (SBP) · Khor Abdullah · Shell fragments · XRD analysis · Grain size · Fauna

1 Introduction

The sedimentary composition of the northwestern section of the Persian/Arabian Gulf is characterized by instability and variability, which may be attributed to the numerous hydrological factors present in the area (Muttashar et al. 2024). These unstable sedimentary conditions, whether at the present or in the past time, resulted in many distinctive sedimentary features in the region. It includes a delta, mudflats, lagoons and creeks, islands (especially on the Kuwaiti side), and submerged islands (shoals), which will be the focus of the current study.

There are many islands of all forms and sizes, which are located along the gulf coastline and lower topography limits (Sabbagh-Yazdi et al. 2007). These shallow islands in Khor Abdullah are mainly located near the Kuwaiti coast, and near or far from the Coast of Bubiyan Island. Few studies have been conducted to identify the origin and the development of these shoals. Goudie (2006) described the shoals by they

Z. A. Al-Humaidan (✉) · W. M. Al-Mosawi
Department of Sedimentology, Marine Science Centre, University of Basrah, Basrah, Iraq
e-mail: zainab.hamed@uobasrah.edu.iq

M. H. Al-Jaberi
Department of Geology, College of Science, University of Basrah, Basrah, Iraq

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are impermeable morphological structure characteristic of shallow marine environments. Scientists disagreed about the origin of these islands, and many of them think that they may have been formed at the end of the glacial period with the sea level. Al-Mosawi et al. (2015) indicated that there is more than one factor involved in the formation of the Palinurus Shoal represented by tectonic, morphological, and sedimentary factors. The current study sheds light on the origin and forming of these shoals in Khor Abdullah using sedimentary analyzes and Sub bottom profilers technique (SBP).

2 Materials and Methods

During field work, sediment samples were collected by the grab sampler device. Four of the islands located on the Iraqi side in Khor Abdullah were studied. The grain size was analyzed (sand%, silt% and clay%) of the sediment samples by the pipette method based on (Folk 1974). These analyses were carried out at the Marine Sciences Center/ Basrah University. Furthermore, mineralogical analysis, in particular *X*-Ray Diffraction (XRD) test of the bulk sediments were carried out. The powdered sample was tested under 2θ between 2° and 65° by Shimadzu 6000 Device/JAPAN at the Ministry of Industry and Minerals (Industrial Research and Development Center/Baghdad). Fifty grams of the dried samples were washed with a (0.063 mm) sieve. Fauna in sediments was picked under a microscope (WILD type) with a special brush, examined under a microscope and are described in detail with a special camera. Also, two Sub-Bottom sediment profilers were conducted. The first SBP profile with a length of 9 km extends from the eastern breakwater of the Grand Fao Port toward the sea, while the second profiler is located south of the western breakwater and extends from the Iraqi coast to the end of the Iraqi maritime border with a distance of 4 km.

3 Results

3.1 Sedimentary and Fauna Analysis

The results of sedimentological analyses (Table 1 and Fig. 1) showed that the shoal islands are characterized by a sandy texture, except for St.3 which consists of a rocky seabed.

3.2 Sub Bottom Profiler

The SBP sections provided details about the specific locations of shoal sites, primarily in the first section. Three sites were identified at a depth of 6 m, whereas the average depth of the surrounding regions was 8 m, as seen in Fig. 2.

Table 1 The percentages of sand, silt, clay, and texture of the shoal islands

No.	Name of islands	Depth (m) at high tide	Sand %	Silt%	Clay%	Texture	Color
1	Athan shoal (St.1)	4	61	26	13	Muddy sand	Dark gray
2	Small island (St. 2_1)	4.9	98	1	1	Sand	Black
3	Small island (St. 2_2)	4.9	91	7	2	Sand	Black
4	Atlassi shoal (St.3)	4	**Rocky**				
5	An island near Fasht Ayk (St.4)	4.5	99	1	0	Sand	White shell fragments



Fig. 1 **a** Brittle starfish (St.1), **b** Shell fragments at (St.4), and **c** Rock from (St.3)

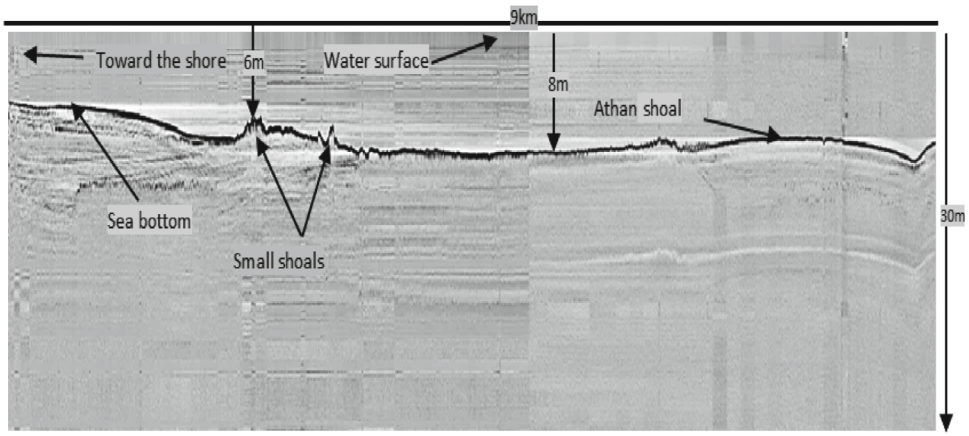


Fig. 2 The first SBP section, two submerged shoal sites have been discovered in addition to the Athan Shoal

4 Discussion

The shoal islands in the study area consist of approximately (60–99%) sand and shell fragments that cover the surface layers of these islands, while the lower layer is made of mud. This consistent with (Morton et al. 2000) indicated that the sand barriers in the Gulf regions are well sorted and consist of high mineral maturity due to the presence of quartz in high proportion. These islands are sand barriers with a rectangular structure parallel to the shore line. They originally formed from sedimentation process of deltaic sediments of Shatt al-Arab River. The SBP sections revealed clear distinct features under the bottom indicating the presence of an extension of these shoal sites to greater depths below seabed.

The XRD analyses show that the shoal islands have low percentages of clay minerals presented by kaolinite. While the largest percentages include quartz, calcite, and albite. Increase in the proportion of the mineral aragonite in St.4 with a value of 33.1% due to shell fragments of different sizes and recent fauna containing this mineral. For St.1 and St.2, the kaolinite content was 17.7% and 1.8%, respectively. This finding is consistent with (Demicco and Hardie. 1994) who showed that the larger grain sizes found in shallow water marine sediment are due to the selective removal of smaller grains washed out to deep water. These islands are exposed to continuous erosion due to the nature of the circular currents in the NW of the Persian/Arabian Gulf, in addition to the tides and the funnel shape of Khor Abdullah water body. It in turn affects the movement and accumulation of sediments on the Iraqi side, in contrast to the Kuwaiti side. Further, this causes problems in determining the baseline (coastline) between the two countries. The sedimentation rate is greater than the erosion rate at Iraqi side, and this is what actually happened when the navigable channel crawled into Kuwait.

5 Conclusions

The current study sought the origin of the shoal islands of Khor Abdullah creek in northwest of Persian/Arabian gulf. It can be concluded that source of the shoal islands is shallow and linked to the most recent sediment layer of the seabed. The formation of these islands is mostly attributed to the influence of tidal currents and sea waves on sedimentary and morphologic processes. These shoals were produced as a coastal environment during the Holocene epoch as a result of sea regression in a coastal setting. Considering its distinctive rock formation and strategic location within the region, the Atlassi Shoal may indicate to the ancient apex of the Gulf. It might be regarded as the remnants of the old shoreline. The continual exposure of the seabed to tidal currents results in a low content of clay minerals in the sediments of these islands. Based on the results of the study, the sedimentary condition of shoal islands predominantly reveals erosion rather than accretion (or deposition).

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Flood Frequency Analysis for Tugela River Catchment

Thandi Venissa Ntuli, Rebecca Alowo, and German Nkhonjera

Abstract

One of the South African places where floods have had a significant negative impact, particularly in eThekwini and eMlazi, is the Tugela River catchment. Floods have occurred in the basin over time because of severe rainfall brought on by climate change. This work conducted a flood frequency analysis of the Tugela River basin in KwaZulu-Natal using four distribution models. To estimate the yearly maximum series for the Tugela River watershed, the four distributions were compared. Log-Pearson Type III was chosen for this investigation because it has the most variable parameters overall. One of the many probability distribution functions used to simulate hydrologic processes with high variability that cannot be deterministically described by physical principles. The requirement for safe and affordable hydrologic design evaluations in the watershed area served as the study's driving force. Based on stream flow observations, the annual peak discharge for the river for the years 1981–2022 was modeled using the Log-Pearson Type III probability distribution. For the engineering design of hydraulic structures, the probability distribution function was applied to return periods of 2, 5, 10, 25, 50, 100, 200, and 500 years. The measured discharges were, in order, 120.4, 269.7, 392.3, 565.0, 702.6, 878.0, 990.8, and 1186.5m^3/s. These figures are helpful for storm water management and hydraulic design of catchment area structures.

Keywords

Flood frequency analysis · Tugela River · Gumbel · Log-Normal · Log-Pearson Type III · Normal distribution

1 Introduction

Over the past 2 years, numerous disastrous flood occurrences in South Africa have brought to light the necessity for more precise and fairer flood estimation (van Bladeren et al. 2017). The most recent floods in KwaZulu-Natal in April 2022 were the most notable events (Lynch et al. 2014). According to the disaster management teams, the Tugela River breached its banks on the weekend of April 10–12, 2022, because of severe rainfall in the catchment areas (2022). These occurrences highlighted the necessity for a consistent method to calculate flood probability before beginning any construction project or evaluating existing projects for flood dangers (Rademeyer 2014). Despite their destructive impacts, the flood peak magnitudes and probabilities of occurrence or return period needed for flood lines are frequently disregarded or treated lightly (Ganamala and Sundar 2017). The National Disaster and New Water Act and the speed at which developments are planned will necessitate the near-mass creation of trustworthy, realistic, and consistent flood peak probabilities across the nation (Karmakar et al. 2016).

2 Literature Review—Environmental and Economic Impacts of Floods in KwaZulu-Natal

The most expensive and widespread natural danger is flooding. Each year, they cause up to 50,000 fatalities, which impact an estimated seventy-five million individuals globally. Disease outbreaks are more common in less-developed

T. V. Ntuli (✉) · R. Alowo · G. Nkhonjera
University of Johannesburg, Johannesburg, South Africa
e-mail: 217032982@student.uj.ac.za

R. Alowo
e-mail: ralowo@uj.ac.za

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nations. In tropical nations, it is also typical for an outbreak of typhoid and malaria to follow a flood. According to estimates, three hundred million people in KwaZulu-Natal reside in flood-prone areas added that one of the main causes of material loss in floods is physical property destruction (Bobée and Rasmussen 2018). Regarding the impacts of climate change on design floods, there is evidence that various ecological systems are impacted by regional climatic changes, particularly temperature variations (Change 2019). The impact of climate change on design rainfall, for example, must be quantified to assess the impact on the estimated design flood. It is necessary to predict and project the statistical properties of non-stationary data into the structure's design life (Bates et al. 2018). Both design rainfall and design floods are anticipated to increase in South Africa because of climate change, with design floods growing more than design rainfall, according to (Strupczewski et al. 2017) results.

3 Materials and Methods

3.1 Study Area Description

The Tugela River is the largest river in KwaZulu-Natal and the second largest in South Africa, with a catchment area of about 28,000 km^2 and a mean annual flow of over 3799 million m^3 (Knoesen 2018; Ismail and Mustaquim 2019). The Tugela River rises in the Drakensburg Mountains, runs eastward, and eventually empties into the Indian Ocean through the open river mouth estuary, where the river's silt load creates the offshore Tugela Bank (Knoesen 2018). The Little Tugela, Bushman's, Mooi, Klip, Bloukrans, Sundays, and Buffalo rivers are among the Tugela River's principal tributaries, and they each have eighty-eight quaternary catchments (Ismail and Mustaquim 2019). There are many diverse types of climates in the Tugela River watershed, ranging from cold and wet in the Drakensberg to hot and dry in the Tugela Valley to hot and humid at the coast (Coffman and Noy 2022). Due to terrain, the catchment's rainfall varies, with higher rainfall on the escarpment's highest points (1905 mm per year) and lower rainfall in the catchment's lower, sheltered valleys (as low as 635 mm per year) (Wade 2019). The coastal region receives 1103 mm annually. As a result, the basin experiences an average annual precipitation of 843 millimeters and an average annual runoff of 3799 million m^3 (Le Maitre et al. 2018; Allanson et al. 2019) (Fig. 1).

3.2 Research Approach and Design

The data that was gathered for this investigation was sorted in descending order, and the rank (m) was given in accor-

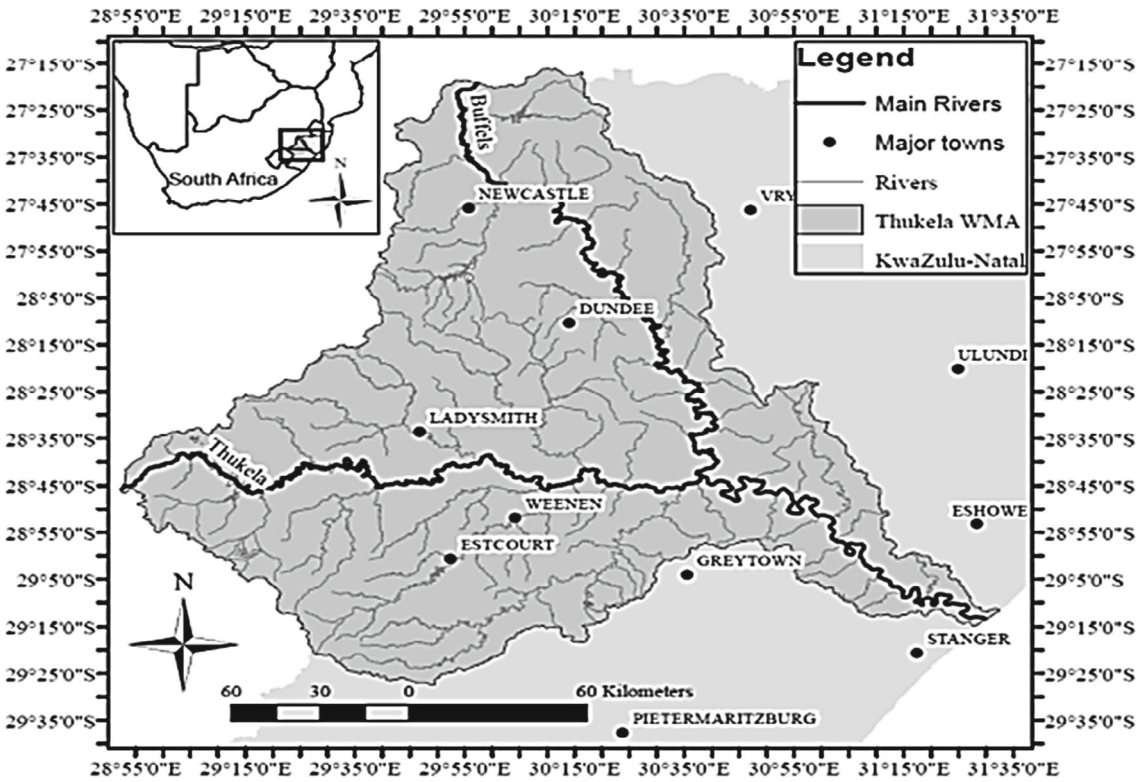


Fig. 1 Tugela River catchment

Table 1 Comparison of expected flood. *Source* Researchers

T	Gumbel	Log normal expected flood	Log pearson expected flood	Normal expected flood
2	265.2002956	281.8716209	242.3365341	287.4575179
5	402.3858624	422.6464451	430.0984253	407.6321613
10	493.2144459	485.7336161	578.8140692	469.8402121
25	607.9766019	539.1099912	794.8840785	536.2897208
50	693.1137251	565.4240383	973.2820757	578.7043009
100	777.6222091	583.6520409	1167.831431	616.8774229
200	861.8223359	596.5032376	1382.481300	653.2229063

dance with the discharges in Table 1. The maximum discharge value (111.04 m^3/s) was given to the first rank, and the lowest discharge value (0.82 m^3/s) was given to the 42nd rank. Important parameters required for estimating the flood using the Gumbel, Log-Pearson Type III, Log-Normal, and Normal distributions were calculated using an Excel spreadsheet. The estimated discharges were then plotted against the return period using all the computed data to create the flood frequency for this study. To choose the distribution with correct flood projections for the Tugela River catchment, all the flood frequency analysis distributions were examined. The Department of Water Affairs provided historical river discharge data for station V1H057 Tugela River at Rhenosterfontein that covered a 42-year period (1981–2022). To plan for flood protection and flood risk management, historical data is crucial for predicting the recurrence in the interval of hydrological extremes. Peak flood is estimated using the Gumbel distribution, Log-Normal distribution, Normal distribution, and Log-Pearson Type III distribution.

3.3 Limitations

This study uses flood frequency analysis method to estimate flooding across South Africa. This method has been used in previous studies in other parts of southern Africa. The results of this study cannot be assumed to apply to regions outside of South Africa. Design floods are estimated for return periods of 2, 5, 10, 25, 50, 100, 200, and 500 years. Design floods beyond the return period of 1000 years were not estimated due to the problems in extrapolating design floods beyond the record length of the datasets used. An estimate of over 1000 years of design flood is statistically and scientifically meaningless when determined from a short record length of 20 years (Dennis et al. 2022). This assumes that the statistical pattern observed for a short record length is also valid over the observed range of values, which is often not the case. In addition, the amount of data used to obtain the design flood estimates was limited by the quality of the datasets obtained from the Department of Water Affairs.

4 Results and Discussion

The Tugela River's yearly peak flood flow is depicted on the graph in Fig. 2. The hydrological year 2022 saw the greatest measured flow of 111.04 m^3/s, while the hydrological year 1983 saw the lowest flood flow of 1.28 m^3/s. A polynomial trendline was smoothed across the data to draw attention to changes in the trend. Significant hydrological conditions were evident in the smoothed trend, which may indicate that irregular rainfall and watershed factors like land use may have increased flood peaks in a particular area. The standard deviation of the 42-year means flood flow, which was 34.18 m^3/s, was 18.53 m^3/s.

4.1 Comparison of the Results

Table 1 and Fig. 3 show that the Normal and Log-Normal flood estimates were poor, whereas Gumbel and Log-Person Type III provided good estimates for floods in the Tugela River catchment. The expected flood discharges with Normal and Log-Normal distribution are lower than the highest measured peak flow of 111.04 m^3/s recorded during the 2022 hydrological year.

A distribution with more flexible parameters than one with fewer parameters would be able to model the input data more precisely (Dennis et al. 2022). In this instance, the Log-Pearson Type III demonstrated more variable factors and was advised for calculating the catchment's flood risks. These values can benefit the engineering design of hydraulic structures in the watershed. Federal agencies in the United States have advised using the Log-Pearson Type III distribu-

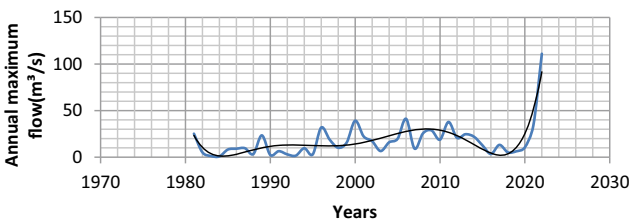


Fig. 2 Annual maximum flood flow. *Source* Researchers

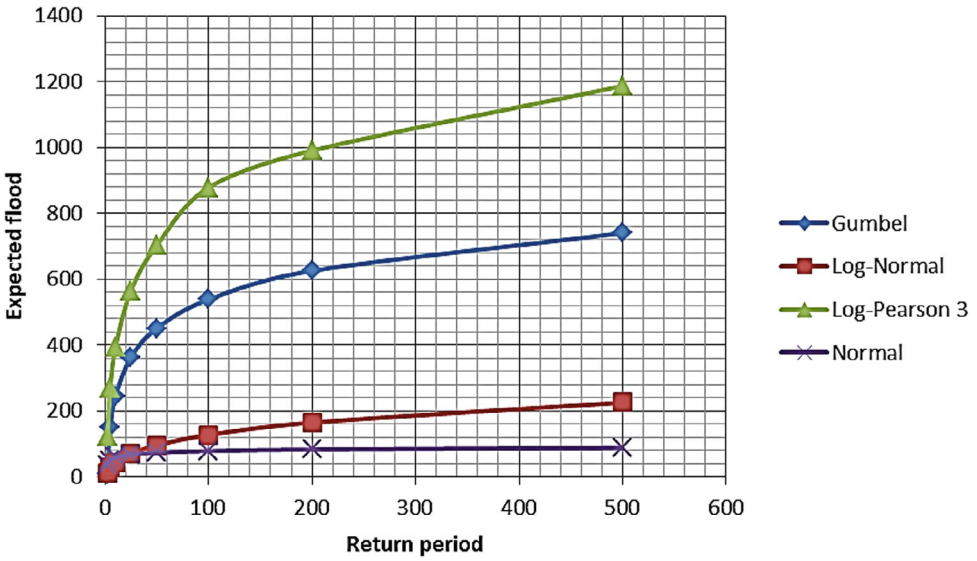


Fig. 3 Flood estimates plot. *Source* Authors

tion when analyzing flood frequency (Oliff 1960). Finally, the graph plot results (Fig. 3) have demonstrated the viability of the Log-Pearson Type III statistical distribution approach for the Tugela River catchment's flood frequency analysis.

5 Conclusion and Recommendations

This study assessed the Tugela River watershed's flood frequency to safeguard the catchment from flooding and control flood hazards in KwaZulu-Natal. According to the findings of this study, flood frequency analysis is an efficient method for forewarning and predicting a river's long-term and near-future discharge flow characteristics. Utilizing peak historical discharge data from 42 years for the Tugela River basin and Excel software, the Gumbel, Log-Pearson III, Log-Normal, and Normal distributions, four flood frequency analysis distribution models, were compared for modeling annual maximum series for the Tugela River watershed. Using the four distributions, peak flood magnitudes for the recurrence intervals of 2, 5, 10, 25, 50, 100, 200, and 500 years were determined. Log-Pearson Type III was chosen for this study since it is the approach with the greatest predicted discharges. These estimations can be used to mitigate flood damage and safeguard the local economy. The recommendations from this study are therefore:

- To research and to validate whether Log-Pearson Type III is the most favored distribution throughout South Africa, the study should be expanded to include additional regions of the country.
- To reduce the discrepancies in the outcomes obtained at various weather stations around South Africa. More research must be done on the use of the Log-Pearson Type III distribution in designing flood practices in South Africa.
- To apply the knowledge gained from this study to the efficient construction of hydrological structures within the study region as well as to preventive actions, as doing so will lessen the effects of flood disasters there.

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Regional Paleoclimate Simulation over the Nile River Basin: A Model Evaluation

Mingyue Zhang, Eva Hartmann, Elena Xoplaki, and Sebastian Wagner

Abstract

The Nile Basin has been the focus of research on the links between climate variability, extreme events and social events over the last 2000 years of history. Unfortunately, we currently only have global climate and Earth system model data with low spatial resolution for this period. To understand how climate affects society, we must rely on proxy data, as global climate models lack the necessary regional process detail. Our goal is to enhance our understanding of the historical climate of the Nile Basin on a regional scale using the customized COSMO-CLM paleoclimate model. We intend to run simulations with COSMO-CLM (forced by MPI-ESM-LR) by using the "past2k" simulation set up with an optimized configuration for both the present (1979–2019 CE) and paleo periods (500–2000 BCE) at resolutions of around 50 and 12 km. In this approach, we tried to systematically consider orbital, solar, and volcanic influences, as well as changes in vegetation, land use, and greenhouse gas concentrations in the simulation. We found that the temperature simulations are overall in agreement with the reanalysis data and the observational record. However, it is worth noting that our precipitation simulations performed relatively weakly, especially in the Nile Basin.

M. Zhang (✉) · E. Hartmann · E. Xoplaki
Department of Geography, Climatology, Climate Dynamics and Climate Change, Justus-Liebig University Giessen, Giessen, Germany
e-mail: mingyue.zhang@geogr.uni-giessen.de

S. Wagner
HZG: Helmholtz-Zentrum Geesthacht, Geesthacht, Germany

E. Xoplaki
Center for international Development and Environmental Research, Justus Liebig University Giessen, Giessen, Germany

Keywords

Paleoclimate · Nile Basin · COSMO-CLM

1 Introduction

Over the past 2000 years, there has been a notable interest in climate variations, extreme climate events, and their interactions with societal changes within the Nile River basin. The Nile River system, and thus the water availability of the massive drainage basin that crosses different hydroclimate zones from the sources to the delta, are affected by various atmospheric patterns. It is necessary to look at the regional Nile River basin atmospheric circulation at a higher horizontal resolution. Nevertheless, the impact of climate on societies is assessed mainly through existing proxy records (such as lake sediments), lacking the detailed insights provided by regional climate model simulations with continuous temporal resolution and the specific atmospheric circulation patterns affecting this region. Recently, the examination of the current and future climate as well as the climate variability within the Nile Basin is conducted within the MENA-CORDEX program, using various regional climate models (with a resolution ranging from 25 to 50 km). However, when it comes to studying the past climate, we are limited to global circulation model (GCM) or Earth system model (ESM) simulations characterized by coarse horizontal resolutions, typically at a minimum of 100-km spatial resolution. To study the past climate at the regional scale, regional climate models (RCMs) are therefore needed, allowing a considerably increased horizontal resolution of up to 10 × 10 km. The MENA region has been identified as a hot spot for future climate change (Planton et al. 2016; Cramer et al. 2018; Zittis et al. 2021). To produce useful climate predictions and prepare adequate responses to the impact of climate change on these vulnerable and already impacted areas

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(Kelley et al. 2015), a better understanding of the past climate is of great importance. Our objective is to enhance our comprehension of the historical climate within the Nile River basin on a regional scale, achieved by employing a modified paleoclimate version of the COSMO-CLM.

To determine the optimal settings for the CCLM, test simulations were conducted for 2017–2018 in the study area. As indicated in Bucchignani et al. (2016), it has been found that the parameters regarding albedo and aerosols play a major role in reasonably simulating the climate over this area and may be the reason for significant biases in comparison to observational data.

2 Data and Methods

2.1 ERA-Interim Datasets

ERA-Interim, a global atmospheric reanalysis dataset, is reanalyzed and homogenized observation data and has been used in many different applications (such as model input and model evaluation). This dataset offers a remarkable horizontal resolution of 0.125°.

2.2 Model Description

The COSMO-CLM (COnsortium for Small-scale MOdeling-CLimate Mode) is a limited-area model that also has a climate version (Rockel et al. 2008). We planned several simulations, which are shown in Table 1. In Experiment Eval_44 (0.44°) and Eval_11_nest (0.11°), we used reanalysis data ERAInterim as the forcing data of COSMO-CLM, it is simulated from 1979 to 2019. While the Experiment Present_44 (0.44°) and Present_11_nest (0.11°) are forced by the "past2k" data generated by MPI-ESM. Furthermore, the fully forced MPI-ESM simulations at resolution 1.875 at the global scale are planned for BCE500 to CE2000. With this fully forced MPI-ESM data, a simulation at 0.44° horizontal resolution over the Nile River basin will be performed from BCE500 to CE2000. On top of this, several simulations at 0.11° horizontal resolution will be performed over selected special periods that have major volcanic eruptions, for example, from 1220 to 1290 and from 525 to 575. All the simulations are running at the German Climate Computing Center (Deutsches Klimarechenzentrum, DKRZ) (https://www.dkrz.de/about-en/about-us?set_language=en&cl=en).

Table 1 Overview of the planned simulations

Experiments	Description	Resolution	Simulation years
Eval_44	Present climate—ERAInterim (finshed)	0.44	1979–2019 (40)
Eval_11_nest	Present climate—ERAInterim (finshed)	0.11	1979–2019 (40)
Present_44	Present climate—MPI-ESM (finished)	0.44	1970–2000 (30)
Present_11_nest	Present climate—MPI-ESM (finished)	0.11	1970–2000 (30)
MPI-ESM_2021	MPI-ESM fully forced	1.875	1–2000 (1999)
Transient_44	Transient—MPI-ESM	0.44	1–2000 (1999)
Early_LIA_11_nest	Early_LIA—MPI-ESM	0.11	1220–1290 (70)
LALIA_11_nest	LALIA—MPI-ESM	0.11	525–575 (50)

3 Results and Discussions

3.1 Annual Cycle

From Fig. 1, we can see that the 2-m temperature over the Nile Basin is well simulated with COSMO-CLM both in 0.44 and 0.11° horizontal resolution, compared to the forcing data ERA-Interim and the observational data CRU (Climatic Research Unit). However, the 2-m temperature shows better accordance in the 0.11° simulation, compared to the 0.44° simulation. Contrariwise, the precipitation shows better performance in the 0.44° simulation compared to the 0.11° simulation.

3.2 Temperature and Precipitation Difference Map

A difference map indicates "Model results" minus "Observation/reanalysis data". From the difference map (Figs. 2 and 3), we can see that both temperature and precipitation show better results in summer (June, July, and August) and winter (December, January, and February) but higher bias in spring (March, April, and May) and autumn (September, October, and November) compared to ERA-Interim. And the differ-

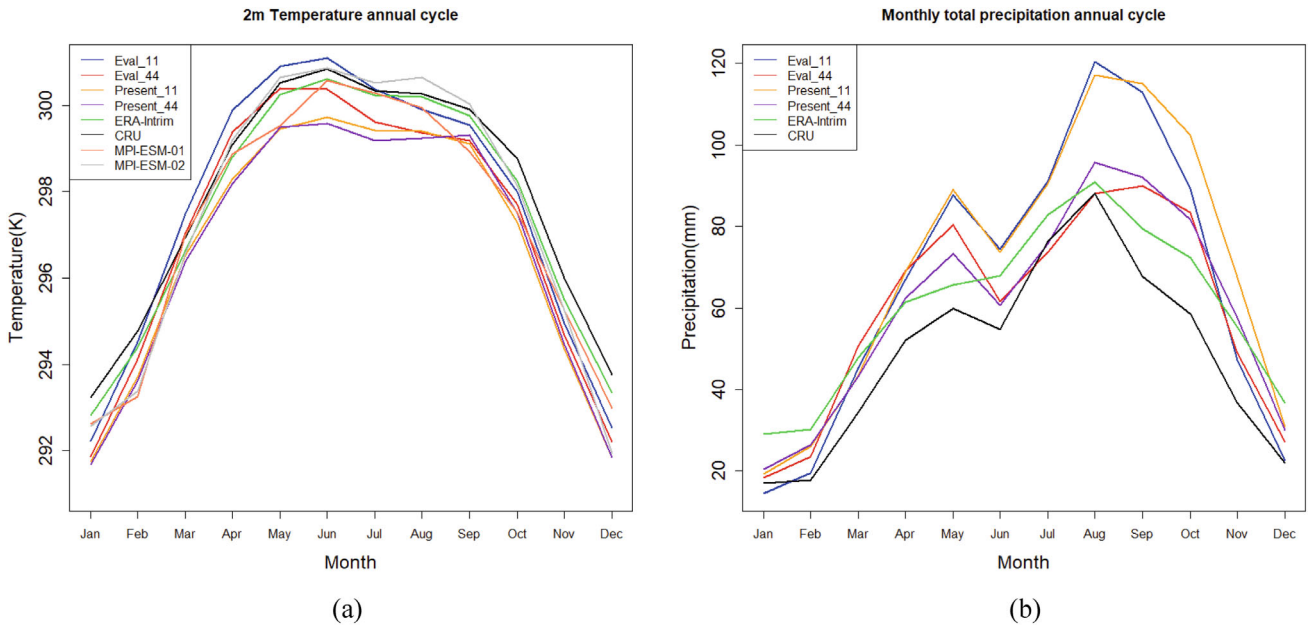


Fig. 1 Annual cycle of **a** 2 m temperature and **b** precipitation

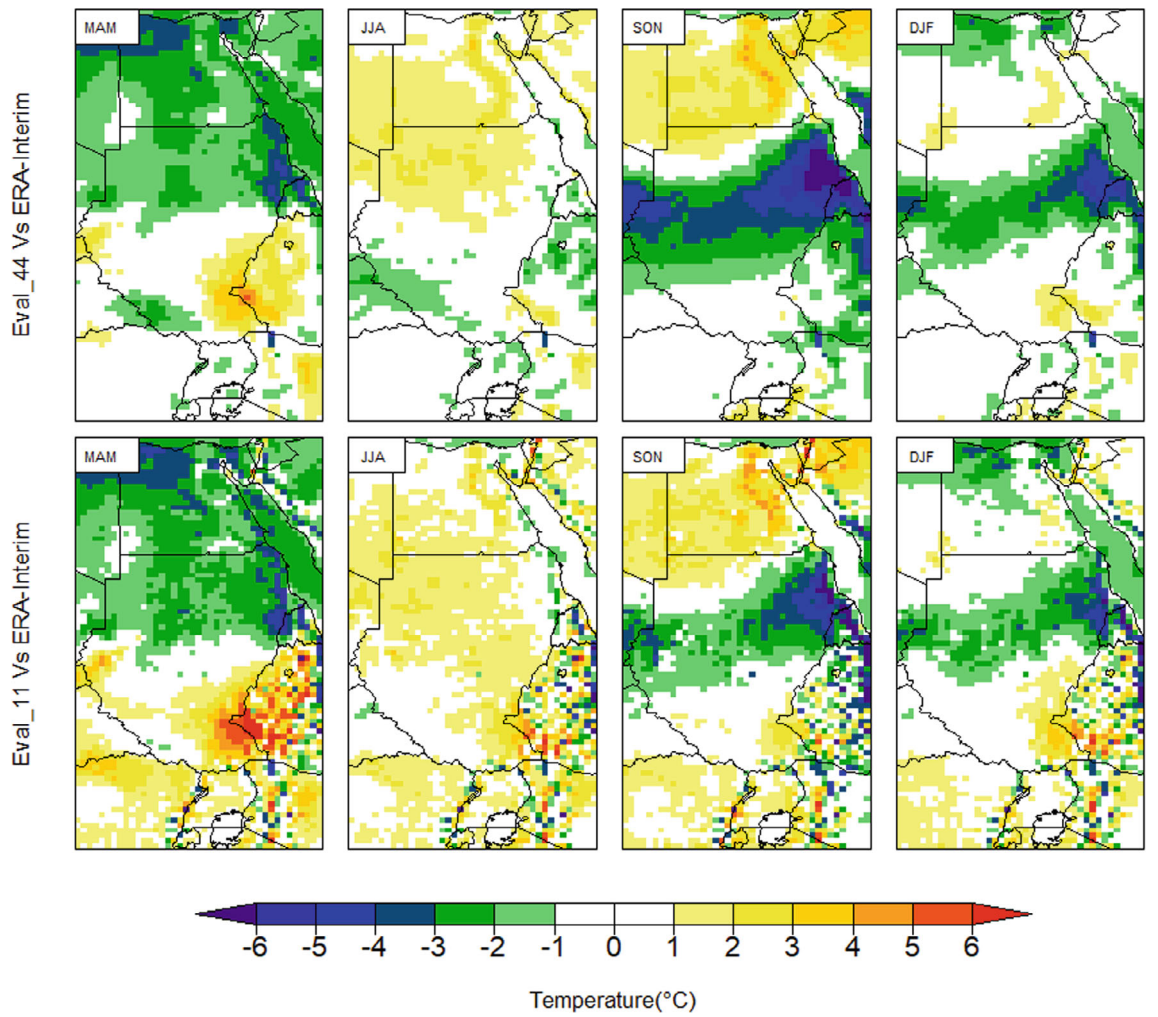


Fig. 2 Seasonal 2 m temperature difference map of Eval_44 (upper panel) and Eval_11 (lower panel) compared to ERA-Interim

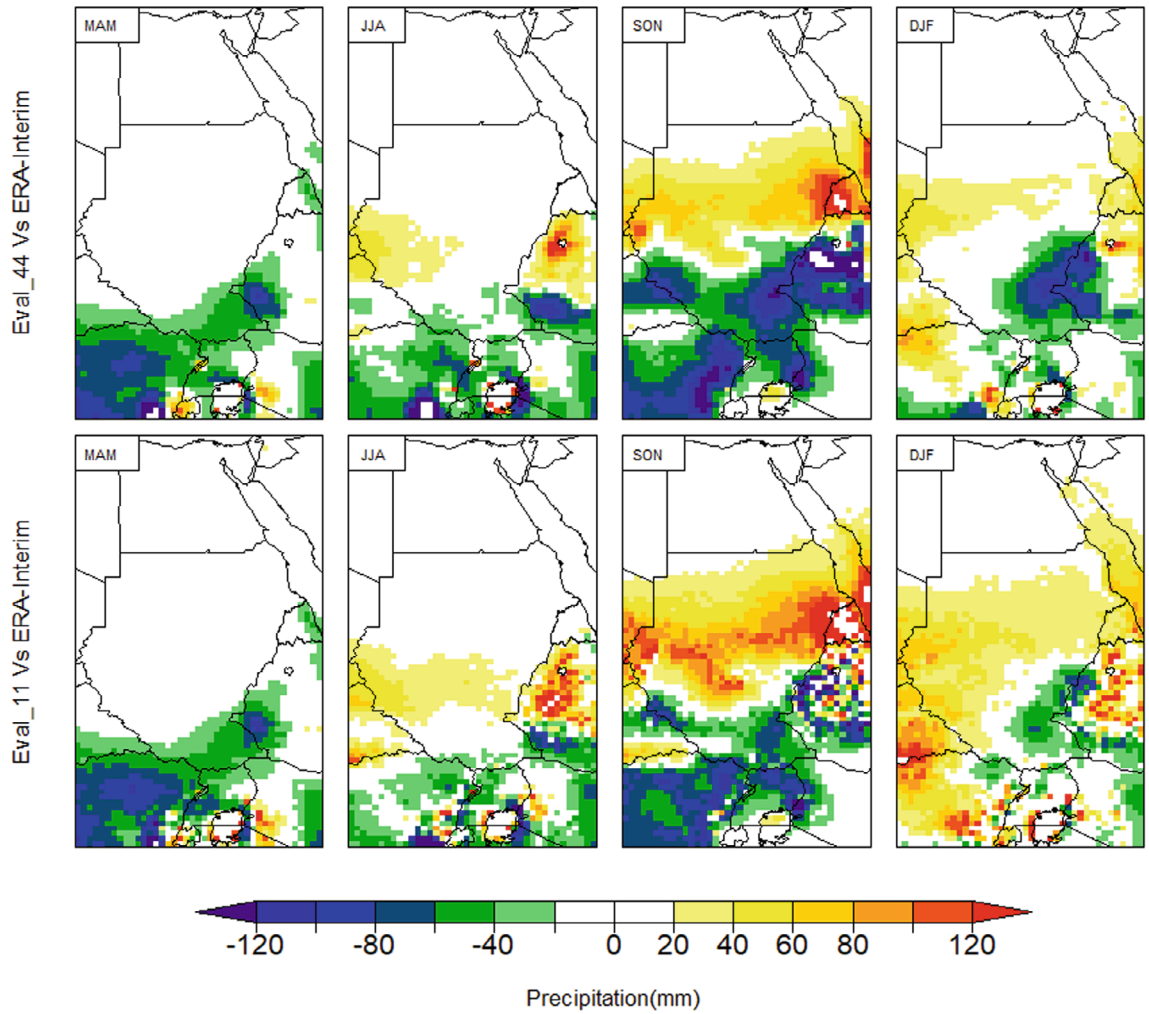


Fig. 3 Seasonal precipitation difference map of Eval_44 (upper panel) and Eval_11 (lower panel) compared to ERA-Interim

ence of the simulation and reanalysis data is up to + 6 k in the south of the Nile River basin and − 6 k in Ethiopia. This is acceptable considering the complex atmospheric circulation over this region. The precipitation also shows higher bias in these regions compared to other parts of the simulation area. We referenced the MENA-CORDEX simulation, which is also performed at 0.44° with COSMO-CLM. It concludes that the simulated precipitation shows a large range of variation in this region (Bucchignani et al. 2016). In addition, when comparing the results of temperature and precipitation in both 0.11° and 0.44° separately, it suggests that there is less significant added value of the 0.11° simulation compared to 0.44°. Over the Ethiopian Highlands, the 0.11° simulation results show much higher variability compared to 0.44°. This could be associated with the orographic processes within COSMO-CLM, particularly in regions like the Ethiopian Highlands and the East African Plateau. These areas experience substantial high elevations that could have a significant influence on the regional and local climate.

4 Conclusions

In this study, we performed several simulations over the Nile River basin with COSMO-CLM to identify the optimum settings for the paleoclimate aspects. The present-day simulations show that the temperature and precipitation are reasonably simulated compared to reanalysis and observational data in general, except that in some regions, there is high variability. This is understandable, considering the complex atmospheric circulation over this region.

Nevertheless, further evaluation is necessary; for instance, statistical indices can be calculated in order to deeply analyze the simulation results. Additionally, if the CCLM correctly captured convection and cloud cover in the greater southern areas of the domain, which are affected by the tropical convection, is needed.

Moreover, the local climate appears to be markedly influenced by factors such as orography and land-sea interactions, potentially resulting in disagreements when compared

to observational data. These could be closely studied under specific spatial resolution in future research.

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Climate Change and Adverse Pregnancy Outcomes: Scoping Review

Karin Windsperger, Ziad El-Khatib, Minyahil Tadessa Boltena, Mulatu Biru, Yousuf S. Khader, Tobias Alfvén, Claudia Hanson, and Alex Farr

Abstract

Context There is a growing concern over the impact of climate change on maternal and child health outcomes. We conducted a scoping review of the literature to determine knowledge gaps in studies on this topic with special emphasis on the assessment of exposure and outcomes. *Reason* A previous report by Kuehn and McCormick included literature until January 2017. Therefore, there was a need to map the available body of evidence to inform the implications of the impact of climate change on maternal and neonatal health outcomes between 2017 and the following years. *Methods* We conducted a scoping review to explore and map, systematically, the published research projects to inform the practice of the field of maternal and child healthcare services regarding the impact of climate change. The relevant literature published between February 2017 and September 2021 was searched using PubMed and Cochrane reviews. An additional search was done for references cited in the relevant reviews. *Results* A total of 15 studies were identified and included in the final review. Over half of the studies assessed exposure throughout pregnancy (n = 8/15; 53%) and the following outcome parameters: preterm birth (n = 11/15; 73%), stillbirth (n = 4/15; 27%), low birthweight (n = 3/15; 20%), and neonatal outcome (n = 1/15; 7%). There was heterogeneity in the data, which did not allow a comparison between the studies. *Significance* The evidence shows an impact of climate change on the length of gestation, birthweight, stillbirth, and neonatal distress. *Implications* There is evidence for an impact of climate change on maternal and child health outcomes. Healthcare providers should create policies to mitigate these effects on mothers and their unborn. Further knowledge is needed to ensure reproductive health in the future.

Keywords

Climate change · Global warming · Pregnancy outcome · Preterm birth · Global health

1 Introduction

Earth's climate is changing and represents the biggest global threat to human health (Costello et al. 2015). The most prominent indicator for the ongoing climate change is global warming, being responsible for acute health concerns such as heatwaves, which, combined with the continued destruction of natural biodiversity, are known to cause more deaths than all weather-related fatalities combined (National Oceanic and Atmospheric Administration (NOAA) 2022; Kuehn and McCormick 2017; Atwoli et al. 2021). Although rising temperatures are a risk for all demographics, they present a major health threat to vulnerable populations such as adults aged 65 years and older, women in lower socioeconomic groups, and pregnant women (IPCC 2021; Roos et al. 2021). To date, only a few systematic reviews conducted in this field of research suggest that temperature extremes adversely impact pregnancy outcomes (Kuehn

K. Windsperger · A. Farr
Division of Obstetrics and Feto-Maternal Medicine, Department of Obstetrics and Gynecology, Medical University of Vienna, Vienna, Austria
e-mail: alex.farr@meduniwien.ac.at

Z. El-Khatib (✉) · T. Alfvén · C. Hanson
Department of Global Public Health, Karolinska Institutet, Stockholm, Sweden
e-mail: ziad.khatib@gmail.com

M. T. Boltena · M. Biru
Knowledge management directorate, Armauer Hansen Research Institute, Addis Ababa, Ethiopia

Y. S. Khader
Department of Public Health, Community Medicine, Jordan University of Science and Technology (JUST), Ar-Ramtha, Jordan

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and McCormick 2017; Sexton et al. 2021; Chersich et al. 2020; Carolan-Olah and Frankowska 2014; Syed et al. 2022; Zhang et al. 2017). As climate-related global warming is likely to continue to increase and has the potential to escalate during the next decades, the establishment of extensive knowledge of how heat exposure affects pregnancy is necessary (IPCC 2021; Hoegh-Guldberg et al. 2019). We conducted a scoping review to examine the impact of global warming on pregnancy outcomes. Risks of preterm birth, early-term birth or shortened gestation, low birthweight, stillbirth, and neonatal heat-related distress were included in the outcomes.

2 Materials and Methods

2.1 Search Strategy

We conducted a literature review to update a previous report by Kuehn and McCormick (2017). This search spanned from February 2017 through September 2021 (Kuehn and McCormick 2017). We used both PubMed and the Cochrane review databases. We included the following search terms: "human" AND "temperature" (OR "ambient temperature" OR "hot temperature" OR "heat wave" OR "climate change") AND "pregnancy" (OR "pregnancy outcome" OR "birthweight" OR "preterm birth" OR "gestational age" OR "stillbirth"). Beyond the initial database inquiries, comprehensive searches included scrutiny of reference lists from pertinent review articles (O'HARA) and citations within included papers to identify potentially relevant studies. ZEK conducted the preliminary screening of titles and abstracts, adhering strictly to the inclusion and exclusion criteria. Studies not fulfilling the criteria were excluded. If it was uncertain that either study met the inclusion/exclusion criteria, they were retained for the next stage. In the second stage, full-text articles were screened out based on inclusion-exclusion criteria.

2.2 Inclusion and Exclusion Criteria

Only published studies were included if they fully met the following criteria: (1) studies focusing on maternal health, birth outcomes, neonatal health, and climate change processes; and/or (2) studies focusing on maternal, fetal, and child populations, with the given exposure of atypical climatic processes. Studies were excluded if they were: (1) not examining human populations; (2) focusing on specific disease processes, such as the vertical transmission of viruses in pregnant women, the indoor ambient environment, or maternal and fetal outcomes unrelated to climate change or temperature.

2.3 Strategy for Data Synthesis

Due to the high heterogeneity of the study designs, intervention characteristics, and reported outcomes in the included studies, we decided to not perform meta-analysis. We consolidated descriptive information on the impact of climate change on preterm birth or shortened gestational age, low birthweight, stillbirth, and neonatal heat-related distress.

3 Results

3.1 Birth Outcomes

The scoping review incorporated 15 studies as outlined in Table 1. Among these, the majority, 11 studies or 73%, focused on preterm birth. Stillbirth was examined in 4 studies (27%), low-birthweight in 3 studies (20%), and neonatal outcomes were assessed in one study (7%).

3.2 Risk Factors for Preterm Birth (PTB) and Stillbirth

The analysis revealed a preterm birth prevalence of 8.1% (which is equivalent to 104,493 preterm births). It was found that exposure to extreme temperatures during pregnancy—both high and low—significantly elevates the risk of preterm birth. The hazard ratios (HRs) were 1.55 (95% CI: 1.48, 1.61) for high temperatures (23.0 °C, 95th percentile) followed by 1.03 (95% CI: 1.02, 1.04) for low temperatures (9.1 °C, fifth percentile) compared to the threshold temperatures (12.0 °C) (Wang et al. 2020). The estimated portion of preterm births attributable to extreme heat is 0.17% (95% CI: 0.14%, 0.19%), which translates to 154 preterm births per million births (95% CI: 127, 173) (Sun et al. 2019). Regarding stillbirths, significant risks were associated with both high and low temperatures (aOR: 5.06, 95% CI: 3.34, 7.68 and aOR: 4.42, 95% CI: 3.43, 5.69, respectively). An increase of 1 °C in the week leading up to delivery was correlated with a 7% increased risk of stillbirth (Kanner et al. 2020).

3.3 Critical Gestational Periods for Heat Exposure

In comparison to the average temperature (23.0 °C), the incidence of PTB was significantly higher during weeks 4–8 and 22–27 of gestation when exposed to higher temperatures, such as 30 °C (95th percentile). The greatest increase in risk was observed during the 6th and 24th weeks (HR 1.79, 95% CI

Table 1 The characteristics of the findings of the included studies

References	Location	Study design	Sample size	PTB	LBW	SB	NO	Exposure
Ward et al. (2019)	USA	CCD	29,854	Yes	–	–	–	Throughout pregnancy
Wang et al. (2019)	Australia	RS	277,133	Yes	–	Yes	–	
Sun et al. (2019)	USA	RS	31,921,046	Yes	–	–	–	
Mohammadi et al. (2019)	Iran	Prospective cohort study	3140	Yes	–	–	–	
Yitshak-Sade et al. (2021)	USA	RS	791,324	–	Yes	–	–	
Kanner et al. (2020)	USA	CCS	500	–	–	Yes	–	
Spolter et al. (2020)	USA	RS	62,547	Yes	–	–	–	
Wang et al. (2020)	China	Cohort study	104,493	Yes	–	–	–	
Ilango et al. (2020)	USA	Cohort study	1,967,300	Yes	–	–	–	3rd trimester
Liu et al. (2020)	China	Cohort study	4101	Yes	–	–	–	Gw: 4th–8th, 22nd–27th
Savitz and Hu (2021)	USA	CCD	1876	–	–	Yes	–	Monthly
Gat et al. (2021)	Israel	Population-based RS		Yes	Yes	–	–	Last week of pregnancy
Li et al. (2021)	China	Birth registry, RS	78,920	Yes	Yes	–	Yes	Gw: 1st–12th; 13th–28th
Xue et al. (2021)	South Asia	CCS	34,197	–	–	Yes	–	4–1 week(s) preceding delivery
Kwag et al. (2021)	Korea	RS	61,182	Yes	–	–	–	1st + 2nd trimester

CCD case crossover design; *RS* retrospective study; *PTB* preterm birth; *LBW* low birthweight; *SB* stillbirth; *NO* neonatal outcome; *gw* gestational week(s)

1.26, 2.54; and HR 1.83, 95% CI 1.27, 2.62, respectively) (Liu et al. 2020). The relative risk of PTB following days of extreme heat and cold was higher compared to the county-specific median temperature, with a relative risk of 1.025 (95% CI 1.015, 1.036) and 0.985 (95% CI 0.976, 0.993) for heat and cold, respectively, over four days. The second trimester presented the most significant risk variations, with PTB rates increasing by 5.8–23.7% per 1 °C rise in the weekly maximum temperature (Li et al. 2021). Moreover, PTB was more prevalent among mothers who experienced extreme heat in the last week of pregnancy, with HR ranging from 1.008 (95% CI 0.997, 1.021) to 1.128 (95% CI 1.052, 1.210) (Ilango et al. 2020).

3.4 Cofactors Interfering with the Heat-Health Linkage

When accounting for co-exposure to particulate matter (PM2.5) pollution, the correlation between heat and the risk of PTB in the second trimester was heightened, with odds ratios increasing across different percentiles (OR for ≤ 25 percentile, 1.148, 95% CI 1.095–1.203; OR for 26–50 percentile, 1.248, 95% CI 1.178–1.323; OR for 51–75 percentile, 1.370, 95% CI 1.245–1.507) (Kwag et al. 2021). Regional differences also emerged in the threshold temperatures for PTB risk, with specific odds ratios associated with the Mountain, Piedmont, and Coastal Plain regions (22.78–23.33 °C; OR 1.01 (95% CI 1.01–1.02); 23.33–23.89 °C, OR 1.01 (95% CI 1.00–1.01); and 22.22–22.78 °C, OR 1.01 (95% CI 1.01–1.01, respectively)) (Ward et al. 2019). Additional factors including season, maternal education, chronic health conditions, and ethnicity were also found to influence PTB rates. When it comes to ethnicity, Bedouin Arabs showed higher susceptibility to temperature-induced preterm births (RR 1.19, 95% CI 1.03–1.37), while Jews demonstrated greater sensitivity to ambient pollutants, two and one days (RR 1.025, 95% CI 1.010–1.040; and 1.017, 95% CI 1.002–1.033, respectively) (Gat et al. 2021).

4 Discussion

Research and policies on the impact of heat exposure on pregnant women have received little attention (National Oceanic and Atmospheric Administration (NOAA) 2022; Lee et al. 2019; Rocque et al. 2021). This scoping review provides an updated synthesis on climate change effects on the risk of adverse pregnancy outcomes, strengthening the idea that global warming is associated with an increased risk of adverse pregnancy outcomes. Our review outlines a clear description of the risk for harmful temperature exposure, as well as substantial cofactors that adversely interfere with the heat-health linkage. The negative effects of heat on the pregnant female are well acknowledged in non-human species, including mice, rats, guinea pigs, goats, and cattle (Samuels

et al. 2022). In these animal models, growth retardation, reduced placental and fetal weights, altered uterine and umbilical blood flow, and even intrauterine deaths have been described (Samuels et al. 2022). In humans, however, research on climate-health linkage in pregnancy has just evolved (Rocque et al. 2021). It is clear that studies to date have extensively analyzed the impact of ambient temperatures on pregnancy outcomes, but they have rarely addressed maternal and neonatal health. Although scientific societies have provided recommendations for pregnant women, including avoiding physical exercise in the heat, prolonged use of saunas, and bathing in hot water (ACOG 2022; Centre for Disease Control and Prevention (CDC) 2022; NHS 2022), consistent guidelines concerning how to deal with environmental heat exposure are still missing (Samuels et al. 2022). Some healthcare providers give general advice, including cooling oneself using air conditioning and maintaining a regular fluid intake (Samuels et al. 2022). However, these are insufficient. Evidence-based knowledge, including an exact definition of what harmful extreme temperatures are, whether there are sensitive periods for exposure during pregnancy, and the length of potentially harmful exposure time, is therefore highly warranted.

5 Conclusion

Data from our scoping review empower healthcare providers to successfully increase awareness of the global environmental crisis, as well as to create policies to mitigate the adverse effects of heat on both mothers and their unborn. It is of paramount importance to increase knowledge about the anthropogenic environmental crisis, as well as to conduct further research and standardize the approach of the studies in order to further assess them. A strategy is urgently needed to reassure the reproductive health of our and future generations.

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Remote Sensing and GIS for Environmental Monitoring and Management

Groundwater Recharge Estimation Using GIS-Based Distributed Hydrologic Models, WetSpass: An Application to Central Limpopo, South Africa

Sophia S. Rwanga

Abstract

Groundwater sources are valuable in urban and rural areas for various purposes. In developing countries, especially in rural areas, where most people live, groundwater is frequently the only possible source of potable water. With increased human social and development activities and water demand, the future of sustainable water supply is shifting from surface to groundwater sources. Groundwater is the most dependable water source for many users in the Limpopo water-management area. Most rural settlements and villages in Limpopo depend on groundwater for domestic and agricultural purposes. Therefore, it was crucial to determine the amount of groundwater available in the study area. The main objective of this study was to estimate the spatial and temporal variations in groundwater Recharge in Central Limpopo. A physically based water balance model called WetSpass, which simulates recharge spatially and temporally, was used together with a Geographical Information system (GIS). Input data for the WetSpass model included grid maps of rainfall, temperature, wind speed, soil, elevation, slope, groundwater depth, and land use/cover. The WetSpass simulation was divided into two seasons, summer and winter. The long-term average spatial and temporal distributions of the groundwater recharge were obtained. The average simulated summer and winter recharge values were 76 mm and 1.98 mm, respectively. The calculated annual average recharge was 105 mm, which was 22.1% of the average annual rainfall (475 mm) in the study area. This study demonstrates the applicability of the WetSpass model in conjunction with GIS to determine groundwater recharge. These results were in good agreement with those reported in other studies. Thus, the GIS-based WetSpass model can be used to simulate recharge, and the results can be further used in groundwater flow modeling and management analysis.

Keywords

Groundwater · GIS · Limpopo · Recharge · WetSpass

1 Introduction

Water is a precious commodity for human life. Not only do humans use it every day, but every living thing needs it to live. Although freshwater is a renewable resource, the global supply of clean freshwater is steadily decreasing. This scenario is caused by a continuous increase in demand for freshwater resources driven by an increased population worldwide (Obuobie et al. 2012) Increase in potable water demand worldwide leads to a consistent water scarcity problem in many parts of the world. (UNDP 2006) asserted that water use has grown at a rate approximately twice that of population growth in the last century. Although this may not be noticeable, numerous countries face water shortages.

Groundwater sources are used for various purposes in both urban and rural areas. In developing countries, especially in rural areas, where most people live, groundwater is frequently the only possible source of potable water. (Wang et al. 2008) reported that groundwater is often the only water resource available throughout the year. It is because groundwater has the advantage that it is frequently widely available in quantities sufficient to supply the needs of scattered communities. Determination of groundwater recharge has shifted from a basic problem to an urgent and fundamental issue in hydrogeological research for the sustainable development of groundwater (Stoll 2012; Gieske 1992). It has been reported that direct groundwater recharge from precipitation in semiarid areas is generally small, usually less than 5%

S. S. Rwanga (✉)
Civil Engineering Science, University of Johannesburg, Johannesburg, South Africa
e-mail: sophiar@uj.ac.za

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of the average annual precipitation, with high temporal and spatial variability. Recharge occurs when groundwater infiltrates a saturated zone (Yeh et al. 2009). Recharge can be estimated using several approaches depending on the data availability and required accuracy level. In arid and semiarid areas, recharge is relatively small and potentially variable (Ketema and Broder 2009). GIS has emerged as an effective tool for handling spatial data and decision-making in several areas, including engineering, geology, and the environment. GIS utilities can also create a hydrogeological database (Krishnamurthy et al. 2000) for groundwater recharge mapping and simulation. Employing GIS to analyze the impact of factors on water infiltration can more precisely delineate zones with different groundwater potentials (Gaber et al. 2020).

Reliable recharge estimation is crucial for efficient and sustainable management of groundwater systems. Effective comprehension and quantification of the processes that contribute to groundwater recharge are essential for effective management of groundwater resources (Xu and Beekman 2019). Various methods exist for estimating the recharge. These methods can be used over different spatial and temporal scales, complexity, and expense. Recharge estimation methods can be classified into three hydrological zones: surface water, unsaturated zone, and saturated zone (Scanlon and Cook, 2002; Beekman et al. 1999). Various methods for estimating recharge can be found in (Lerner and Issar 1990; Stephens 1996). Internationally, there is a vast amount of literature on groundwater recharge, and according to (Simmers 1998), the project objective is the key to recharge studies. (Xu and Beekman 2003) Stated that the first systematic recharge studies in South Africa were done in the early 1970s in the western "Transvaal" (now the province of Gauteng) and in the Northern Cape. Most studies on recharge were conducted by (Verhagen et al. 1978; Fleisher 1981; Connelly et al. 1989; Kirchner et al. 1991; Gieske 1992; Wright and Burgess 1992; Vegter 1995; Xu and Beekman 2003). Based on previous studies carried out in South Africa, the majority used old methods to estimate groundwater recharge, including the Chloride Mass Balance method (CMB), rainfall recharge relationship, and the Mean Annual Precipitation (MAP) approach. However, the use of new approaches incorporating GIS and remote sensing for recharge estimation in South Africa is new. Studies are yet to be conducted in areas that use the water balance GIS hydrological model (WetSpass) for groundwater recharge estimation. Therefore, this study opted to use a new GIS-based approach, the WetSpass model, to estimate the groundwater recharge. The calculated results were compared to those obtained in a previous study.

WetSpass Model

Efficient groundwater management requires accurate recharge estimation. This study introduces a novel method using the WetSpass model, which represents Water and Energy Transfer between Soil, Plants, and Atmosphere in a quasi-steady state (Batelaan and De Smedt 2007). WetSpass forecasts long-term spatial patterns of surface runoff, evapotranspiration, and groundwater recharge (Batelaan and Woldeamlak 2007). This model is well suited for providing accurate and reliable estimates of these important water-related processes, making it a valuable tool for hydrologists and water management professionals. Initially scripted in Avenue, the model predicts hydrological processes seasonally and annually. As Python's popularity in scientific research has grown, the WetSpass model has been re-written in Python using the Hydrology and Hydraulic Programming Library (H2PL). The enhanced version of the model now includes simulations for landscape runoff, interception from vegetated surfaces, evapotranspiration, recharge, and soil water balance, all of which are calculated on a seasonal or annual basis. The model's effectiveness in managing and planning resources has been demonstrated through its application in regulating the components of water balance (Al-Badry and Shamkhi 2021; Salem et al. 2019).

The WetSpass model has been extensively employed in a range of investigations carried out in diverse locations, such as the Nete River and Dijle, Demer catchments in northeast Belgium (Batelaan and De Smedt 2007), the Osun River in Nigeria (Ashaolu et al. 2020), the Obra River in Poland (Graf and Przybyłek 2018), and the (Yenehun et al. 2020) river basin in northwest Ethiopia. Furthermore, studies were conducted in Hungary by (Salem et al. 2019) and Geba basin in Ethiopia by (Gebreyohannes et al. 2013).

2 Materials and Methods

2.1 Study Area Description

The study area is located in Central Limpopo, South Africa. This area covers approximately 19,188 km^2. Groundwater supply requirements and data accessibility played a role in the selection of the study region. The geographic (Lat/Lon WGS 84) coordinates for the location were − 23 °0 31.0956 S, 29 °30 48.5697 E, 24 °2 48.3007 S, and 29 °32 16.9088 E. The study area is illustrated in Fig. 1. The study area has a semiarid subtropical climate. Winter temperatures range from 9.2 to 4.3 °C, and the average summer temperature ranges from 32.2 to 27.3 °C. This region experiences considerable climatic variability, with an average annual rainfall in the area ranges from 93.8 to 418.9 mm in the summer and 11.5 to 56.8 mm in the winter. The annual average rainfall is 105.3 to 475.8 mm, making it prone to drought and water scarcity. Furthermore, many smallholder farmers rely on groundwater for agricultural activities (Senyolo et al. 2020).

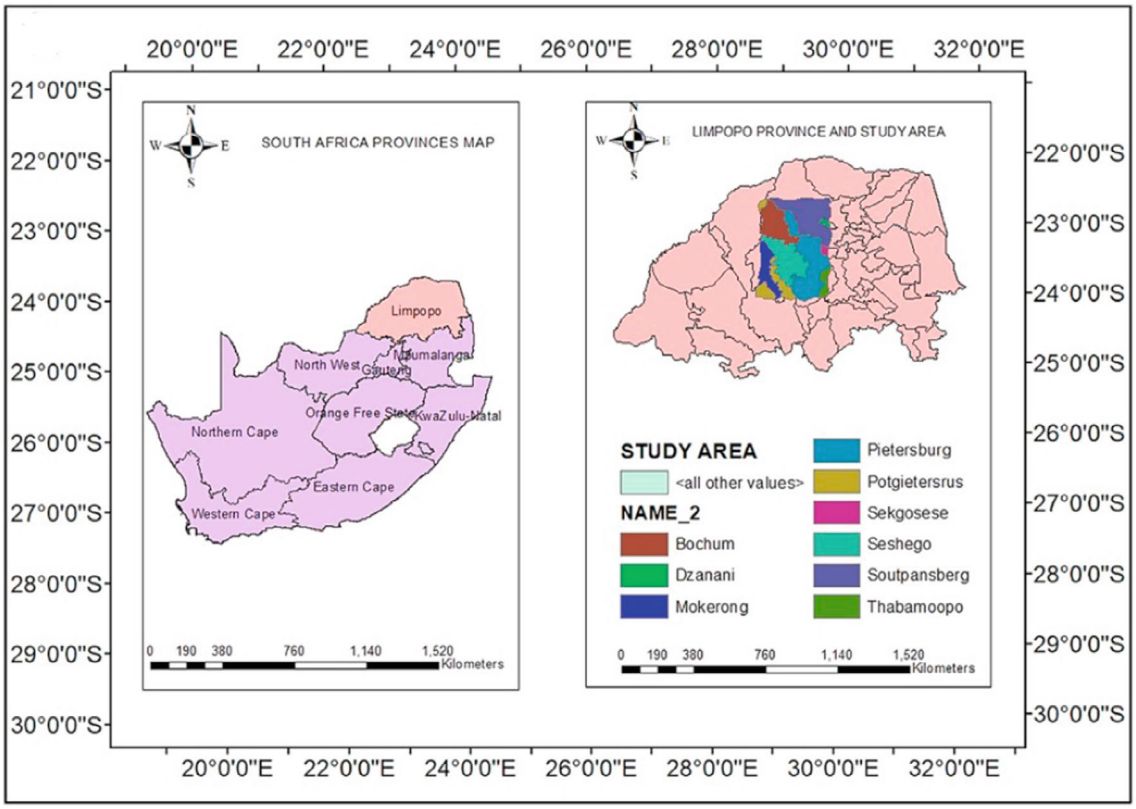


Fig. 1 Study area location map

The study area's geology and lithology indicate that bare volcanic rocks are generally present in the south-north portion of the study area, at the same time Goudplaats gneiss predominates in the center. Sandstone and mudstone were most frequently found in the southwestern area. The main river in the study area is the Sand River, which flows from south of Polokwane to the north through the Soutpansberg mountain range before entering the Limpopo River (Department of water affairs and forestry (DWAF) 2003). According to (Parsons 1995), the research region is distinguished by its main and minor aquifers. The major aquifers encompassed approximately 50.6% of the research area, indicating that considerable water can be extracted for public supply. Minor aquifers account for 49.6% of the study area.

2.2 Research Methodology

The WetSpass model was used to simulate the temporal average and spatial differences in actual evapotranspiration, surface runoff, and groundwater recharge in the study area on a seasonal and annual basis. WetSpass requires parameters on a seasonal basis; therefore, in the case of Limpopo conditions, specifically in the research region, the four months of June, July, August, and September are treated as winter (dry season), and the remaining months are deemed to be summer (wet season). Generally, two primary input parameters hydrometeorological and biophysical data from the study area are required to run the WetSpass model. Several steps were taken to prepare the input data for the WetSpass model, including (i) developing meteorological input maps such as rainfall, temperature, evapotranspiration, and wind speed. (ii) creation of grid maps for soil, elevation, slope, and groundwater depth; and (iii) creation of a land use/cover grid map. This information was included in the WetSpass model to predict the groundwater recharge, as shown in Fig. 2.

2.2.1 Input Data

Climatic variables, including maximum and minimum temperature, rainfall, wind speed, and humidity, were acquired from the South African Weather Service (SAWS) database. This study used a long time-series of data from 2000 to 2015. Grid maps were prepared for the summer and winter seasons, and annually. Subsequently, the grid maps were converted into ASCII files for use with the WetSpass model. Soil physicochemical and hydrological property data for South Africa were obtained from the Food and Agri-

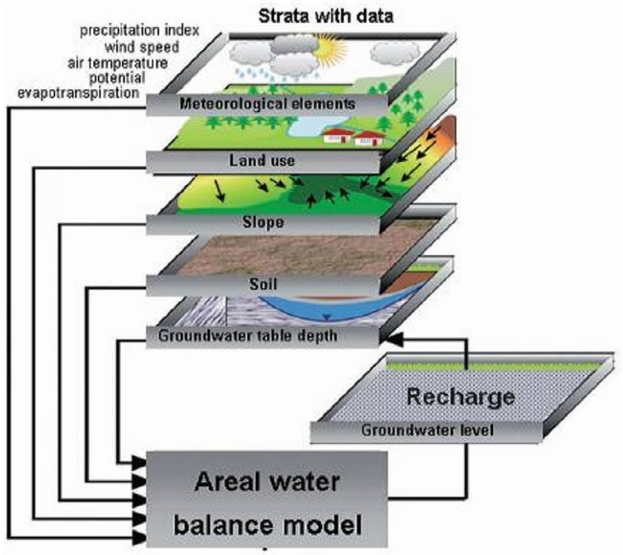


Fig. 2 Integration of input data in the WetSpass model (Batelaan 2007)

culture Organization database (FAO 2002; FAO 2005) soil map. The attributes of the soils (soil texture, Hydrological Soil Group (HSG), soil type, and WetSpass serial number) were captured in a database using ArcGIS, which provided a link for use in the WetSpass model. ArcGIS generates a slope-grid map from the elevation map using the surface function in the spatial analysis tool. Both grid maps were converted into ASCII files and were used in the WetSpass model. Borehole data were obtained from different sources, including the Department of Water Affairs (DWA), the National Groundwater Archive (NGA), and GRIP Limpopo. The recorded groundwater depths ranged from 23 to 291 m. The groundwater level grid map was then converted to ASCII format and used as a grid map input in the WetSpass model. In this study, land use/cover mapping was developed through two major steps: (i) land use/cover supervised classification and (ii) accuracy assessment through the utilization of ground control points in image processing software (ERDAS IMAGINE). The classification map is shown in Fig. 3.

2.2.2 WetSpass Water Balance Components Estimation

The total water balance of a specified area was calculated as the summation of the water balances of each raster cell (Batelaan and Woldeamlak 2007), using the following water balance equations;

$$\mathrm{ET}_{\mathrm{raster}} = a_{\mathrm{v}}\mathrm{ET}_{\mathrm{v}} + a_{\mathrm{s}}E_{\mathrm{s}} + a_{\mathrm{o}}E_{\mathrm{o}} + a_{\mathrm{i}}E_{\mathrm{i}} \quad (1)$$

$$S_{\mathrm{raster}} = a_{\mathrm{v}}S_{\mathrm{v}} + a_{\mathrm{s}}S_{\mathrm{s}} + a_{\mathrm{o}}S_{\mathrm{o}} + a_{\mathrm{i}}S_{\mathrm{i}} \quad (2)$$

$$R_{\mathrm{raster}} = a_{\mathrm{v}}R_{\mathrm{v}} + a_{\mathrm{s}}R_{\mathrm{s}} + a_{\mathrm{o}}R_{\mathrm{o}} + a_{\mathrm{i}}R_{\mathrm{i}} \quad (3)$$

$\mathrm{ET}_{\mathrm{raster}}$, S_{raster}, and R_{raster} are the total evapotranspiration, surface runoff, and groundwater recharge of the raster cell, respectively. The water balance of a vegetated area depends on average seasonal precipitation (P), interception fraction (I), surface runoff (S_{v}), actual transpiration (T_{v}), and groundwater recharge (R_{v}).

$$P = \mathrm{I} + S_{\mathrm{v}} + \mathrm{TV} + R_{\mathrm{v}} \quad (4)$$

Groundwater recharge was calculated as a residual term of the water balance, that is,

$$R_{v} = P - S_{\mathrm{v}} - \mathrm{ET}_{\mathrm{v}} - E_{\mathrm{s}} - \mathrm{I} \quad (5)$$

where ET_{v} is the actual evapotranspiration given as the sum of transpiration T_{v} and E_{s} (evaporation from bare soil between the vegetation).

3 Results and Discussion

This study aimed to estimate the groundwater recharge using the WetSpass model. Several maps were used to achieve this exercise, as described in Sect. 2.2.1. The simulated seasonal groundwater recharge varied from 1 to 218 mm, with a mean of 76 mm and standard deviation of 52 mm in summer. For winter, the recharge rate ranged from a minimum of 0.19 mm to a maximum of 1.98 mm. The annual recharge ranged from 1 to 283 mm/annum, with a mean of 105 mm and a standard deviation of 58 mm (Fig. 4). The average annual groundwater recharge in the study area is 22.1% of the average annual precipitation (475.8 mm). Approximately 88.04% of the annual groundwater recharge occurs during the wet season (summer) and the remaining 11.96% occurs during the dry season (winter). The simulated recharge at some locations in the western part of the study area resulted in low recharge rates. This could be because the western part of the study area experiences high temperatures ranging from 30.4 to 32.2 °C and thus causing high evapotranspiration and, therefore, less recharge. Similarly, some western locations had negative values, indicating no groundwater recharge (i.e., discharge). This occurred because the discharge from the subsurface exceeded recharge. Furthermore, the southeastern half of the research region receives substantially higher rainfall (ranging from 408 to 636 mm/annum). It has a significant groundwater recharge compared with other locations (133–283 mm/annum).

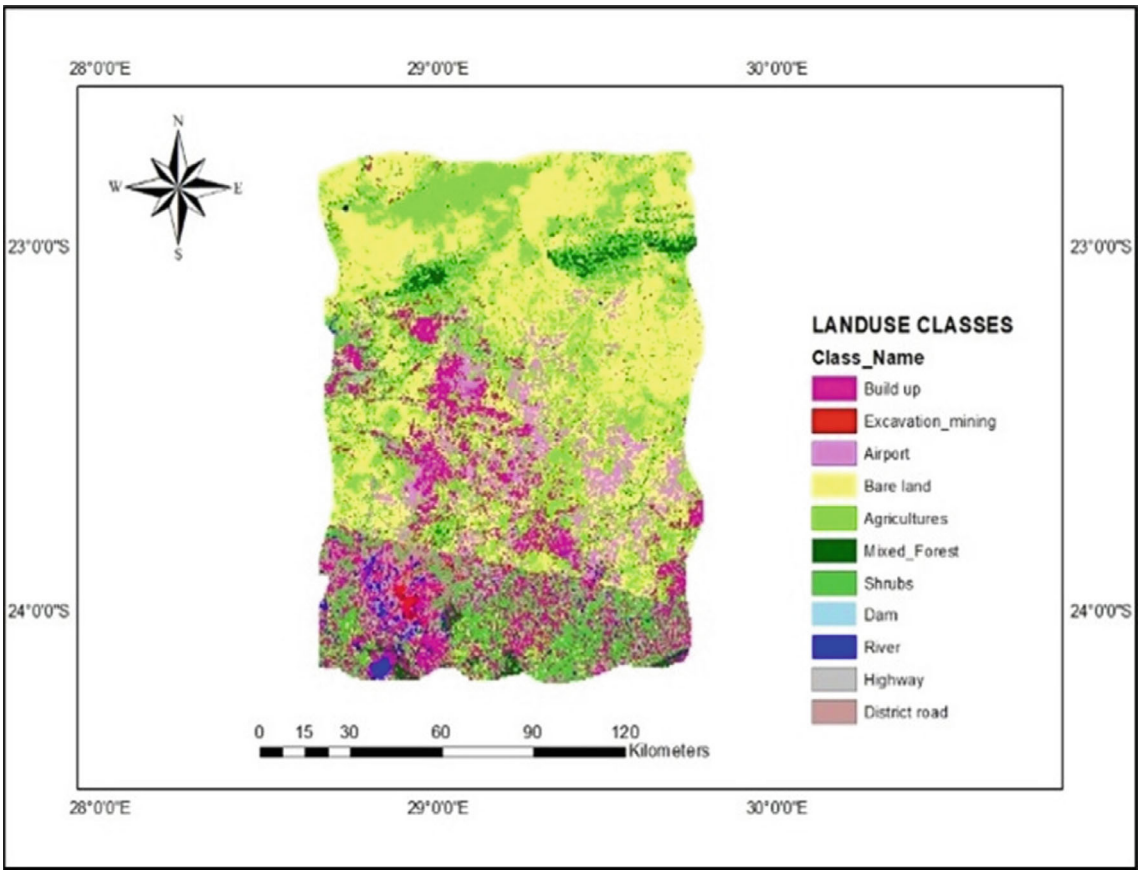


Fig. 3 Land use classification map

3.1 Comparisons of Estimated Groundwater Recharge Results with Previous Studies

(Vegter 1995) determined groundwater recharge using the Chloride Mass Balance (CMB) method, which resulted in an annual recharge value of 75 mm/year. The same method was used by the Groundwater Resource Assessment (GRA II) (Department of water affairs and forestry (DWAF) 2006) to estimate the groundwater recharge, resulting in a value of 98 mm/year. Both results were lower than the 113 mm/year recharge value determined by GRA II (Department of water affairs and forestry (DWAF) 2006) using the Mean Annual Precipitation Approach (MAP). Notably, the recharge value obtained by the GRA II (Department of water affairs and forestry (DWAF) 2006) showed a good relationship between rainfall and recharge. This observation was based on the fact that the rainfall intensity observed in 2006 was more significant than in the preceding three years in the research area. According to this analysis, the amount of rain percolating into the ground contributes significantly to recharge. Moreover, in this study, the groundwater recharge estimated using the WetSpass model resulted in a mean recharge value of 105 mm/year, which is in close agreement with the results of previous studies. These findings imply that the WetSpass model can be used to estimate Recharge even in areas where data are scarce. A summary of these results is presented in Table 1.

4 Concluding Remarks

The evaluation of groundwater involves several factors, of which recharge is of paramount importance. Recharge can be estimated using several approaches depending on the data availability and required accuracy level. WetSpass, a GIS-based distributed hydrologic model, was used to calculate the groundwater recharge in a semiarid study area. The long-term average spatial and temporal distributions of the groundwater recharge were obtained. The summer and winter recharge averages were 76 mm and 1.98 mm, respectively. The calculated annual average recharge was 105 mm with a standard deviation of 58 mm, accounting for 22.1% of the average annual precipitation (475 mm) in the study area. Further studies indicated high groundwater recharge potential in the southeastern parts of the study area and low groundwater recharge potential in the western part of the study area. These findings imply that WetSpass can be used to estimate

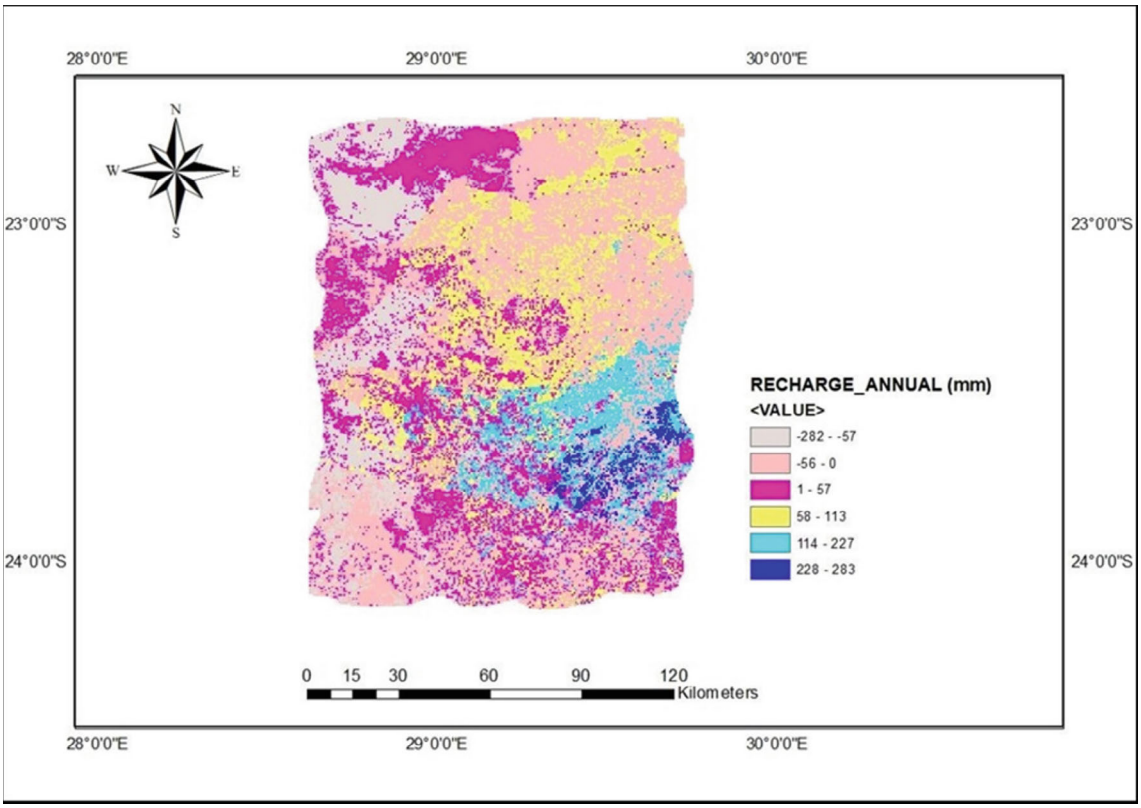


Fig. 4 Groundwater recharge (annual) map

Table 1 Comparisons of estimated recharge with previous studies

Year	Mean annual recharge (mm/a)	Method used	Source
1995	75	Chloride mass balance (CMB)	(Vegter 1995)
2006	113	Rainfall recharge relation (Woodford approach)	DWAF GRA II report (2006)
2006	98	Chloride mass balance (CMB)	DWAF, GRA II report (2006)
2024	105	GIS hydrological model (WetSpass)	This study

Recharge even in areas where data are scarce. The calculated annual average Recharge compared well with the values reported by other studies, implying that GIS-based WetSpass can be used to estimate the spatial recharge for groundwater management.

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Remote Sensing and Ground Truth via AI for Monitoring Seagrass Beds

Jörn Kohlus, Friederike Nowak, Kerstin Stelzer, and Hannah Böhm

Abstract

180 km^2 of eulitoral seagrass beds cover the Schleswig-Holstein part of the Wadden Sea. Since the 1990s, a rough estimate by means of aircraft observation is carried out. After 7 years of parallel operation, this is now being replaced by a more accurate satellite-based method. Still, this new method is limited to detect seagrass beds under certain conditions. Surveys of seagrass cover on the ground provide for verification data, but also subject to inaccuracies due to sometimes harsh weather, light, and ground conditions. Therefore, a measurement technique independent of observers is desirable. In our approach, we take RGB control images of the surface from standardized directions, which are then split by a segmentation algorithm and the resulting sub-images are classified into seagrass or background categories by a neural network. The classified data are then subjected to three different methods to determine coverage. This provides objective, independent, and complementary information to the remote sensing results.

Keywords

Seagrass bed · Remote sensing · Ground truth · Artificial intelligence · Monitoring

J. Kohlus (✉)
LKN, Administration for national park and world heritage area Schleswig-Holstein Wadden Sea, Tönning, Germany
e-mail: Joern.Kohlus@lkn.landsh.de

F. Nowak · H. Böhm
Dataport, Altenholz, Germany

K. Stelzer
Brockmann Consult, Hamburg, Germany

1 Introduction

Mediterranean seagrass beds are found in sublittoral or lagoonal areas. In the European Wadden Sea, there are also areas with low influence by waves, but today, seagrass grows only in the high eulitoral. Seagrass forms an important habitat, which today covers more than 180 km^2. After the seagrass perishes in winter, a new lifecycle begins with strong growth in May of the following summer and reaching its maximum in August/September. Changes of more than 10% occur between years. Since the 1990s (Dolch et al. 2013), a rough estimation by means of aircraft observation has been carried out in the area of Schleswig-Holstein, Germany. After 6 years of parallel operation, this is now being replaced by a satellite-based method.

Compared to aerial monitoring, the new methods using satellites increase accuracy. Nevertheless, they cannot always account for local effects such as interaction of water coverage, differentiation from green algae, and very low seagrass coverage, which cannot be well distinguished from diatoms growing on the sediments. Surveys of seagrass cover on the ground optimize the methods and verify the results.

However, not only remote sensing methods, but also data collection during a survey—under often harsh weather, light, and ground conditions—can lead to inaccurate results. Therefore, a photo-based measurement independent of observers is desirable. In our approach, we use a handheld device to take photographs of the surface from standardized directions. These RGB control images are split by a segmentation algorithm and the resulting sub-images are classified into seagrass or background categories by a neural network. This provides objective, independent, and complementary information to the remote sensing results. The classified data are then subjected to three different methods to determine coverage (Kohlus et al. 2020).

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2 Remote Sensing and Ground Truth Validation Data

2.1 Remote Sensing

Satellite data from Sentinel-2 MSI sensors and Landsat-8/9 OLI are collected and processed for suitable low-tide acquisitions over the season. The processing comprises an atmospheric correction and the generation of spectral indices followed by a knowledge-based decision tree (Jiang et al. 2010). In order to receive comparable results for the monitoring, the images need to be acquired during August/September to meet the maximum extent of the seagrass beds. Satellite data acquired during spring and early summer allow an estimate of the growing cycle during the season. However, due to cloud conditions, the distribution over time is not regular and therefore influences the assessment. For the past years, 4–6 images could be analyzed during each season. A validation within the regular monitoring is performed with different data sets: seagrass beds from airplanes and ground-based assessment of seagrass density are mapped to the satellite-based results at selected stations acquired in the framework of the routine seagrass monitoring for Water Framework Directive and Flora-Fauna-Habitat Directive reporting.

2.2 Automated Ground Truth Validation Data

Each of the control images described above is divided by the SLIC segmentation algorithm (Achanta et al. 2010) to separate different objects. The resulting sub images are classified by a neuronal network in segments containing seagrass, segments containing background like bare soil and algae, and segments with effects that obscure the presence or absence of seagrass, like reflections, dispersed sediments, or the cartographer's own shoe. The area of segments from the obscuring classes is removed from the evaluable area of the image. Segments classified as containing seagrass are then subjected to three different methods to estimate the amount of coverage.

"Simple": the classes themselves provide already a rough estimate on the coverage and are divided into "scant," "medium," and "plenty" coverage. These are assigned as a flat coverage value of 10%, 50%, and 95% respectively, weighted with the classification probability.

"GLI": The Green Leaf Index (Louhaichi et al. 2001) is a vegetation index using the RGB channels of standard devices. It is calculated for each pixel of a segment.

"Otsu": The method developed by Otsu (1979) is used to divide the segment image into bright and dark parts and is calculated on the pixel level. Dark pixels are considered "seagrass."

Segments toward the border of the image comprise more real area than segments of the same pixel size than in the middle of the image. This is taken into account by scaling the pixel area of a segment according to its position within the image relative to the center. For the coverage of the transect point, the average over the individual image results for the given method is taken.

Considered sources for uncertainties are the classification by the neural method and the overall training uncertainty, the area scaling, and the coverage methods.

3 Results

3.1 Remote Sensing

During routine monitoring, airborne mapped data provide the information needed for consistent time series. We compared both methods for selected seagrass beds over seven years to assess how information on seagrass can be derived from satellite data. Figure 1 shows the result of the seagrass detection from satellite data on the left and from airplane mapping on the right. Both show the seagrass bed northeast from island Groede. The results from satellite data provide more detailed information and fit the real shape of the seagrass bed better. On the other hand, it shows limits for sparce seagrass densities. Therefore, the areas of seagrass beds gained from satellite data are often smaller compared to the airborne mapping method.

The comparison between satellite data and ground truth has been taken place with the assessment of the density of seagrass beds at selected positions along transects. The assessment has been made until now with a human-based classification of seagrass densities into 8 categories. This method enables to compare directly between satellite data at one specific position with ground truth data. Both can be compared in a confusion matrix showing the cases in which both methods agree and in which they differ. The confusion matrix shown in Fig. 2 includes data from 2018 along transects along the seagrass bed northeast from Groede.

We observed differences of the agreement for different transects acquired by different people and between different years. Here, we expect advantages from the new approach for retrieving more objective assessment of seagrass densities.

3.2 Ground Truth

For evaluating the performance of the proposed method, a set of 26 test images was defined. These images were selected such that they cover a diverse range of conditions and coverage values in order to get a realistic evaluation of the methods (for examples, see Fig. 3). In addition to the calculation by the three methods, a coverage value was estimated by an

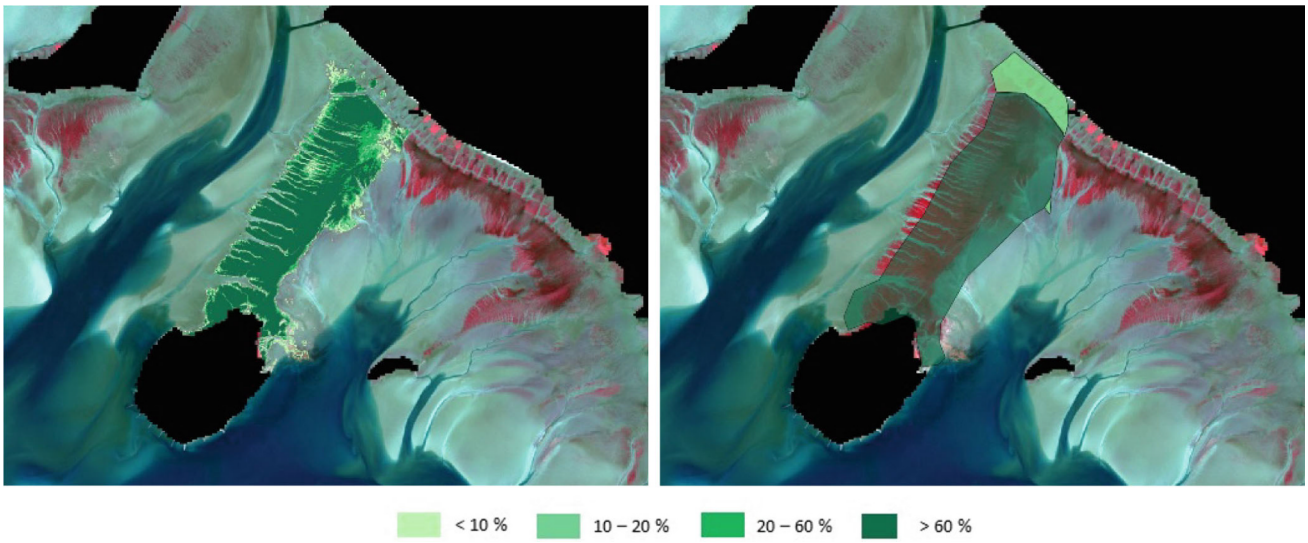


Fig. 1 Seagrass classification (different density classes) from satellite (left) and mapping from airplane (right) for seagrass bed NE from Groede (satellite acquisition: 07.08.2020)

		Sat. Klassen						
		0	< 10	10-20	20-60	>60	Σ	%
Transekt	0-5%	98	2	0	0	0	100	98.0
	10%	17	5	0	0	0	22	22.7
	20%	11	5	5	4	0	25	20.0
	30-50%	6	1	4	10	2	23	43.5
	70-90%	0	0	1	2	31	34	91.2
	Σ	132	13	10	16	33	204	
	%	74.2	38.5	50.0	62.5	93.9		**73.0**

Fig. 2 Confusion matrix between satellite-derived seagrass density classes and point measurements on ground level at a seagrass bed near Groede

Table 1 Mean Signed Deviation (MSD) and Mean Absolute Error (MAE) of the three coverage estimation methods for the test image set

	"Simple" [pp]	"GLI" [pp]	"Otsu" [pp]
MSD	2	−7	2
MAE	5	9	13

expert. For the three different methods, both the Mean Signed Average (MSD) as well as the Mean Absolute Error (MAE) in relation to the expert value are shown in Table 1.

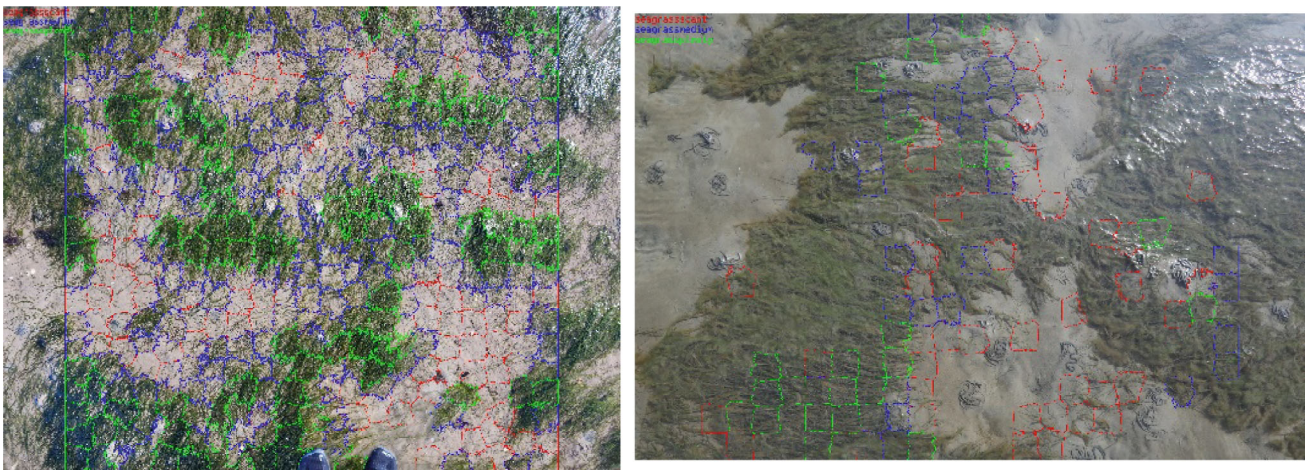


Fig. 3 Left: The seagrass coverage estimate for this example from the test image set is 48 + 1–6% ("Simple"), 36 + 4–4% ("GLI"), and 48 + 5–5% ("Otsu") in comparison with the expert estimate of 45–50%. Right: Another example from the test image set. In this case, the conditions for identifying seagrass are much more difficult. The results are 15 + 4–5% ("Simple"), 3 + 5–3% ("GLI"), and 23 + 6–5% ("Otsu") coverage with an expert estimate of 0%

4 Discussion

On the image level, the ground truth estimation method "simple" is able to reproduce the expert estimate on seagrass coverage with only a small deviance toward larger values. This method has the advantage to rely on the optical structure of the seagrass for identification by the neural network, instead of using similar methods to the remote sensing analysis by using ratios of the reflected spectrums. Thus, it can be considered an independent measurement of the coverage.

For image creation, a high quality camera with a good resolution capable to differentiate between single blades of seagrass has to be used. In addition, effects that obscure objects on the ground like reflections, strong shadows, and dispersed soil are to be avoided.

With good illumination, normal conditions with full or patchy seagrass coverage, or bare soil reasonably dry, the "simple" method can reliably reproduce a reasonable estimate of the coverage. In more difficult conditions, e.g., seagrass overgrown by large patches of algae or occurrences in deeper puddles, the estimate should be supported by an expert opinion. In the future, estimates could be enhanced by adding training data specifically for these conditions.

The reasoning for taking ground truth data is to establish a reference for a pixel of the satellite images used. These pixels extend over ground areas of 10–30 m side length. Single RGB images which are taken during a ground truth survey represent only about 2 m^2. Therefore, a ground truth area consists of several single images, which summarily represent the characteristics of a reference area for one pixel of the satellite images.

For data taking, using drones is the most obvious step forward. In the Wadden Sea, common wind conditions do not allow for the usage of small cheap drones. In addition, it is not allowed to operate below 24 m due to restrictions by national park rules, and each flyover has to be applied for. Despite this, a trial with a Matrice 300 RTK with a ground sampling distance of 0.3 cm at 24 m height has been conducted (courtesy of BioConsult Schobüll). Unfortunately, the resolution of the resulting images was not sufficient for the identification of seagrass by our proposed method. Still, future developments in drone camera outfit might make the transition to image taking by drones feasible.

5 Conclusions

A core problem of optical remote sensing is that it can only classify surfaces that differ in color and spectral behavior. This is usually sufficient for a qualitative area classification. But to what extent classification results are linked to measurable properties—grain size of a sediment, vegetation cover by a specific species—can only be clarified by means of ground truth on the real object. Likewise, these comparative measurements are necessary to be able to determine the uncertainties in remote sensing data. This is a requirement for legally valid statements, but also for many monitoring tasks.

The classification methods for seagrass have been optimized in recent years. The new data have a higher accuracy than the airborne monitoring. By reprocessing old images, it has now been possible to obtain comparative results to the previous method over seven years. Trends in the results of the old methods could be traced. Whether the scope is now sufficient to change the monitoring procedure will be clarified in 2024.The evaluation is therefore difficult, as errors of various kinds are to be expected even in the comparative data collected on the ground. When spatially recording, seagrass covering boundaries, stock areas, as well as stock gaps can be overlooked due to the difficulties in recognizing them. Both in the spatial survey on the ground as well as when obtaining comparative values on transects, the cover measurement is based on the assessment by experts.

A dependence on stress factors such as weather, time pressure, ground conditions, and distances cannot be excluded. AI-based ground-truth estimates are currently in the testing phase. The Analysis of ground-truth images appears to produce reliable results under good environmental conditions.

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Automatic Recognition of Asbestos Roofing Based on High-Resolution Orthophotos and Deep Learning Approach

Antonietta Varasano and Meriame Mohajane

Abstract

Asbestos-containing (AC) materials pose a negative impact on human health and in environment sustainability. Therefore, urgent actions should be taken for its removal in a best possible way. In this regard, Remote Sensing (RS) technology is an efficient tool for detecting, mapping, and monitoring of AC roofs. Although the use of Hyperspectral Images (HSI) from airborne sensors (e.g., MIVIS) has shown good results with acceptable classification accuracy of AC roofs, some challenges have made such use unsuitable for large-scale mapping, mainly due to the spatial resolution of HSI, which generates large errors of omission in detecting small AC roofs (less than 100 m^2). In addition, in HSI, using an optimal number of bands is still a big challenge due to the large number of bands and the resulting low accuracy in terms of commission errors. In this context, our project started in July 2021 and still ongoing, employed and tested the potential of a specific U-Net architecture, as a Deep learning (DL) Convolutional Neural Network (CNN) model for automatic recognition of AC coverages based on high-resolution optimized linear stretch RGB orthophotos with a pixel resolution of 0.20 m.The metrics, evaluated on an initial U-Net neural network model, trained on ROIs (Region Of Interest) from simple RGB images, showed strong pattern recognition ability for complex features like red roofs and industrial sheds, making any rotations, translations, or small changes in the recognition process irrelevant. To identify discriminating "features" for AC roofs, the focus was on the extraction of statistical descriptors capable of detecting the regularity of Eternit corrugations, even for small roofs (< 100 m^2). In order to characterize the specific textures related to AC roofs, in this project, the use of the Gray-Level Co-occurrence Matrix (GLCM) was explored for calculating the frequency with which pairs of pixels occur with specific values and in a specific spatial relationship, thus calculating and testing numerous quantitative features and descriptors: mean value, moments, etc., related to AC coverages. The trained network model led to excellent results in terms of accuracy, even finding values as high as 93% in industrial areas.

Keywords

Remote sensing · Asbestos roofing · RGB images · nDSM · U-Net neural network · GLCM features

1 Introduction

The implications of asbestos on human health raise noteworthy concerns. Globally, the risk associated with asbestos has experienced a remarkable increase since the 1960s (Gibril et al. 2017). Considering these harmful effects of AC roofs, the comprehensive removal of these materials from buildings is an imperative obligation. In this context, several studies have shown the power of Machine Learning (ML) algorithms in combination with Remote Sensing (RS) data and Geographic Information System (GIS) tools to address the critical impact of asbestos mapping and the necessity of an urgent call for its management. For instance, Abriha et al.(2018) employed ML techniques on WorldView-2 satellite imagery to automatically detect AC roofs. Exploring high-resolution satellite data and LiDAR, Norman et al. (2020) developed detailed maps of AC roofs. Also, automated detection of asbestos-cement roofs was

A. Varasano (✉)
ITC-CNR, Construction Technologies Institute, National Research Council, Bari, Italy
e-mail: varasano@itc.cnr.it

M. Mohajane
ITC-CNR, Construction Technologies Institute, National Research Council, Naples, Italy

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exploited by de Pinho et al. (2012), demonstrating the efficacy of machine learning in identifying these hazardous materials from aerial imagery. More recently, researchers have extended their approaches to incorporate the opportunities of Deep learning (DL) models, to address this heavy issue. For instance, the work conducted by Raczko et al. (2022) employed the deep U-net architecture for asbestos mapping in Poland. They showed the deep U-net's ability to accurately identify asbestos-containing materials in buildings. Also (Krówczyńska et al. 2020), their approach based on Convolutional Neural Networks (CNNs), have achieved promising outcomes in learning the distinctive features of asbestos-cement coverings and extracting relevant features. In this sense, we developed an U-net CNNs architecture that leverages both RGB high-resolution orthophotos enhanced through optimized linear stretching and integrated with GLCM features, with the aim of developing a novel approach for an automated classification of AC roofs.

2 Materials and Methods

The work presented here is conducted across three distinct study areas within the Basilicata region in Italy. Each of these regions possesses unique characteristics, encompassing an urban area, an industrial zone, and an agricultural area, in order to undertake comprehensive AC roofs mapping. In this study, orthophotos (RGB) covering the regional landscape of Basilicata region at a scale of 0.20 m were used. Additionally, the Digital Surface Model (DSM) and Digital Terrain Model (DTM) with a 5-meter pixel size were integrated to build nDSM to enhance our understanding of AC roofs. The first stage for this work was to build "ground truth samples" to train a binary Deep learning model. QGis software was used for this task to accurate labeling and digitization of vector polygon classes: "Asbestos Coverings" and "Probable Asbestos Coverings."

Texture features and spectral features combined together can improve classification accuracy. Hence, we adapted the Haralick Grey Level Co-occurrence Matrix (GLCM) (Haralick et al. 1973) to characterize the corrugation regularity in asbestos cement. For this study, the following eight widely used GLCM texture features were selected: contrast, dissimilarity, homogeneity, angular second moment, entropy, mean, variance, and correlation. On the basis of the classification results, we conclude that the variance texture feature provides great advantages over the other texture features for AC roofs discrimination. Then, spectral (RGB) and texture features (variance) were stacked together to generate a new image composed of three spectral bands and one texture band, with a total of four layers. This composition was then put into the U-net deep learning model classifier. For the training of this model, a total of 148 RGB orthophotos were employed, with a pixel size of 0.20 m. From these orthophotos, 867 Regions of Interest (ROIs) were processed, for both the training and testing datasets. These were randomly divided into 70% training samples and 30% for validation samples. The U-net architecture implemented here has a 5 "level" and 27 convolutional layers. Each level represents a different pixel resolution in the model, with the repeated application of two 3×3 convolutions, each followed by a Rectified Linear Unit (ReLU) and a 2×2 maximum pooling operation with a stride of 2 for downsampling. At each downsampling phase, the number of channels is doubled for the function. The methodology developed here was implemented through Python using TensorFlow Deep Learning libraries.

The methodology adopted for this research is shown in Fig. 1.

3 Results

In this study, we employed a Deep learning model with a training duration spanning 25 epochs. Through this iterative process, we achieved good outcomes: a validation loss function value of 0.60 and a training loss of 0.21. The model achieved up to 93% accuracy for binary classification in both the training and validation phases. The results indicated an accuracy of 84% in classifying asbestos-containing roofs in industrial areas, 58% in urban areas, and only 19% in agricultural regions. The reason for the lower accuracy in urban areas is attributed to the presence of ancient roofs that share a similar color profile with asbestos roofs. This similarity makes it challenging for the model to distinguish between them accurately. In the case of agricultural areas, the primary factor contributing to the low accuracy is the imbalance in the number of ground truth data samples. The dataset might have an inadequate representation of different types of roofs in agricultural regions, making it difficult for the model to generalize effectively. When a class has a significantly lower number of training samples compared to others, the model tends to perform poorly in accurately classifying that particular class. The binary classification simplifies the complexity of building coverage types within the study areas, categorizing them into only two classes. This can lead to incorrect classification of other types of coverings, resulting in a less comprehensive understanding of asbestos distribution and other relevant classes, due to the limitations of binary classification approach. In this context, we have considered a different approach: multiclass classification. For the identification and differentiation of various

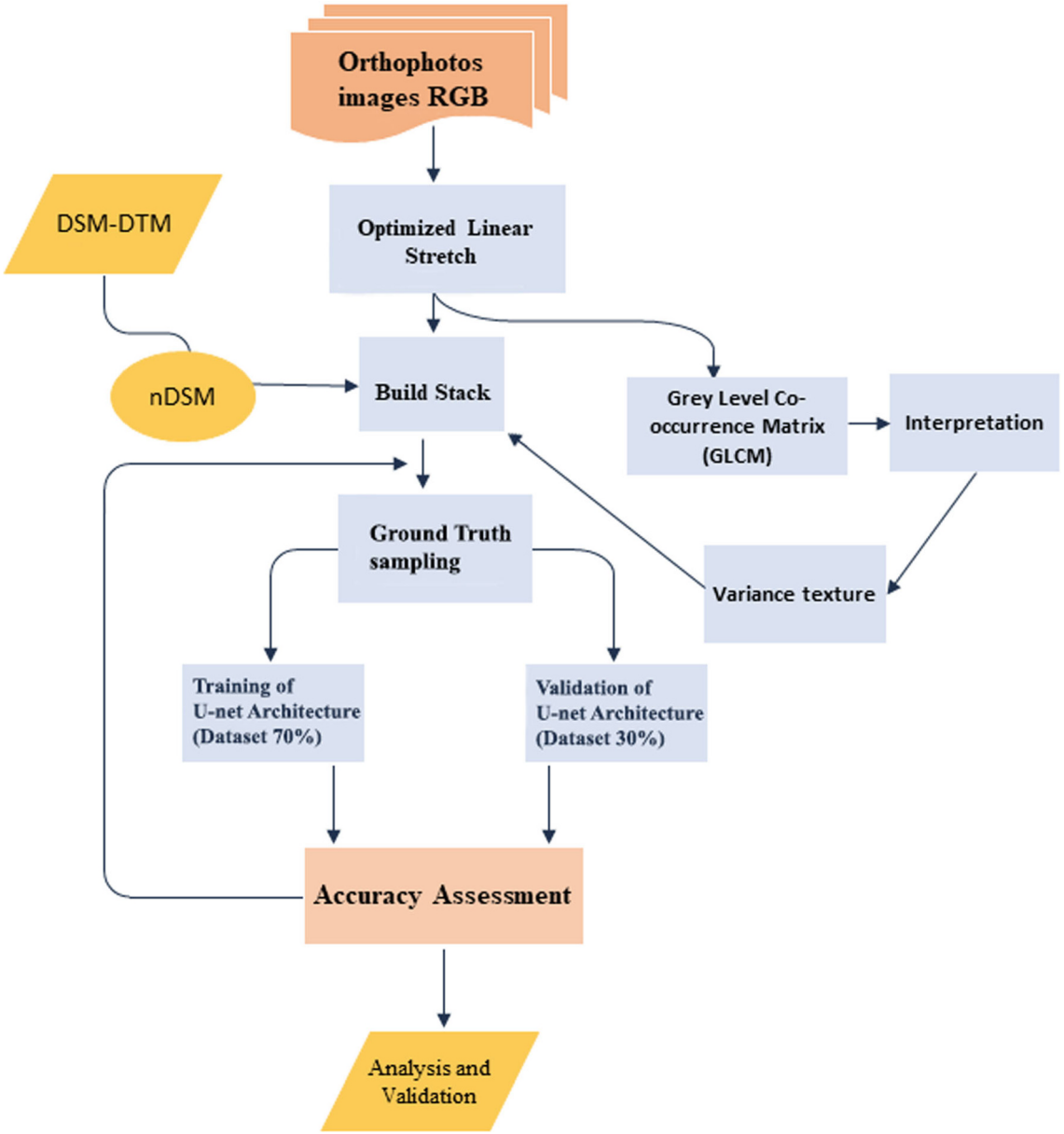


Fig. 1 Methodology followed in this study

types of coverings, including asbestos-containing coverings, non-asbestos coverings, and potentially other classes of interest, the Gray-Level Co-occurrence Matrix (GLCM) for characterizing textures are investigated. Based on the results of GLCM texture features extraction, four classes were extracted, including asbestos-cement roofs, red roofs, white roofs, and sheet metal roofs. The multiclass model achieved up to 95% accuracy and the outcomes demonstrated a good enhancement in our classification approach, yielding an overall accuracy of 68.10% and 73.61% for agricultural areas and urban areas, respectively. Furthermore, the initial overall accuracy (i.e., 86%) achieved in industrial areas was reaffirmed by our adoption of the multiclass approach.

4 Discussion

Our achieved validation loss function value of 0.60 and training loss of 0.21, after employing a Deep learning model over 25 epochs, resonate with the effectiveness demonstrated by Krówczyńska et al. (2020). Additionally, the integration of the Gray-Level Co-occurrence Matrix (GLCM) for characterizing textures akin to asbestos-containing roofs parallels the texture analysis approach highlighted by Park et al.(2020)

to enhance classification accuracy. However, the results from Gonzalez-Audicana et al. (2006) showed that the enhanced spectral data with the Haralick algorithm and the use of thermal data did not positively affect the classification accuracy. The same authors highlighted that a few very simple spectral bands indices from the RGB range were enough to achieve accuracy as high comparable to those achieved by multi- or hyper-spectral resolutions. In distinction to prior studies, to address the challenges arising from misclassification of asbestos roofing with other roofing types, we have already embraced upon a multiclass classification approach, by considering diverse classes of roofing types, including both asbestos and non-asbestos coverings.

5 Conclusions

In summary, an advanced Deep learning model persistently trained over 25 using RGB orthophotos with a spatial resolution of 0.20 m. The model achieved up to 93% accuracy for binary model and up to 95% accuracy for multiclass model. Furthermore, the model exhibited an accuracy of 86% in the case of industrial area classification. These results confirm the ability of this approach for asbestos roofing identification and mapping. However, the misclassification of asbestos roofing with other roofing types presents a challenge in our study associated with processing and obtaining a sizable labeled training dataset. Despite these constraints, these results, obtained from a limited labeled training dataset with different characteristics, remain a significant advantage within the realm of Deep learning models implementation, setting the study apart. Additionally, the methodology remains applicable for utilization by other researchers, because our objective is to identify a minimum of 2000 asbestos-cement roofing label dataset, which are crucial for constructing "ground truth" samples and forming a foundational training dataset. This pivotal stage is essential for effectively training Deep learning algorithms. Hence, with a larger dataset, we can anticipate achieving a very higher level of accuracy in this research field.

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Spatiotemporal Analysis of Landscape Fragmentation Based on the Degree of Naturalness of Land Cover

Daniel Jato-Espino, María-Ángeles Rodríguez-Sánchez, Sophie Lierow, and Marina B. Jensen

Abstract

Increasing global urbanization is leading to biodiversity loss and habitat fragmentation. To restore habitats, landscape dynamics must first be understood. In this context, this research aims to analyze the spatiotemporal dynamics of landscape fragmentation based on land cover. For this purpose, the European Space Agency (ESA) Climate Change Initiative (CCI) Land cover maps from 1992 to 2015 were reclassified into four classes according to their degree of naturalness. Geospatial tools were then applied to study the evolution of their fragmentation by analyzing several patch-level landscape metrics: area, distance, or contiguity, among others. The trends of these metrics were analyzed using the Mann–Kendall test and Sen's Slope estimator. To ascertain whether the classes defined for various years differed statistically significantly, the Kruskal–Wallis and Mann–Whitney tests were also used. The results indicate a significant increase in the number of patches for all classes, with class 1 (artificial) growing the most in terms of mean area and contiguity. Instead, the area and contiguity for the three other classes (less artificial) decreased significantly over time. This suggests a progressive fragmentation and loss of natural and semi-natural landscapes in favor of larger and connected artificial areas. The spatial trends of these results can serve to identify critical areas where measures to restore ecological connectivity should be implemented.

Keywords

Land cover · Landscape fragmentation · Naturalness · Spatial analysis · Statistical testing

1 Introduction

The percentage of people who live in cities worldwide has increased in recent years and is expected to continue to increase throughout the century. The presence of infrastructure and built-up areas that this process entails leads to biodiversity losses and habitat fragmentation (Liu et al. 2016). Habitat preservation is essential for the conservation of species (Tarabon et al. 2021), as well as for protecting the resources that humans obtain from ecosystems (Bhatta et al. 2015) and controlling the spread of infectious diseases (Wilkinson et al. 2018).

To promote the development of habitat restoration measures, the first step is to understand the dynamics associated with landscape fragmentation (Fischer & Lindenmayer 2007). Various studies have been developed in recent years that focus on the analysis of landscape changes over time (Muhammed & Elias 2021; Gbanie et al. 2018; Hermosilla-Palma et al. 2021). These studies analyze variations in a specific category of land covers, particularly forest types, using landscape metrics only in some cases.

On this basis, we have identified a research gap whereby there is a need to extend this type of analyses to a wider variety of land covers using a representative set of landscape metrics. As a result, our goal is to automate every task necessary for analyzing the spatiotemporal patterns of landscape fragmentation. We also seek to improve the reproducibility of the suggested methodology by utilizing open data. The

D. Jato-Espino (✉) · M.-Á. Rodríguez-Sánchez · S. Lierow
GREENIUS Research Group, Universidad Internacional de Valencia—VIU, Valencia, Spain
e-mail: djato@universidadviu.com

M.-Á. Rodríguez-Sánchez
Valencian Research Institute for Artificial Intelligence (VRAIN), Universitat Politècnica de València, Valencia, Spain

M. B. Jensen
Landscape Technology, Department of Geosciences and Natural Resource Management, University of Copenhagen, Frederiksberg C, Denmark

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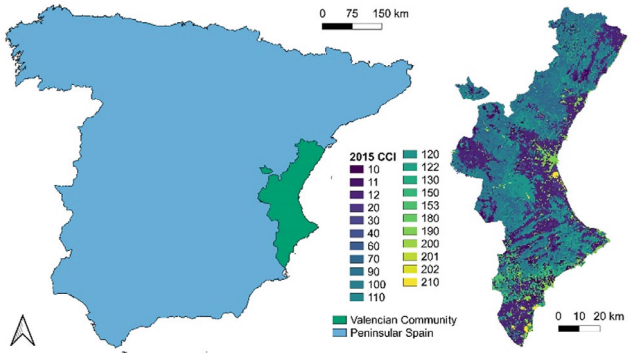


Fig. 1 Geographical setting and baseline data: location of the Valencian Community within Peninsular Spain (left) and the spatial distribution of the 2015 ESA CCI land cover map (right). The numeric codes in the legend represent the original ESA CCI codes used as the basis for the reclassification into naturalness categories

Valencian Community in eastern Spain served as a case study to test this methodology.

2 Methods

Land cover is the most crucial piece of data required to examine landscape fragmentation. The global scope and extended time span (1992–2015) of the ESA CCI maps led to their selection over other options such as the SIOSE and CLC maps. Figure 1 displays the ESA CCI land cover map for the most recent year (2015) along with a location map of the study area.

The ESA CCI land cover codes were divided into four categories based on the Land Cover Naturalness (LCN) weights (Vollmer et al. 2018): Completely artificial when LCN is below 10, Transformed system when LCN is between 30 and 50, Cultural assisted system when LCN is between 60 and 70, and Natural areas when LCN is equal to 100 (FHI 2022). The consideration of these classes aimed to gain insights into how land use/land cover impact landscape fragmentation.

The patches derived from these classes were calculated using R's landscape metrics package (Hesselbarth et al. 2023). These metrics were then analyzed using statistical tests. First, the Mann–Kendall test (Kendall 1975) was applied to determine whether there were increasing or decreasing monotonic trends in the metrics for the classes considered over the study period. Also, the nonparametric Mann–Whitney test (Mann & Whitney 1947) was used to determine whether there were differences in landscape metrics for each pair of years. The null hypotheses were that there was no trend in the time series and no difference between pairs of years in terms of central tendency, respectively. The significance level was set at 0.10 for all tests.

3 Results

The number of patches increased for all categories (Fig. 2). The Mann–Kendall test showed that this increase was statistically significant for all categories except the Cultural assisted system. The trend is particularly pronounced for the Completely artificial category.

In spite of the rise in the Completely artificial category, the main categories in terms of area were the Transformed and Cultural assisted system. The trend is toward area loss for these two categories, while it is positive for the Natural and semi-natural category, but statistically less significant (only at the 0.10 level) according to the Mann–Kendall test.

The trend in contiguity was very clear, with all categories showing statistically significant decreasing trends, except for the Completely artificial category, which was positive and also statistically significant. The general pattern suggested a reduction in interpatch spacing for all categories except the Cultural assisted system.

In the case of the Completely artificial category, the only significant differences from the Mann–Whitney test concerned the distance between patches for a few years. In the transformed system, there were fewer compact and larger patches in the early years. The trend in the Cultural assisted system over the past few years indicates that the patches are much more complicated and fragmented. The pattern in the Natural and semi-natural category with regard to area and contiguity again leads to a significant reduction in these metrics at the end of the period.

4 Discussion

The results on the number of patches in Fig. 1 suggest a general fragmentation of the landscape. However, simply observing this variable is not enough to make such a statement. According to trends in contiguity, the growing number of patches discovered for the Completely artificial category is actually caused by an increase in artificial surfaces brought on by urbanization rather than the fragmentation of already-existing patches.

The housing bubble in Spain from 1997 to 2007 may be connected to the increased area in the Completely artificial category. This could also account for the irregularities seen in the intermediate categories during this time (Fig. 1). The growth in the Natural and semi-natural category could be

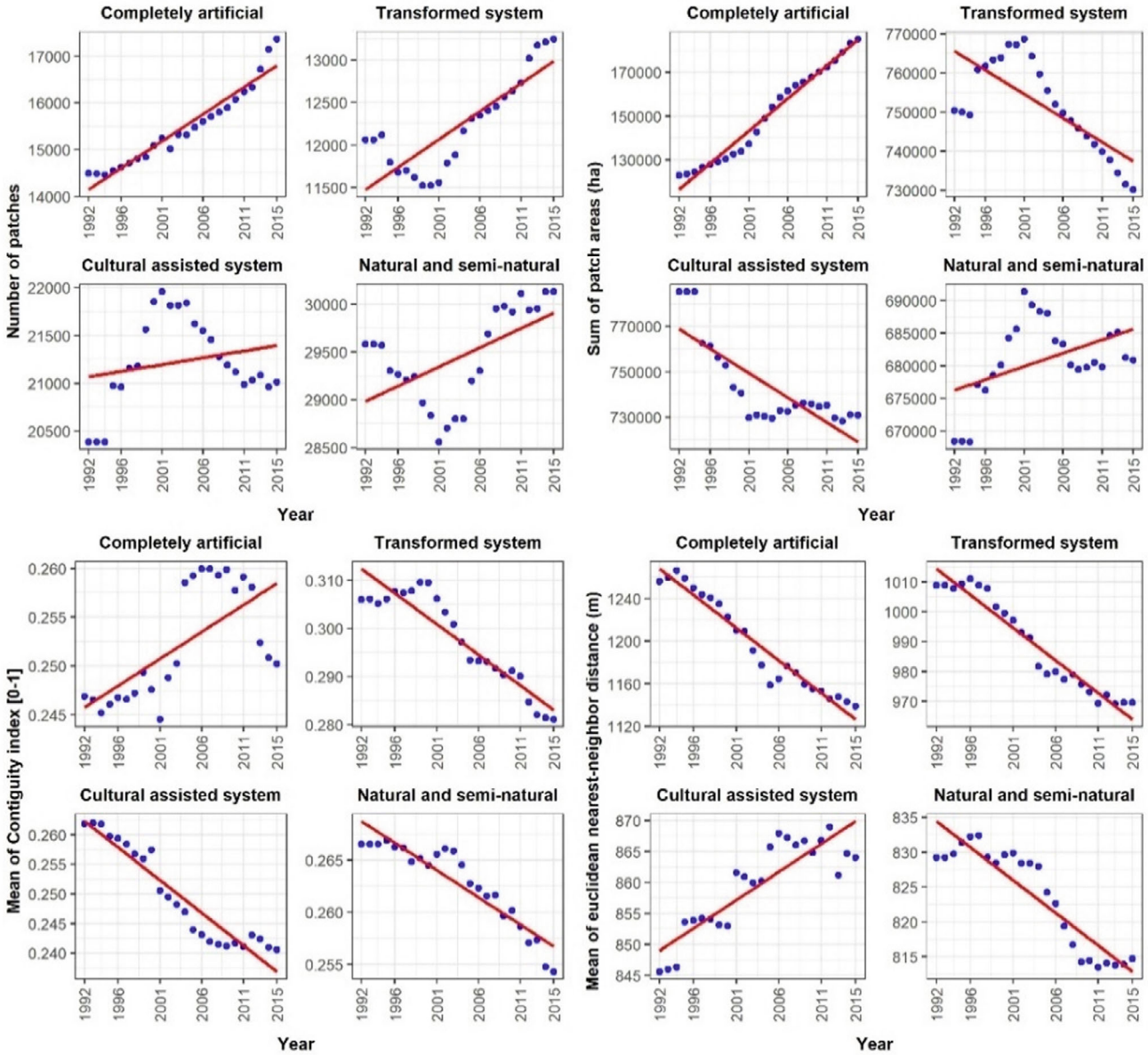


Fig. 2 Spatiotemporal trends (1992–2015) of patch-level landscape metrics categorized by land cover naturalness categories. Annual data points (blue) and trend lines (red) illustrate changes in these metrics over time

related to the major fires between 1999 and 2001 in the region, which destroyed an average of 6000 ha per year. This encouraged reforestation activities that may explain the increased area of this category in subsequent years.

The arguments presented above can also be applied to the distance between patches, the trend of which suggests a progressive increase in proximity within patches, possibly relate to urbanization and reforestation. This trend was true for all categories except the Cultural assisted system, whose reduction may be due to the increased patch area in other categories. This category needs to be protected because it contains a variety of land types with high vegetation diversity that can be utilized for ecological restoration (Yang et al. 2014).

5 Conclusions

This study proved how landscape fragmentation can be addressed using landscape metrics and land covers ranked by their degree of naturalness. The results obtained in the Valencian Community (Spain) from 1992 to 2015 revealed a statistically significant increase in the number of patches for all land cover categories: 2868 for Completely artificial, 1188 for Transformed system, 624 for Cultural assisted system, and 552 for Natural and semi-natural. This was accompanied by a remarkable increase in area (62,208 ha) and contiguity (0.034) for the most artificial class. Instead, patch conti-

guity for the less artificial classes decreased significantly over time (−0.025 for Transformed system, −0.021 for Cultural assisted system, and −0.012 for Natural and semi-natural).

In general, it can be concluded that natural and semi-natural landscapes have become increasingly fragmented in favor of larger and contiguous artificial areas. Future research should focus on the implementation of measures for ecological restoration. To this end, areas at risk could be identified through a habitat suitability index using the landscape metrics created here as inputs.

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Groundwater Potential Mapping of the Niger Delta Region, Nigeria

Ajibola Oyebamiji, Mohammad A. Hoque, and Malcolm Whitworth

Abstract

Globally, water pollution, its over-abstraction, urbanization, climate change and rising population growth rapidly result in the decline of potable groundwater supplies. Geographic information systems (GIS) is a powerful and reliable tool, valuable for managing and predicting the potential for groundwater resource. The Niger Delta, an oil-prolific region in Africa, has in recent times encountered a great demand for drinkable water supplies. This is further challenged by incessant oil spills and saltwater intrusion experienced in the region. This huge need has resulted in the indiscriminate drilling of shallow boreholes and hand dug wells. Therefore, the main objective of this study is to assess and map the groundwater potential of the Niger Delta region, Nigeria. For this purpose, eight factors influencing groundwater accumulation and storage were considered in this investigation via a Multicriteria Decision Analysis (MCDA) technique that integrated GIS towards achieving a geospatially correct delineation of sites that are favourable for groundwater accumulation. The opensource datasets utilized in this research include slope, soil, lithology, drainage density, annual rainfall, aspect, lineament density and land use land cover types, as these critically guide water infiltration into the subsurface and consequently impact groundwater storage and accumulation. These criteria were compared pairwise, then standardized and weighted, using the Analytical Hierarchical Process (AHP) and expert opinions. Finally, a spatial prediction of the groundwater potential in this region was generated using the weighted overlay analysis. This resulted in delineating three main zones from low to high across the entire region. The groundwater potential sites proposed here are significant for local residents and farmers, regional planners and local governments as they will aid efficient decisions to determine sites for installing wells and boreholes for effective water supply. In conclusion, the results obtained are critical for sustainable groundwater conservation, management and protection; and are consistent with scientific expectations of deltaic regions.

Keywords

Weighted overlay analysis · Niger Delta · GIS · Groundwater potential mapping

1 Introduction

Globally, groundwater depletion due to excessive withdrawals seems to be looming because many nations abstract water much faster than it can be replenished and recharged (Yihunie 2023). Other factors such as climate change, natural hazards, population explosion and urbanization threaten groundwater resources (Saha et al. 2022). Therefore, effectively managing and conserving groundwater resources is vital for sustaining diverse ecosystems (Kumar et al. 2022).

Recent innovations in Geographic Information Systems (GIS) and Remote Sensing (RS) tools have proven more effective in terms of labour, cost and accuracy for estimating groundwater potential (Ahmad et al. 2023; Mandal et al. 2021; Nag & Kundu 2018; Ogungbade et al. 2022; Regmi et al. 2022).

This study assesses Niger Delta's groundwater potential for sustainable drinking, domestic, agricultural and industrial activities by combining two main geospatial approaches, viz. Multicriteria Decision Analysis (MCDA) and Analytical Hierarchical Process (AHP).

A. Oyebamiji (✉) · M. A. Hoque · M. Whitworth
School of Environment, Geography and Geosciences (SEGG), University of Portsmouth, Portsmouth, UK
e-mail: ajibola.oyebamiji@port.ac.uk

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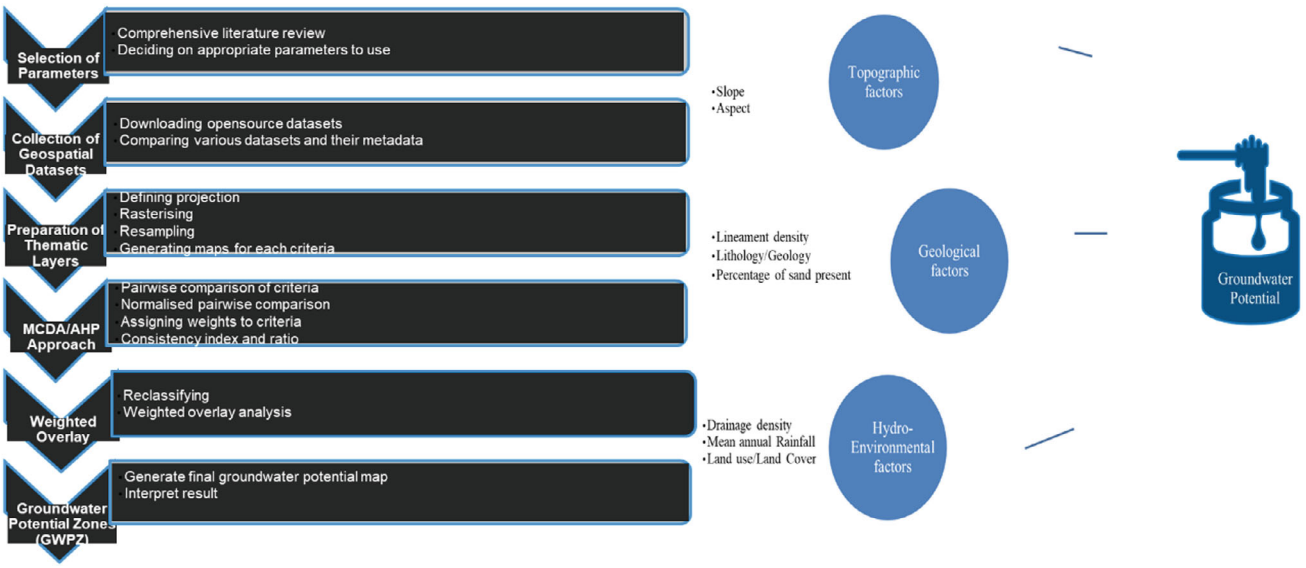


Fig. 1 Overall research methodological summary and selected criteria for evaluation

2 Methodological Summary

The Niger Delta Region (NDR) faces erosion from nature, ocean surges and urbanization, affecting river courses (NDRMP 2004). Saltwater intrusion into groundwater systems is high (Eyankware et al. 2020, 2021), with more than 40% of the population relying on it (NDRMP 2004).

This study uses eight spatial criteria (Fig. 1) in geostatistical AHP estimation following Regmi et al. (2022). The methodological summary is shown in Fig. 1.

3 Results

Various thematic layers were generated for each of the eight criteria in use, which were all rasterized and resampled to 30 × 30 m for higher resolution and data compatibility/interoperability (Fig. 2). These generally revealed that the NDR is a relatively flat terrain, with mean annual rainfall above 1800 mm, and a moderate to high drainage density. It also revealed that the area is made up of varied land use/land cover and a diverse soil type that includes clay, loam and sandy characteristics. The lineament mapping also showed a high density, especially within the central and northern parts of the NDR.

The level of impact exerted by each parameter and subcriteria are displayed in Table 1, which also gives a reflection of the final weightings assigned after normalized pairwise comparison have been carried out (where 1 indicates least impact).

After the above estimations, the final regional groundwater potential map for the Niger Delta (see Fig. 2) was delineated using the Weighted Overlay Analysis (WOA) tool in the ArcGIS software (Fig. 3).

4 Discussion

GIS-based AHP technique generates groundwater potential indices for each pixel, classifying them into low, moderate and high zones. This improves understanding of groundwater potential distribution in the Niger Delta region.

Niger Delta region has moderate groundwater potential, with 89% of its area (about 36,260 km^2) in this zone, whilst 10% (4060 km^2) have high potential, and less than 1% (278 km^2) with a low groundwater potential. This indicates the presence of great potential for nationwide water supply from the region, if adequately managed.

This novel research has the likelihood to transform groundwater studies in the Niger Delta region, offering insights on suitable well locations and borehole locations, benefiting residents and farmers. It also highlights the need for groundwater management and conservation schemes to combat environmental degradation caused by oil spill disasters.

5 Concluding Remarks

The study uses a GIS-based AHP approach to integrate eight parameters affecting groundwater storage in Nigeria's Niger Delta region. The datasets are rasterized and resampled for

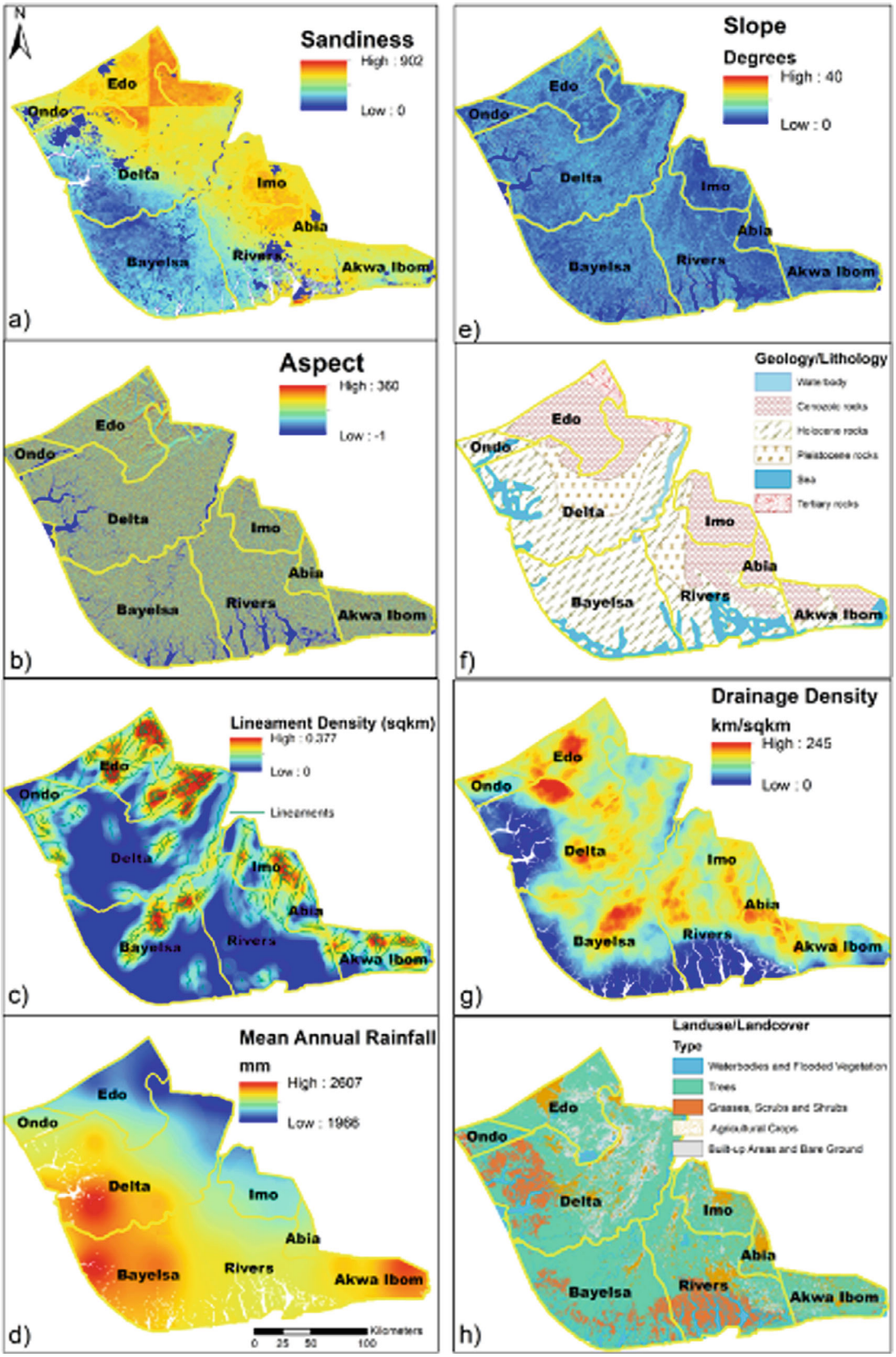


Fig. 2 The various thematic layers aggregated for the weighted overlay analysis and final groundwater potential map generated

Table 1 Factors influencing groundwater (Parameters and their sub-parameters) and their weighted scores

Parameters	Source of data	Weight	Sub-parameter	Score
Slope	Derived from DEM via United States Geological Survey (2022)	0.19	0	3
			40	1
Aspect	Derived from DEM	0.04	1–140	3
			150–290	2
			300–360	1
Geology/lithology	Persits et al. (1997)	0.04	Pleistocene rocks	3
			Holocene rocks	3
			Tertiary rocks	3
			Cenozoic rocks	3
			Waterbodies	2
Lineament density	Calculated/digitized from geologic and river shapefiles in ArcGIS	0.05	0.24–0.38	3
			0.09–0.23	2
			0–0.08	1
Amount of sands	(Poggio et al. 2022)	0.08	453–902	3
			103–453	2
			0–103	1
Drainage density	Derived from DEM	0.20	0	3
			244.99	1
Rainfall	Harris et al. (2020)	0.20	2607.47	3
			1965.79	1
Land use/land cover	Karra et al. (2021)	0.19	Trees	3
			Grasses, scrubs and shrubs	3
			Agricultural crops	3
			Waterbodies and flooded vegetation	2
			Built-up areas and bare ground	1

higher resolution and compatibility. The study developed an overall regional groundwater potential map of the Niger Delta region. The outcome of the study benefits Niger Delta residents, farmers, policymakers and environmentalists for sustainable groundwater exploitation; and could be applied to regions experiencing 104 groundwater challenges.

6 Recommendations

Future research could incorporate models like fuzzy logic, frequency ratio, certainty factors, multi-influencing factors and machine learning. In addition, this research should be incorporated with oil spill mapping which is prevalent in the NDR for improved and sustainable potable water supplies.

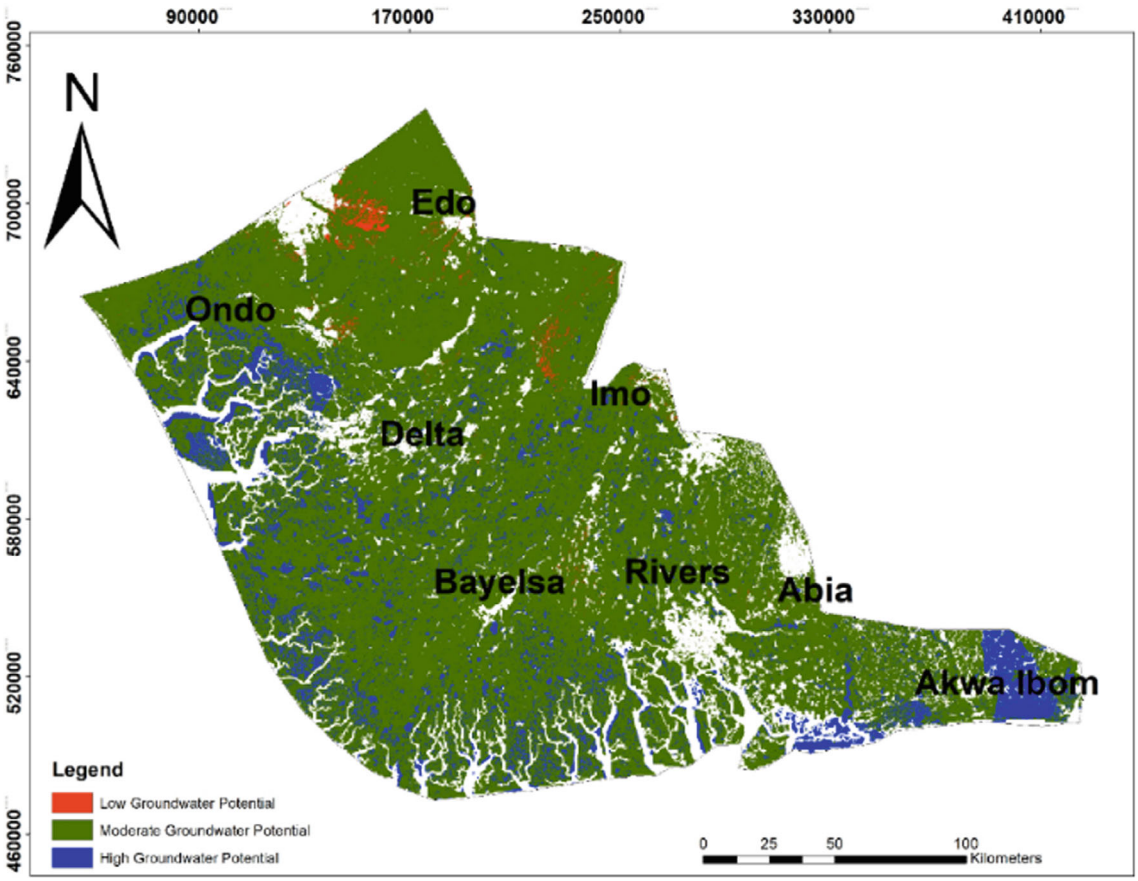


Fig. 3 Overall regional groundwater potential map of the Niger Delta region

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Cultural Heritage within National Parks: A Multitemporal Analysis of Land Use Changes of a Section of the Qhapac-Ñan in Ecuador

Estefanía C. Avilés-Sacoto, Jhonny P. Rodriguez-Ponce, Blas O. Garzón-Vera, and Luis F. Guerrero-Vásquez

Abstract

The Qhapac Ñan-Camino del Inca is a road network of 30,000 km built by the Incas through six countries: Argentina, Bolivia, Peru, Ecuador, Colombia, and Chile and declared by UNESCO as Cultural Heritage of Humanity. Ecuador has 108.87 km of this road that cross areas of environmental importance such as the Cayambe, Coca, Sangay, and Cajas National Parks. The objective of this study was to carry out a multitemporal analysis with medium-resolution satellite images to assess the state of conservation of the section of this road that crosses the Sangay National Park prior to its declaration as a UNESCO heritage site (2006), during its declaration (2014), and after its declaration (2022); and to determine if both the declaration of this road as a cultural heritage of humanity as well as the declaration of the Sangay National Park as a protected area have been efficient in curbing the anthropogenic pressure on the paramo ecosystem where this section is located and have helped its conservation. Additionally, a high-resolution satellite image was used to determine if the vegetation of the paramo is exerting pressure on the patrimonial asset. The methodology used consisted of obtaining satellite images, making radiometric, atmospheric, and geometric corrections, classifying satellite images through objective-based image analysis, calculating changes in land use, and generating cartography of land use changes. For the year 2006, the study area had a percentage of 22.97% occupied by paramo, in 2014 it dropped to 22.28%, and in 2022–22.03%, being replaced mainly by agricultural mosaics. With the high-resolution image was seen that the vegetation of the paramo is exerting pressure on the patrimonial asset and 22.92% of the road is covered by natural vegetation. There is an advance in the agricultural and urban frontier, in addition to the fact that natural processes of plants expansion are endangering the road. It is important to define and re-define strategies that allow the recovery, conservation, and maintenance of the patrimonial asset as well as measures that make its presence within a national park compatible with the pressure that its vegetation exerts on the road.

Keywords

Satellite image · Multitemporal analysis · Land use changes · Cultural heritage · National park

1 Introduction

The Qhapac Ñan, or Inca Trail, was an important network of roads that connected the territories of the Inca empire in South America, declared a UNESCO World Heritage Site in 2014 (UNESCO 2014). In Ecuador, this road extends for more than 100 km, and crosses several provinces and regions of the country; lots of its sections have been restored, but the best preserved section is the one known as "Achupallas-Ingapirca," which has an extension of 40 km and crosses through the Sangay National Park (Instituto Nacional de Patrimonio Cultural 2022).

The Sangay National Park is one of the largest and most important national parks in Ecuador, with an approximate area of 502, 105 hectares. It was declared by UNESCO as a Natural Heritage of Humanity in 1983 and houses various types of ecosystems such as tropical forests, paramos, lagoons, rivers, and volcanoes; it has 150 species of mammals, 400 species of birds, 90 species of amphibians, 26 species of reptiles, and 17 species of fish (Ministerio del Ambiente del Ecuador 2016).

E. C. Avilés-Sacoto (✉) · B. O. Garzón-Vera
Universidad Politécnica Salesiana, Cuenca, Ecuador
e-mail: eaviles@ups.edu.ec

J. P. Rodriguez-Ponce
AGP Geospatial Company, Quito, Ecuador

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Both heritages are being threatened by various factors such as the lack of awareness and appreciation, the human development activities (agricultural and livestock activities, urbanization, unsustainable tourism), as well as natural processes.

The goal of this research is to know if the declarations as National Park and Cultural Heritage of Humanity have been efficient in the preservation of the Qhapac Ñan in the section that crosses the Sangay National Park through a multitemporal analysis with satellite images evaluating the main pressure that is exerted on these, so that later measures that allow their preservation.

2 Materials and Methods

The methodology used is proposed by (Chuvieco 2010). The study area was defined using secondary information and high-resolution images to delimitate the road. A buffer area was established according to the level of intervention that can be found in the road. The total study area was of 1167.81 hectares.

The satellite images were obtained from Landsat 7 (year 2006) and Landsat 8 (2014 and 2022) sensors (Earh Explorer USGS 2022) with a resolution of 30 m.

Radiometric, atmospheric, and geometric corrections were made with the ATCOR and OrthoEngine modules, from Catalyst. The training sites were defined and a supervised classification of the land use units using a thematic legend was carried out (Catalyst 2021). The results were verified on site and using high-resolution images. The final precision of the classification was evaluated through the Kappa index, which had an average of 0.80.

Finally the visibility existing along the road was defined using a high-resolution image with a resolution of 0.5 m.

3 Results

The results for the classification process are presented in Table 1.

For the year 2006, the agricultural mosaic occupies the highest percentage of area with a total of 42.94% (501.28 hectares), while the paramo and herbaceous vegetation occupy 22.97% (268.04 hectares) of the study area.

For the year 2014, it is seen that the agricultural mosaic unit maintains the highest percentage of occupation with a total of 44.93% (524.41 hectares). The paramo and herbaceous vegetation units occupy 22.28% (261.19 hectares) of the study area. They have decreased.

Table 1 Land use and coverage for the years 2006, 2014, and 2022

Land use coverage	Area in Ha and Area % per study year		
	2006 (%)	2014 (%)	2022 (%)
Agricultural mosaic	501.28/42.94	524.41/ 44.93	542.71/46.49
Grass	298.66/25.59	299.79/25.68	288.63/24.73
Paramo	178.42/15.29	164.55/14.10	150.30/12.88
Herbaceous vegetation	89.62/7.68	96.64/8.28	106.80/9.15
Shrubby vegetation	58.05/4.97	41.91/3.59	38.86/3.33
Infrastructure	27.24/2.33	27.24/2.33	27.24/2.33
Bare ground	10.60/0.91	9.32/0.8	9.32/0.8
Wetland	3.41/0.29	3.41/0.29	3.41/0.29
Total	1167.27/100	1167.27/100	1167.27/100

Table 2 Land use and coverage changes for the period 2006–2014 and 2014–2022

Land use coverage	Area changes (Ha) per period of years	
	2006–2014	2014–2022
Agricultural mosaic	+23.13	+18.3
Grass	+1.13	−11.16
Paramo	−13.87	−14.25
Herbaceous vegetation	+7.02	+10.16
Shrubby vegetation	−16.14	−3.05
Infrastructure	0	0
Bare ground	−1.28	0
Wetland	0	0

For the year 2022, the agricultural mosaic unit maintains the highest percentage of occupation, with 46.49% of the study area (542.71 hectares). The paramo and herbaceous vegetation units occupy 22.03% (257.10 hectares) of the study area, they have decreased.

The variation in land use coverage for the period of years 2006–2014 and 2014-2022 is presented in Table 2.

In the period 2006–2014, it is shown that within the study area, the agricultural mosaic, the grass, and the herbaceous vegetation units are exerting pressure on the paramos and on the shrubby vegetation. A total of 13.87 hectares of paramo and 16.14 hectares of shrubby vegetation have been lost due to their advance.

For the years 2014–2022, the agricultural mosaic and the herbaceous vegetation units continue to exert pressure on the paramo and the shrubby vegetation units; 14.25 hectares of paramo and 3.05 hectares of shrubby vegetation have been lost.

No changes in the infrastructure are shown, but using the high-resolution image, it is seen that parts of the road are

being covered with natural vegetation and correspond to a total length of 11.67 km (22.92%) located in various segments along the road and are areas with the presence of natural vegetation.

4 Discussion

The importance of the conservation of the Qhapac-Ñan as well as the Sangay National Park is considered of the utmost importance, as is also promulgated by the Constitution of the Republic of Ecuador, article 3, numeral 7 (Constitución de la República del Ecuador 2008).

Declarations such as heritage assets and national parks are efficient for the conservation of spaces as mentioned (UNESCO 1972) and (UNESCO 1998); however, it is observed that additional policies are required since human development processes invade these spaces and generate their loss (Sahagún y Reyes 2018).

Satellite images are a very useful tool for this type of study because they allow access to information without the need to be in direct contact with the object of study, thus avoiding its disturbance or damage as specified by (Flórez- Yepes et al. 2017) and (Silva y Rubio 2013).

5 Conclusions

The declaration of the Qhapac-Ñan as a cultural heritage of humanity has been efficient for its conservation.

Its main threat within the Sangay National Park, which is anthropic pressure with the advance of the agricultural and livestock frontier, has not had an impact on it, but it has had an impact on the paramo and the natural vegetation of the Sangay National Park, with losses of approximately 12.24 hectares in the total study years.

Its main loss is due to the natural vegetation that has made that 11.67 km of its defined route have a poorly visibility.

Protection policies and new development models must be incorporated into their management considering the importance of the cultural asset and the fragility of the natural asset.

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Coastal Vulnerability Analysis in Torrevieja (Alicante, Spain)

José Ignacio Pagán, Pablo Ortiz, Luis Bañón, and Isabel López

Abstract

Throughout the world, both rocky and sandy coastlines are affected by the issue of coastal erosion. Determining appropriate coastal management strategies requires assessing how vulnerable beaches and cliffs are to erosion. The aim of this work is to obtain the coastal vulnerability in the municipality of Torrevieja (Alicante, Spain) through the calculation of a Coastal Vulnerability Index (CVI). The 7 km of coastline in the study area features a variety of typologies, including low cliffs (2, 5–3, 0 m), high cliffs (>8 m), and two sandy beaches. The methodology followed consists of obtaining the CVI from representative transverse profiles in sections spaced 100 m apart. For each section, the following variables are evaluated: geomorphology (geology, coastal slope, erosion rate, beach width, and dune width), hydrodynamics (significant wave height, mean tide range, and flood level indicator), and vegetation variables (presence of seagrass meadows, depth and width of these meadows, and backshore surface covered by vegetation). In cliff areas, instead of erosion rate, beach width, and dune width, wave energy will be used. QGIS, an open-source geographic information software, has been used to manage the variables derived from cartographic information compiled from multiple sources. Finally, an evaluation of vulnerability was obtained for each section in a 5-range classification, from Very Low to Very High. The results show a very low vulnerability of the low and high cliff areas, whereas, on the beach areas, one has a very high vulnerability and the other moderate. This is mainly due to the low coastal slope, the high erosion rate, and the limited beach width. By identifying the most vulnerable areas, the coastal manager can more effectively allocate resources and prioritize actions to increase the resilience of the coast to climate change risks.

Keywords

Coastal vulnerability · Shoreline evolution · GIS · Cliff · Beaches

1 Introduction

Coastal erosion is a problem that affects sandy and rocky shores all over the world. Furthermore, the potentially massive impact of climate change on coastal zones, which is globally recognized, should be contemplated. The Mediterranean Sea region is considered one of the main hotspots, due to the concentration of population, biological diversity, and economic activities in coastal areas (Vousdoukas et al. 2018). The municipality of Torrevieja (Alicante, Spain) is a highly urbanized and very well-known internationally tourist area, with 7 km of coastline of different typologies, from 8 m high cliffs, low cliffs (2.5–3.0 m), and two sandy beaches. Storms cause damage to some coastal stretches, so it is crucial to measure their vulnerability to define proper coastal management strategies.

The Coastal Vulnerability Index (CVI) is a synthetic index to assess coastal vulnerability (Gornitz 1990). A series of variables are calculated to evaluate the relative vulnerability of different stretches of a coastal area. Regarding the application of the CVI in the Mediterranean area, a study was conducted to map the relative vulnerability of the western Peloponnese in Greece for a coastline length of about 50 km (Doukakis 2005), while the Egyptian Mediterranean coast was also examined (Hereher 2015). In Italy, it was applied on the Apulian coast (Pantusa et al. 2018) and in Spain across the 160 km coastline of the province of Barcelona (Koroglu et al. 2019).

J. I. Pagán (✉) · P. Ortiz · L. Bañón · I. López
University of Alicante, San Vicente del Raspeig, Spain
e-mail: jipagan@ua.es

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However, the majority of these studies are focused on variables for sandy beaches, excluding cliff areas. Moreover, the presence or absence of marine phanerogams such as *Posidonia oceanica* (L.) Delile can be relevant. Several studies have demonstrated their influence on the nature and dynamics of coastal sediments (Holmer et al. 2009), playing a crucial role in the physical equilibrium of a large part of the Mediterranean coasts, both by reducing the energy of incident waves and by protecting against coastal erosion (Koch et al. 2006).

This work aims to obtain the coastal vulnerability of the studied area, enabling the identification of vulnerable coastal stretches using the available data which is critical to defining proper coastal management strategies.

2 Materials and Methods

The data used in this study to assess coastal vulnerability were grouped into three main indicators: geomorphology (coastal slope, erosion rate, beach width, and dune width), hydrodynamics (significant wave height, mean tide range, and flood level indicator), and vegetation variables (presence of seagrass meadows, depth and width of these meadows, and backshore area covered by vegetation). A total of 10 variables were considered. All the required data have been downloaded from open and official sources and stored within a geographic information system. For this study, QGIS 3.32 Lima was used. Therefore, a geodatabase in GeoPackage format was created containing all the geospatial information collected (cartography, bathymetry, DTMs, orthoimages, etc.), and that generated during the research (analysis of coastal erosion, calculations of the different variables of the CVI), as well as the results and their associated cartographic maps.

The methodology followed consists of dividing the coastal area into sections spaced 100 m apart, obtaining the CVI from representative transverse profiles on each one. For beach areas, the overall CVI is described as the square root of the product of the variables (Table 1) divided by the number of variables.

$$\mathrm{CVI} = \sqrt{\frac{a \cdot b \cdot c \cdot d \cdot e \cdot f \cdot g \cdot h \cdot i \cdot j}{10}} \tag{1}$$

In cliff areas, instead of erosion rate, beach width, and dune width variables, wave energy were used. The wave energy at the foot of the cliff can be calculated according to the following approximate model (Besio et al. 2016).

$$P = \frac{1}{16} \cdot \rho \cdot g \cdot {H_{m0}}^2 \cdot C_g \tag{2}$$

where

ρ is sea water density
g is the acceleration of gravity,
H_{m0} is the spectral wave height at 5 m depth
C_g is the group velocity at the determined depth

The levels of wave exposure are mainly influenced by the orientation and geometry of the cliff, as well as the morphology of the bathymetry, according to the following classification (Table 2).

Table 1 Ranges of vulnerability for the considered variables

Variable (Vulnerability)	Very low (1)	Low (2)	Moderate (3)	High (4)	Very high (5)
a. Coastal slope (%)	> 12	12–8	8–4	4–2	< 2
b. Erosion rate (m/yr)	> +1.5	+1.5 to +0.5	+0.5 to −0.5	-0.5—1.5	< −1.5
c. Beach width (m)	> 100	100–60	60–30	30–15	< 15
d. Dune width (m)	> 100	100–75	75–50	50–25	< 25
e. Significant wave height (m)	< 1.0	1.0–2.0	2.0–3.5	3.5–5	> 5
f. Mean tide range (m)	< 0.2	0.2–0.4	0.4–0.6	0.6–0.8	> 0.8
g. Relative flood level (m)	< −1.5	−1.5 to −0.5	−0.5 to +0.5	+0.5 to +1.5	> +1.5
h. presence of seagrass meadows	*P. Oceanica* meadow	*P. Oceanica* with other species	*P. Oceanica* in regression	*P. Oceanica* degraded	Absence of *P. Oceanica*
i. Depth and width of these meadows (m)	< 4.0	4.0–6.0	6.0–9.0	9.0–12	> 12
j. Backshore area covered by vegetation (%)	> 80	80–60	60–40	40–20	< 20

Table 2 Vulnerability for cliff areas for wave energy variable, adapted from Besio et al. (2016)

Variable	Very low (1)	Low (2)	Moderate (3)	High (4)	Very high (5)
k. Wave energy (kW/m)	< 10	10–20	20–30	30–40	> 40

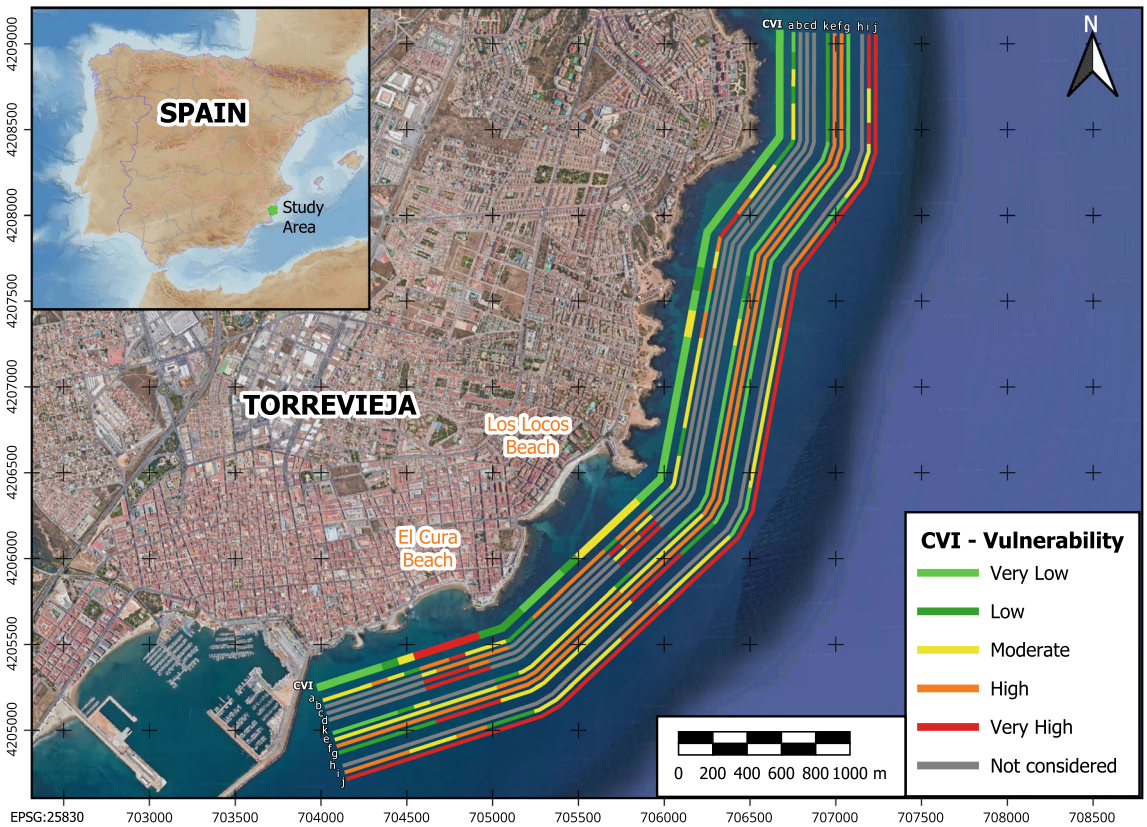


Fig. 1 Overall CVI distribution and for each variable considered

3 Results

A total of 44 transects were obtained, of which 16% were sandy beaches, 52% were high cliffs (3–8 m), and 32% low cliffs (2.5–3.0 m). For each variable, its vulnerability and the overall CVI have been calculated (see Fig. 1).

The results show a very low vulnerability of the low and high cliff areas, whereas on the beaches, one has a very high vulnerability (el Cura Beach) and the other moderate. This is mainly due to the low coastal slope (1.8%), the high erosion rate (−1.62 m/yr), and the limited beach width (an average value of 12 m), as well as the lack of dunes in both beaches, which causes that during the S and SW storms the waves hit the promenade with a relative flood level reaching more than 1.5 m. Although exists *P. oceanica* seagrass meadows close to the shoreline, vulnerability increases due to the absence of backshore vegetation. Energy reaching cliff areas are lower than 20 kW/m.

4 Discussion

Coastal Vulnerability Indexes have been widely used in multiple coastal areas as strong management tools to highlight potential coastal hotspots to a given set of climatic hazards (Doukakis 2005). However, when the coastal area is complex, with a mix of cliffs and low areas such as beaches, current CVI methods need to be adapted (Pantusa et al. 2018).

Robust evaluation approaches such as CVI facilitate decision-making processes of coastal management strategies, like beach nourishment or coastal defense works, especially in view of adaptation to the increasing threats posed by climate change (Koroglu et al. 2019). This research provides

a CVI customized for the complex coastal area of Torrevieja, providing a methodology that considers 10 variables applicable from rocky cliffs to sandy beaches, including vegetation variables as an evaluation of the ability to dissipate the wave energy.

5 Conclusions

This study identifies the most problematic areas of the municipality of Torrevieja, enabling the coastal manager to prioritize the investments and actions to be carried out to reduce vulnerability and increment the coastal resilience against the risks of climate change. The results show a very low vulnerability of the low and high cliff areas, whereas on the beach areas, one has a very high vulnerability and the other moderate. Thus, the priority for coastal managers should be to carry out a nourishment action on the most vulnerable beach to increment its width and slope.

This research has been funded by the Generalitat Valenciana through the project CIGE/2021/046 (Influencia del desgaste del sedimento de las playas en la vulnerabilidad costera de la Comunidad Valenciana).

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Assessing Site Suitability for Aquifer Storage and Recovery ASR in Qatar Using a GIS-Based Multi-criteria Decision-Making Technique

Hazrat Bilal, Rajesh Govindan, Slim Zekri, Ali Al-Maktoum, Mohammad Mahdi Rajabi, and Chefi Triki

Abstract

Utilizing aquifers as underground water storage reservoirs can effectively meet water management goals. Aquifer Storage and Recovery (ASR) technology involves injecting water into aquifers through specialized wells and withdrawing it when needed. The success of ASR depends on evaluating and modeling the specific hydrogeological characteristics of a site, such as groundwater salinity, transmissivity, storativity, slope, soil properties, proximity to recharge water networks, and road accessibility. This study introduces an ASR site-scoring system to identify the most suitable locations across Qatar based on these criteria. The results provide valuable insights into the feasibility of using ASR technology for water management in Qatar. The study reveals that approximately 7414.11 km^2, or 64%, of Qatar's land is suitable for ASR, while the remaining 36% is unsuitable due to constraints such as built-up areas, roads, farms, and protected areas. Notably, significant suitable land is available in the middle northern regions, which could be used for ASR technology, utilizing treated wastewater and surplus seasonal desalinated water. These findings indicate that ASR technology has strong potential to enhance artificial water storage and recovery in Qatar, contributing to overall water resource management.

Keywords

ASR · TSE · MCDM · GIS · Desalination · AHP

1 Introduction

Water security is a critical issue in Qatar due to challenging environmental conditions like erratic rainfall, lack of surface freshwater resources, and high temperatures (Al Malki 2009). Additionally, the expanding population and changing socioeconomic conditions place further pressure on the water sector's demand and supply. According to the Planning and Statistical Authority, Qatar's population has surged from 373,395 in 1986 to 2,748,162 in 2021 (Bunsen and Rathod 2016). This dynamic population includes many expatriates from Asia, Africa, and Europe working in Qatar. The national population is expected to grow as more workforce is needed to achieve developmental goals under Vision 2030 and the expansion of oil and gas industries. This population increase will, in turn, raise the demand for natural resources, especially food and water. Despite importing about 90% of its food (Bunsen and Rathod 2016), local food production has significantly increased since the Gulf rift in 2017 (Kahramaa 2016). The area under fodder crops, vegetables, and cereals grew by 46%, 39%, and 26% respectively between 2016 and 2021 (Gibson et al. 2018). As a result of population growth and socioeconomic development, per capita water consumption increased from 216 cubic meters per year in 2016 to 246 cubic meters per year in 2021 (Gibson et al. 2018). Additionally, groundwater resources have been heavily exploited, primarily for agriculture, resulting in an annual water deficit of 11 million cubic meters and negatively impacting ground-

H. Bilal (✉) · R. Govindan
Division of Sustainable Development, College of Science and Engineering, Hamad Bin Khalifa University, Qatar Foundation, Doha, Qatar

S. Zekri
Department of Soils, Water and Agricultural Engineering, Water Resources Management—Arid zone hydrology, Water Research Center, Sultan Qaboos University, Muscat, Oman

A. Al-Maktoum
Department of Natural Resource Economics, College of Agricultural and Marine Sciences, Sultan Qaboos University, Muscat, Oman

M. M. Rajabi
Faculty of Civil and Environmental Engineering, Tarbiat Modares University, Tehran, Iran

C. Triki
Kent Business School, University of Kent, Canterbury, UK

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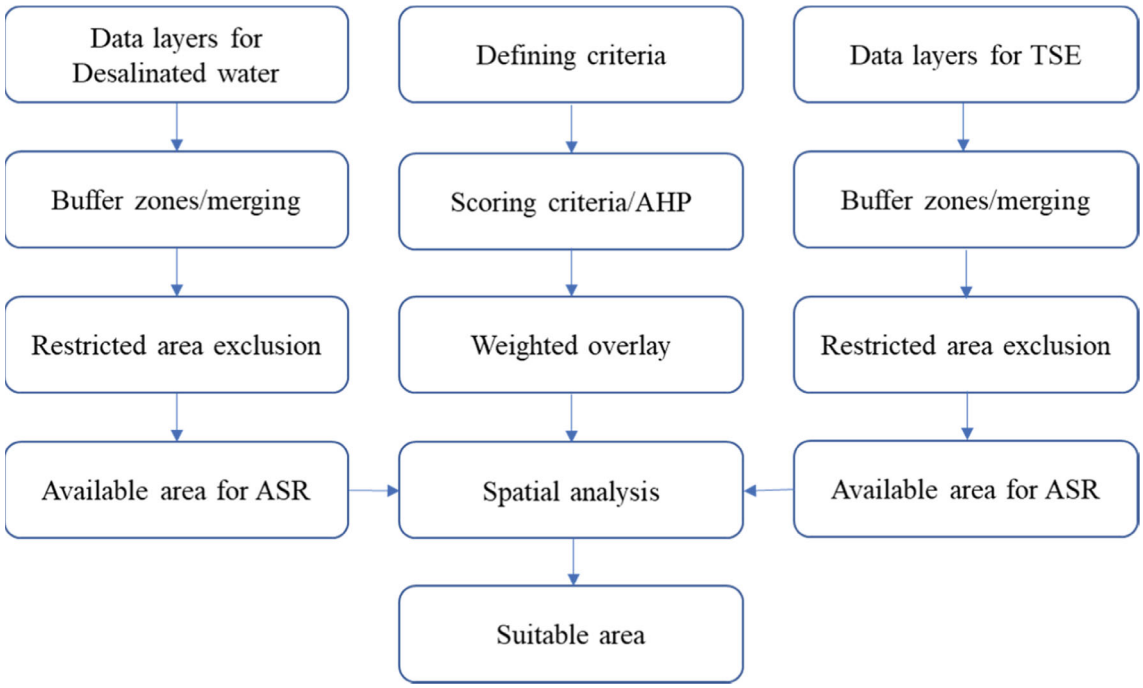


Fig. 1 Flow chart of the proposed GIS-based multi-criteria decision-making process

water quantity and quality due to seawater intrusion (Khan et al. 2008).

ASR technique shows great potential, but it requires specific conditions for success, including suitable surface and subsurface characteristics. This study assesses the suitability of ASR techniques in Qatar using a GIS mapping approach and a multi-criteria weighting technique. The primary goal is to identify suitable sites for artificial storage and recovery based on various criteria and constraints that could impact the future implementation of ASR projects. Additionally, the hydrogeological properties of the aquifer, which affect its intake ability and the capacity of the installed pumps, are crucial constraints that control the volume of water that can be injected into the aquifer.

2 Methodology

The success of ASR technology depends on several factors, categorized into three main groups: (1) surface conditions related to topography and land use, (2) subsurface conditions focusing on storage capabilities, and (3) socioeconomic conditions. Each factor was reclassified into appropriate classes in a GIS environment, mostly using Jenks Natural Breaks or natural groupings inherent in the data (Khan et al. 2008). These classes were standardized on a common scale of 2–8 (with 8 representing very low suitability and 2 representing very high suitability). Standardization converts each criteria map to a uniform measurement scale, facilitating easy comparison (Missimer et al. 2015).

The weights computed using the AHP approach are comparative weights of individual criteria, based on their determined ranks. Calculating the Consistency Ratio (CR) helps to identify and correct logical inconsistencies in the pairwise comparison matrix developed from experience or expert judgment. If the CR value exceeds 0.1, the judgment may be deemed unreliable, indicating the need for modification as it could be too close to randomness (Murray 2008) (Fig. 1).

3 Results

Restricted areas where construction or drilling is prohibited due to physical constraints and legal regulations are excluded from the ASR suitability estimation. Figure 2 highlights the areas excluded based on the factors that have the strongest impact on land exclusion. After excluding these restricted areas, approximately 36% of the total land area remains available for ASR projects, corresponding to 4196.80 km^2 out of a total land area of 11610.92 km^2.

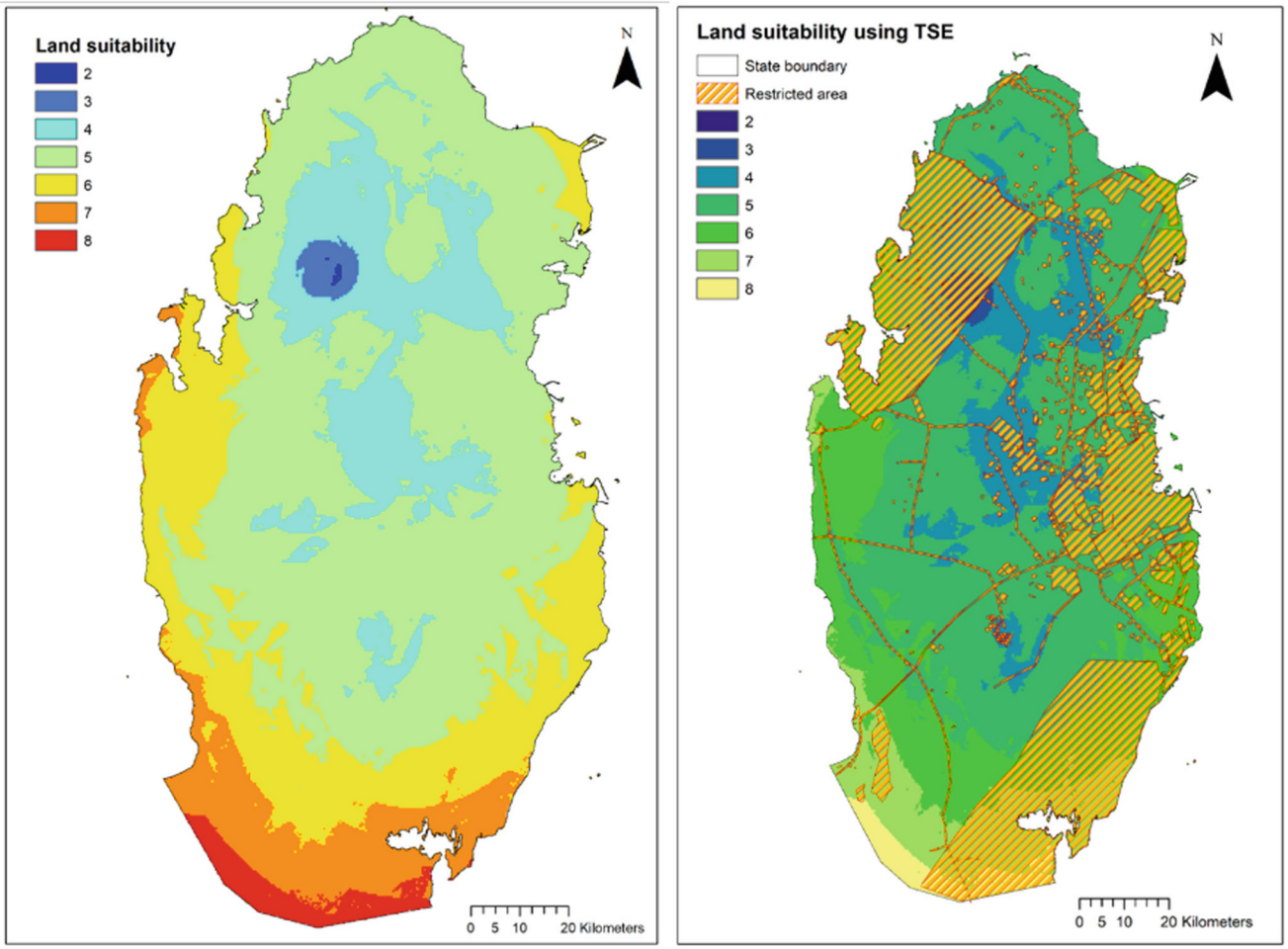


Fig. 2 ASR suitable sites using TSE, left without restrictions and right with constraints

3.1 ASR Land Suitability Using TSE

Based on the modeling, a land suitability map was generated for potential ASR sites. Key criteria for land suitability assessment include groundwater salinity, transmissivity, and storativity. Groundwater salinity decreases inward as elevation increases. One of the most suitable sites was identified in the northwest, covering 4 km^2; however, this area falls within a natural reserve and is therefore excluded from consideration. The second most suitable area spans 22.39 km^2, accounting for about 0.3% of the total suitable land. A larger suitable area of approximately 1058.26 km^2 is identified in the north and central regions, representing around 14% of the total suitable area. This region is optimal in terms of groundwater quality, transmissivity, and storativity, with most existing ASR sites located within this suitable area. A moderately suitable area, the largest in terms of coverage, corresponds to 59% of the total land and is mainly concentrated in the northern part, including the coastal areas of the far north. The remaining two identified land areas, covering 412.08 km^2 and 125.23 km^2, are considered the least suitable.

3.2 ASR Land Suitability Using Seasonal Surplus Desalinated Water

Based on seasonal surplus desalinated water, a land suitability map has been generated for potential ASR sites. Only 64% of the land is available for ASR technology, with the remaining areas restricted due to physical and policy regulations. One of the most suitable sites is identified in the northwest, covering 5.16 km^2, which corresponds to only 0.1% of the total identified suitable land. The second most suitable area spans 34.67 km^2, accounting for about 0.5% of the total suitable land. A larger suitable area of approximately 1645.88 km^2 is identified in the north and central regions, representing around 22.20% of the total suitable area (Fig. 3).

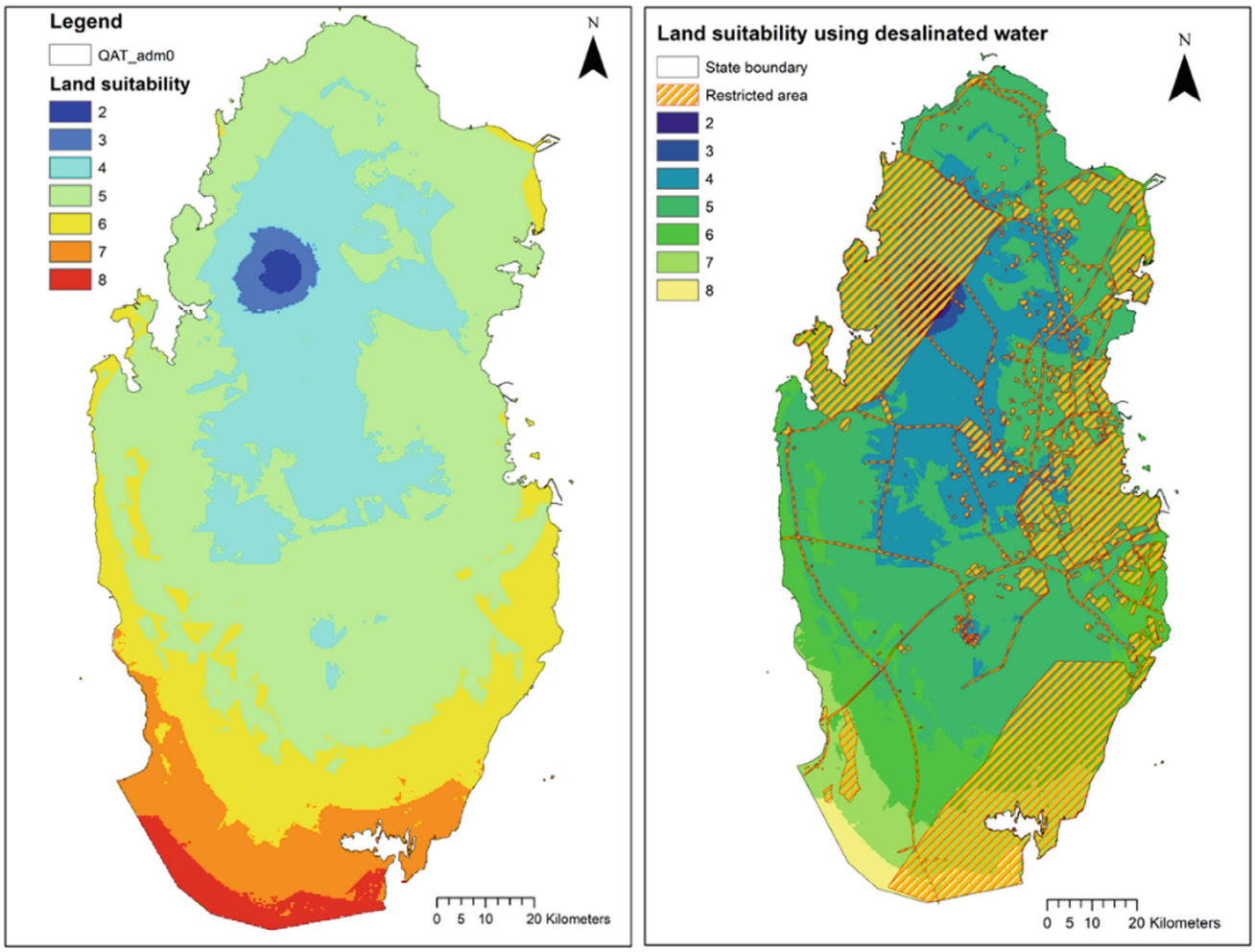


Fig. 3 ASR suitable sites using desalinated water, left without restrictions and right with constraints

4 Conclusions

This study provides a comprehensive assessment of the feasibility of ASR technology in Qatar, considering various surface, subsurface, and socioeconomic factors. The findings have identified extensive areas suitable for ASR implementation. The analysis indicates that about 64% of the study area is potentially suitable for ASR technology, ranging from moderate to very high suitability. However, it is essential to conduct detailed site-specific field investigations to accurately determine the suitability in these areas. Despite this need for further investigation, the study's results suggest that ASR is a viable option for statewide expansion, which could enhance existing water storage and guide future research efforts.

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Evaluating Solar Energy Potential through Geographic Information System and Remote Sensing: A Systematic Review

Muhammad Ehtsham, Marianna Rotilio, and Muhammad Irfan

Abstract

To optimize the potential of solar energy, it is essential to analyze the amount of solar energy that can be harnessed. In this article, we provide a comprehensive review of the literature on the use of remote sensing (RS) and Geographic Information System (GIS) for assessment and maintenance of solar energy systems. The study reveals that researchers have employed LiDAR and unmanned aerial systems (UAS) to identify and monitor photovoltaic installations. ArcGIS solar and Quantum GIS (QGIS) packages are utilized and found suitable to optimize PV plant operation and identify suitable locations for photovoltaic power plants in case studies. Moreover, in some recent articles, machine learning and deep learning algorithms have been exploited for optimizing the performance and installation of solar energy systems. It can be concluded that RS, particularly through satellite imagery, enables the analysis of long-term trends in solar energy availability and aids in identifying optimal locations for solar installations. RS proves valuable in assessing the productivity and efficiency of solar energy systems, considering factors like temperature, wind speed, and humidity, allowing for system performance optimization. The incorporation of a combination of satellite and UAV data into machine learning algorithms can play a vital role in acquiring accurate data.

Keywords

Solar energy · GIS · Remote sensing · Data acquisition · Data monitoring

M. Ehtsham (✉) · M. Rotilio
Department of Civil, Construction-Architectural and Environmental Engineering, University of L'Aquila, L'Aquila, Italy
e-mail: muhammad.ehtsham@graduate.univaq.it

M. Irfan
Department of Civil Engineering, HITEC University, Taxila, Pakistan

1 Introduction

Remote sensing has proven its importance over the last three decades and has emerged as a modern source of data acquisition in various scientific fields (Angelopoulou 2019; Hussain 2023; Lapointe 2019; West 2019; Babaeian 2019). Similar to all other fields, remote sensing serves as an important tool for investigating the solar energy resource, especially for monitoring, forecasting, and evaluating solar energy systems (Angelopoulou 2019). Remote sensing enables effective investigation of the solar energy resource at various scales, which is a crucial aspect for resource assessment (Stengel 2020).

Researchers have exploited the potential of GIS and RS for PV resources, and a thorough analysis of the methods used to weigh their benefits and drawbacks is essential. This research article aims to provide a comprehensive review of the potential applications of RS and GIS techniques in assessing, evaluating, and maintaining solar energy systems. This research article includes a bibliometric analysis of the selected articles using VOSviewer software. Additionally, in accordance with the PRISMA statement methodology, several case studies investigating solar energy resources using remote sensing and GIS are reviewed.

2 Research Methodology

A systematic review can be briefly described as a systematic method of compiling and summarizing prior research (Tranfield 2003). This study follows a mixed review methodology, combining bibliometric analysis and systematic review.

The SCOPUS database was used to acquire the records; it covers a wide range of interdisciplinary study topics in peer-reviewed journals (Martinez 2019). The database search was conducted on May 4, 2023, using the keywords "Solar Energy", "GIS", "Remote Sensing", "Data Acquisition", and

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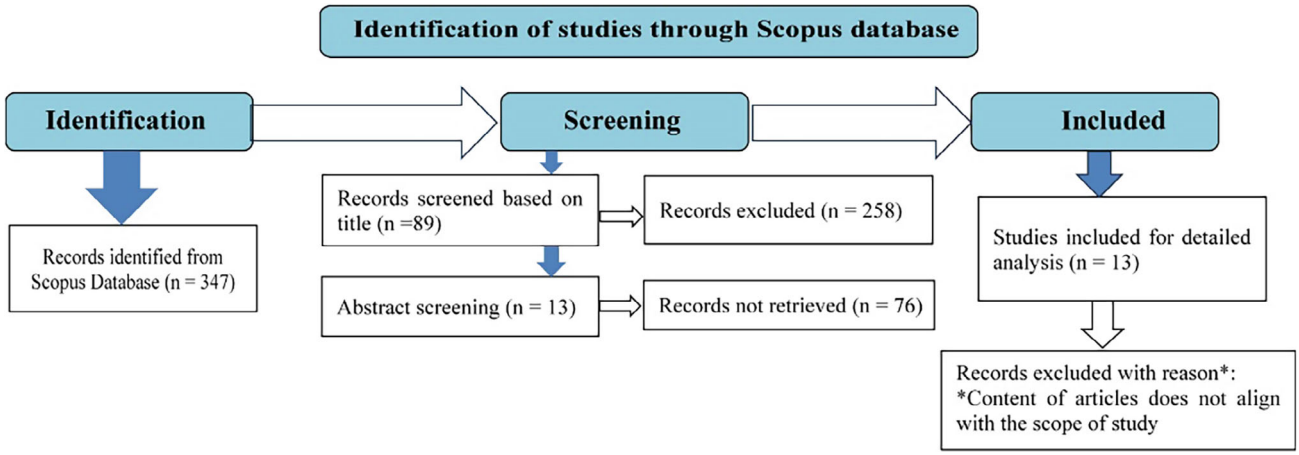


Fig. 1 Flowchart of research methodology

"Data Monitoring", and the time filter was applied for 2011 to 2023, time span chosen guarantees that the review focuses on current and relevant research. In the final search string, the keywords were combined. This search yielded 347 research items.

Bibliometric analysis refers to a variety of mathematical and statistical methods for evaluating bibliometric data (Donthu 2021). VOS is a data visualization tool used for exploring and analyzing complex networks and hierarchies (Van Eck 2010); the same was used for our analysis.

The methodological process of systematic review is divided into different stages. In the preliminary stage, a research strategy and primary keywords were developed. The criteria for finalizing the papers were defined at the succeeding stage in light of the PRISMA statement (Liberati 2009; Galvão 2022; Sarkis-Onofre 2021). Data extraction was done to do more analysis. This study's research flowchart is depicted in Fig. 1.

3 Results

VOSviewer software was used for bibliographical analysis. Figure 2 depicts a graphical representation of research collaboration among different countries. It is clear from the figure that the United States has the major output regarding the research topic in question, with China in second and the United Kingdom and Australia in third position.

Co-citation analysis used "cited sources" as the unit with a 20-citation minimum. "Agricultural and Forest Meteorology" had the highest link strength, while "Remote Sensing" and "Remote Sensing of Environment" had 267 and 250 citations. VOSviewer generated the map showing four clusters, some without direct links. "Sensors" and "Remote Sensing of Environment" had notably high link strength. The co-occurrence of keywords demonstrates how closely related they are to one another (Xia 2020). A network analysis of 19 selected author keywords, revealing the connections between them, was generated in VOSviewer. Co-occurrence network of indexed keywords was also created, considering a minimum occurrence threshold of 10 out of a total of 2696 keywords. Among them, "Remote Sensing" exhibits the highest link strength, as in the case of author keywords. "Solar Energy" is strongly linked to "Unmanned Aerial Vehicles". Additionally, "GIS" is prominently positioned in the top-left of the network and shows significant link strength with "Remote Sensing", "Land Use", and "Decision Support Systems". (Co-citation analysis map, co-occurrence network of author keywords, and co-occurrence network of indexed keywords are provided in the full-length paper).

4 Discussion

This research work was designed to assess the advancements in the field of solar energy, specifically utilizing the modern technologies of remote sensing and geographical information systems. A systematic review in parallel with bibliographic analysis was done. Bibliographic analysis showed that America has the highest research output in the research topic in question. Iran and India have produced a significant number of publications during the selected span of review. Co-citation analysis was also performed in VOSviewer. It was evident that "Remote Sensing" and "Remote Sensing of Environment" journals have significantly higher citations than other sources.

In parallel to bibliographic analysis, a systematic review was also performed; several articles published in known journals were shortlisted using PRISMA statement methodology. During in-depth analysis of shortlisted articles, it was found that multiple researchers have evaluated GIS, QGIS, and 3D GIS for the assessment of the solar potential in

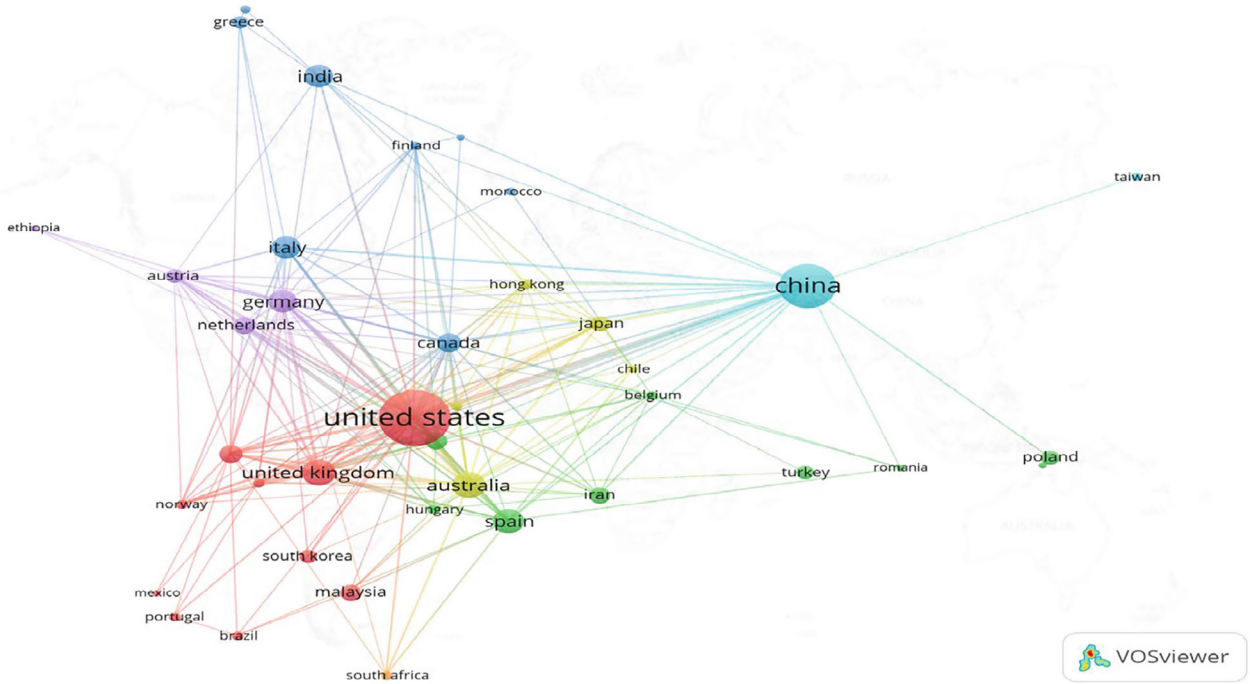


Fig. 2 Network visualization map of country co-authorship generated in VOSviewer

different parts of the world. The majority of researchers have concentrated on the assessment aspects of solar energy; researchers also worked on the detection of building roofs using 3D GIS, and it was found suitable during initial investigations. In some case studies, LiDAR and UAVs are exploited for the detection of rooftop surfaces for installation of photovoltaic plants; LiDAR specifically was found suitable for the detection of rooftops. Nelson (2020) compared the results of LiDAR and WingtraOne Unmanned Aerial System (UAS) and found that the results obtained from UAS are more accurate than LiDAR, it was concluded that UAS can be effectively used to monitor already operational photovoltaic plants. Piccinini (2020) designed a GIS-based relational database which uses UAS-captured images and analyzes those in QGIS. Fault management companies can employ this model to demonstrate its suitability in real-life applications.

In some recent articles, artificial intelligence, artificial neural networks, and machine learning have been exploited for the potential detection of suitable rooftops for installing solar energy plants and for the detection of already installed PV plants. Researchers employed the pixel-based analysis method (PBIA), the object-based analysis method (OBIA), and deep learning for the detection of photovoltaic plants, and it was found that among these methods, deep learning has a high level of accuracy in segmenting PV systems of all sizes. Lan (2022) used five different machine learning algorithms for understanding the correlation between urban form and solar energy potential at the mesoscale, and the artificial neural network was found to be most suitable with an accuracy level of 86%.

5 Conclusions

This research employed a hybrid methodology, combining bibliometric analysis and systematic review. The bibliographic analysis revealed the USA as a major contributor. Co-citation analysis highlighted the impact of "Remote Sensing" and "Remote Sensing of Environment" journals. Moreover, the systematic review identified a global interest in employing GIS, QGIS, and 3D GIS for solar potential assessment. Looking ahead, there is significant potential in integrating satellite data with that from UAVs for enhanced accuracy. This heightened precision can then be effectively utilized in seamless analysis in machine learning algorithms, thus facilitating precise analyses concerning suitable rooftops and regions for the successful installation of photovoltaic (PV) systems.

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Mapping the Biophysical Sensitivity of Agrosystems in the Central Sahel Using Machine-Learning Models

Ismaguil Hanadé Houmma, Sébastien Gadal, Loubna El Mansouri, Mounir Oukhattar, Amadou Abdourhamane Touré, and Rachid Hadria

Abstract

Climate extremes and their trends in several parts of the world have exacerbated the biophysical susceptibility of agrosystems in semiarid regions. In the Sahel region, this is reflected in a gradual deterioration in the climatic resilience of agrosystems and their ecosystem productivity, with potential losses in cereal yields of up to 27% by 2050. To meet current and projected challenges in terms of food security, resilience of rural communities, and the sustainability of agricultural systems, a better understanding of the biophysical sensitivity of the spatial units that make up an agrosystem is crucial. In previous studies, the mapping of the biophysical sensitivity of spatial units was approached by using anomalies in vegetation condition indicators to quantitatively approximate the response of agrosystems to climatic water deficits. However, due to the complex interactions of factors affecting the biophysical susceptibility of agrosystems, anomalies in a single component may not be sufficient to assess biophysical sensitivity. The aim of this study is therefore to propose a new approach to mapping biophysical sensitivity by considering gradients in the magnitudes of changes in anomalies of biophysical variables in place of simple anomalies. To this end, time-series data of the vegetation index, surface temperature, vegetation primary productivity, and soil moisture from NOAA/AVHRR and TerraClimate products were used to assess the biophysical sensitivity by comparing the performance of four machine learning models. Methodological steps included analysis of significant trends obtained by linear regression of the index using the lm() function in RStudio. Next, models were implemented using the caret package with a data partitioning of 70% for model training and 30% for testing. The results suggest spatial variability in biophysical sensitivity. The highest is obtained in croplands and lower in other land-use types, and the random forest model stood out for its high ability to predict biophysical sensitivity classes, with an ROC = 94%, while the ROCs of support vector machine, K-nearest neighbors, and naive Bayes were 78.6%, 72.03%, and 77.6%, respectively. Finally, the analysis highlights the importance of combining multi-indicator change amplitudes to obtain an overall assessment of the biophysical sensitivity of agrosystems, particularly with random forest.

Keywords

Machine learning · Biophysical sensitivity · Drought index · Sahel

I. H. Houmma (✉) · S. Gadal · M. Oukhattar
ESPACE UMR 7300, Aix-Marseille Univ., CNRS, Univ. Nice Sophia Antipolis, Avignon Univ, 13545 Aix-en-Provence, France

I. H. Houmma · L. El Mansouri
Department of Geodesy and Topography, Hassan II Institute of Agronomy and Veterinary, Rabat, Morocco

S. Gadal
Institute of Computer Science, Vilnius University, Vilnius, Lithuania

A. A. Touré
Faculty of Science and Technology (FAST) - Department of Geology, Abdou Moumouni University, PB 10662 Niamey, Niger

R. Hadria
National Institute of Agricultural Research, (INRA), Rabat, Morocco

I. H. Houmma
Department of Environmental Sciences, University of Québec at Trois-RivièresTrois-Rivières, Trois-Rivières, QC G8Z 4M3, Canada

Present Address:
Research Centre for Watershed-Aquatic Ecosystem Interactions (RIVE), University of Québec at Trois-Rivières, Trois-Rivières, QC G8Z 4M3, Canada

International Water Research Institute, Mohammed VI Polytechnic University (UM6P), Benguerir, Morocco

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1 Introduction

Biophysical sensitivity refers to how a natural or agricultural ecosystem responds to changes in climatic and environmental conditions such as variations in rainfall, high temperatures, prolonged droughts, and soil degradation. In this sense, biophysical sensitivity is a measure that provides information on drought resistance that partly reflects its seasonal climate resilience. Seasonal variance or historical anomalies in biophysical characteristics, including changes in vegetation indices, are the most commonly used variables for mapping biophysical sensitivity (Saha et al. 2023; Noureldeen et al. 2020; Mohmmed et al. 2018). However, the quantitative numerical evaluation of the spatial distribution of biophysical sensitivity of agrosystems is a particularly complex task that cannot be adequately addressed by univariate or bivariate approaches. In the Central Sahel region, agrosystems are particularly sensitive to climatic hazards. Crops and rangelands often face extreme drought and heat conditions, reducing their growth and yield. The objective of this study is to develop an approach to mapping the biophysical sensitivity of agrosystems based on magnitudes of changes in anomalies of biophysical indicators and deep-learning techniques.

2 Study Area and Method of Research

The study area is the segment of the Niger River basin straddling three countries (Niger, Mali, Burkina Faso). It lies between 10° 57′5.40″ N and 17° 5′14.76″ N and 1° 59′4.34″ W and 6° 0′31.33″ E over an area of 340,723 km^2. The topographical conditions are not very contrasted and its climate is tropical with three distinct zones: Sahelo-Saharan zone 150–250 mm, Sahelian zone 250–500 mm and Zahel-Sudanian zone 500–750 mm/year. Socio-economic characteristics are highly variable with a south-north gradient depending on physio-climatic conditions (Fig. 1).

In the south, rainfed agriculture is the main activity of the population (about 90%), while in the north pastoralism replaces agricultural practices. As indicated by the simplified methodology flowchart (Fig. 2), the biophysical sensitivity mapping of agrosystems was performed by combining the magnitudes of historical trends from six biophysical indica-

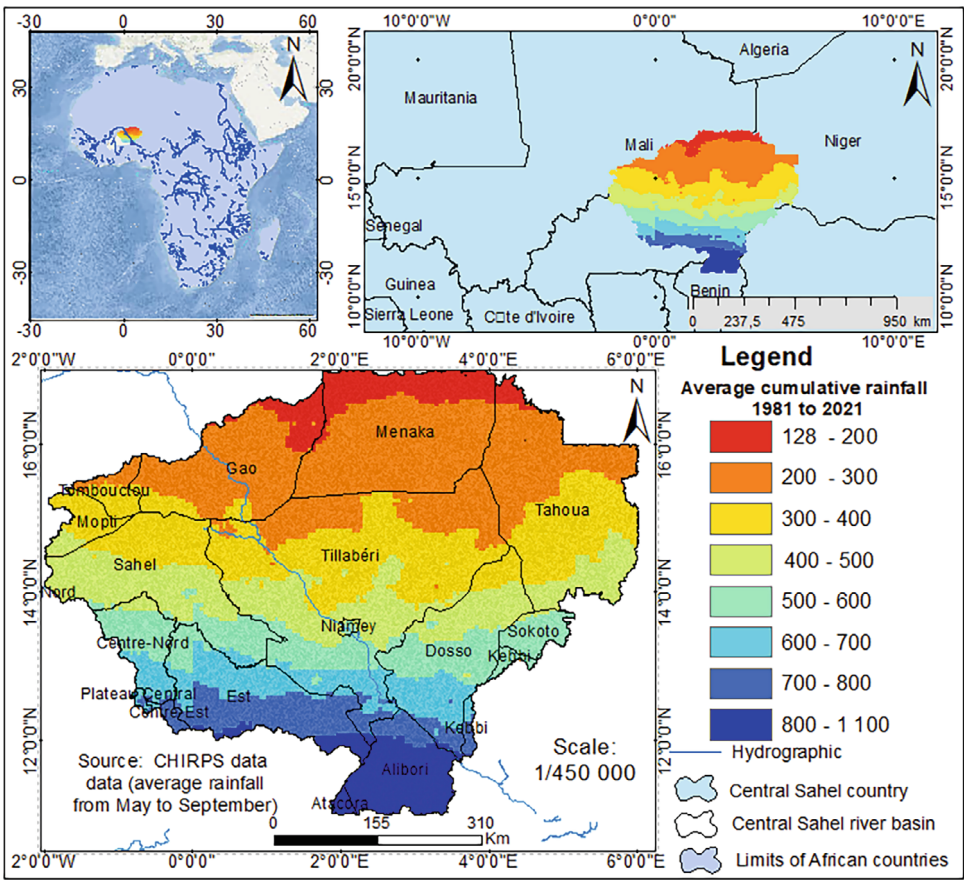


Fig. 1 Geographical location of the study area

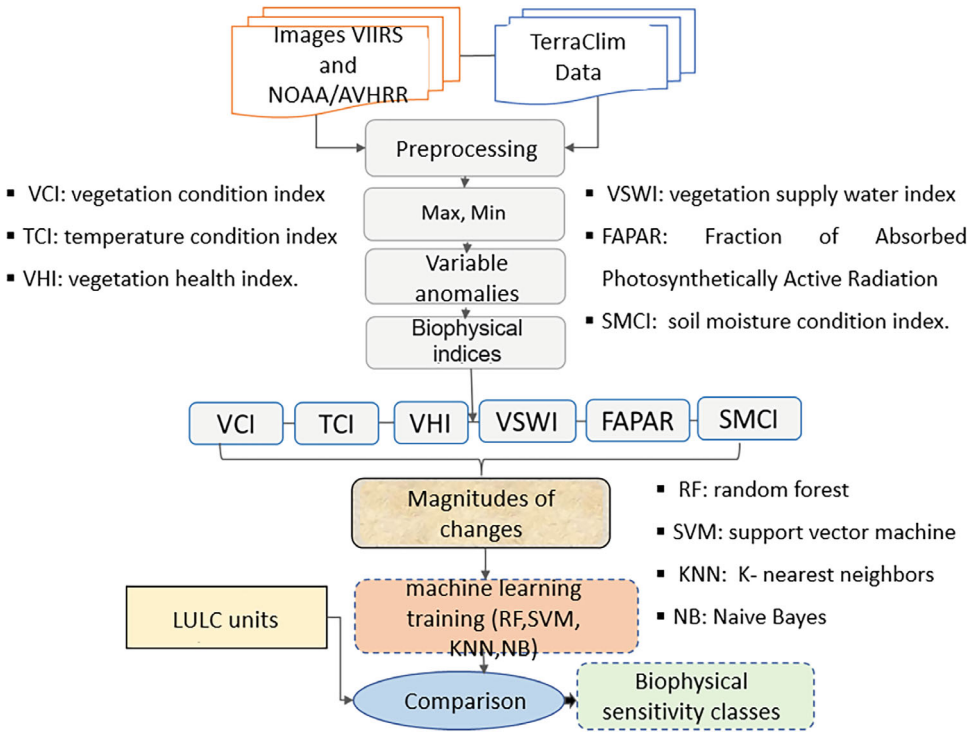


Fig. 2 Methodology of biophysical sensitivity mapping

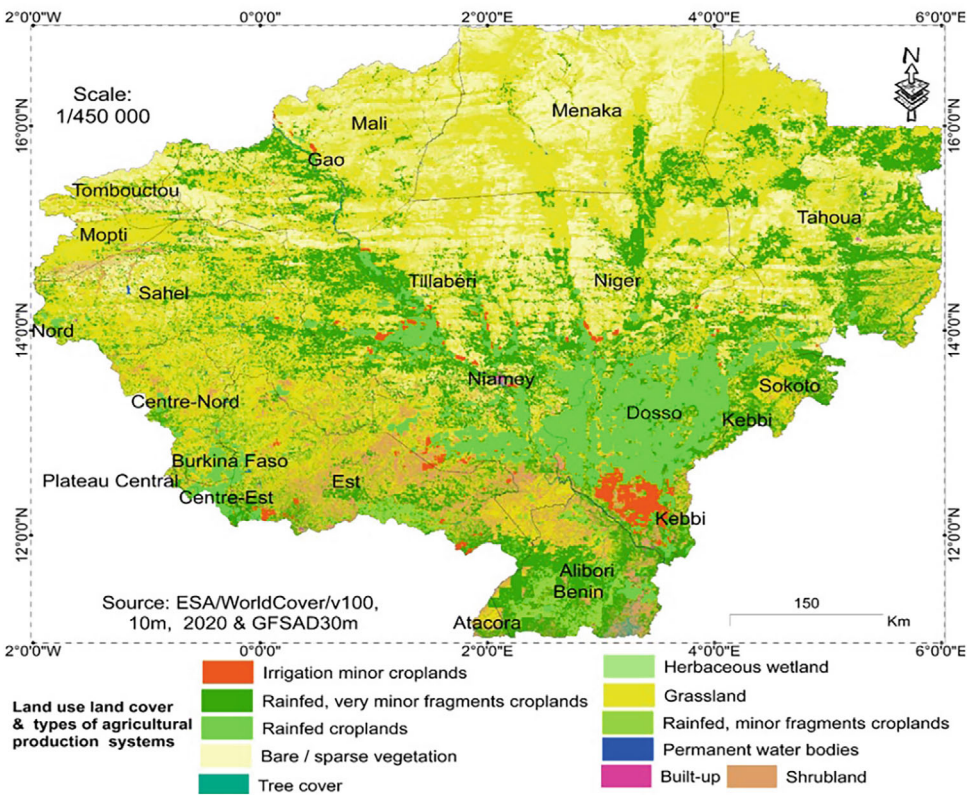


Fig. 3 Spatial distribution of the main natural and anthropogenic agrosystems

tors. Machine learning models (RF, SVM, KNN, and NB) were used for spatial modeling of biophysical sensitivity.

3 Results

3.1 Mapping of the Main Agrosystems of the Study Area

Figure 3 shows the spatial distribution of natural and agricultural agrosystems. Agricultural production systems are mainly located in the extreme south of the watershed. Different degrees of green intensity correspond to rainfed production systems, which dominate compared to semi-irrigated systems. This includes the main rainfed crop species, namely cereals (millet, sorghum, fonio, and maize) and the main cash crops (cowpea, groundnut, voazu and sesame). The red color of the card corresponds to production systems with complementary irrigation. This production system apparently occupies only a very small part of the watershed. The other main land-use and land-cover units, namely grassland and bare soil, are the most dominant land-cover units in the basin. This analysis is not intended to provide accurate and detailed mapping of land-use and land-cover units. It was established to assess the spatial correspondence between biophysical sensitivity classes and the spatial distribution of land-cover and land-use systems.

3.2 Spatial Modeling of Biophysical Sensitivity of Agrosystems

Figure 4 shows the spatial distribution of six biophysical sensitivity classes of agrosystems from four machine learning models with much better performance obtained with the RF model. Nevertheless, overall, regardless of the model, the highest biophysical sensitivity is observed in rainfed crop areas mainly in the southwestern part of the river basin. This corresponds to the red color of the legend. The northern pastoral zone constituting rangelands and perennial vegetation of thorns is relatively less sensitive (green colors) compared to cultivated agrosystems. Thus, the use of machine learning models has enabled better prediction of complex spatial patterns of biophysical sensitivity in the Central Sahel zone. However, when comparing their predictive skills, it is interesting to note that the RF model performs significantly

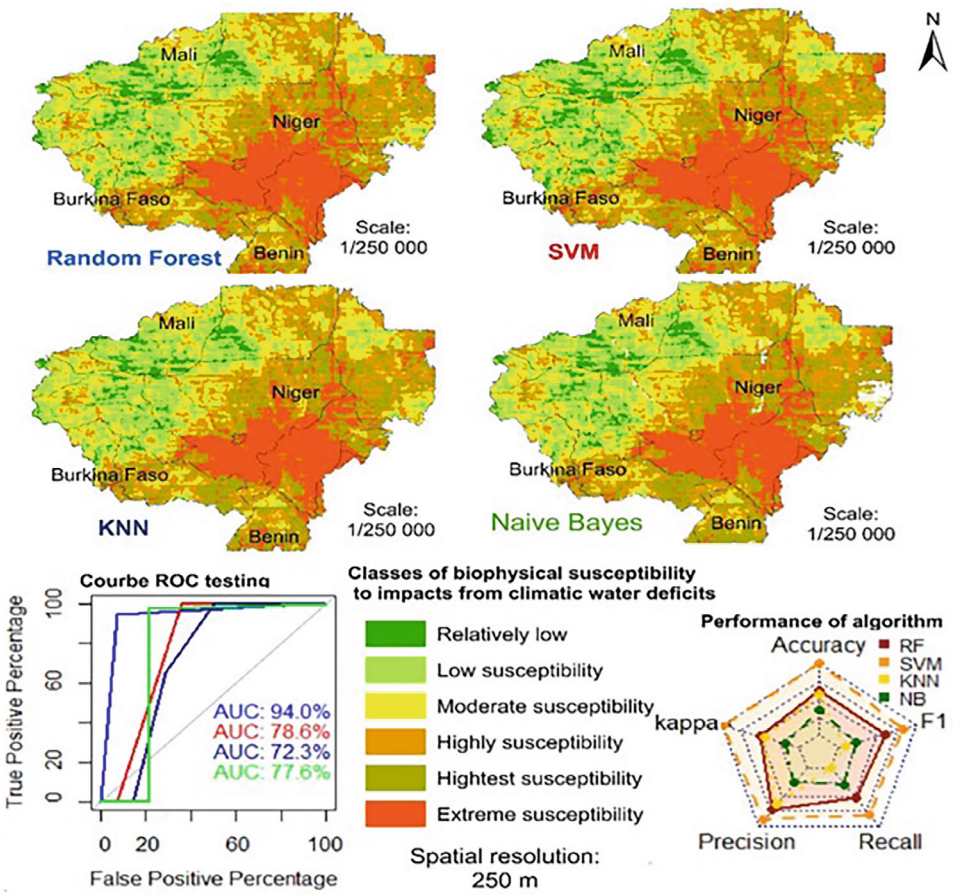


Fig. 4 Map of biophysical sensitivity classes of agrosystems (Hanadé Houmma et al. 2023)

better than other algorithms such as SVM (ROC = 78.6%), KNN (ROC = 72.3%) and NB (ROC = 77.6%). This superiority can be explained by the fact that RF has an architecture of several decision trees which reduces the biases and errors of each individual tree by considering the diversity and combination of their predictions, as well as their sensitivity to missing values.

4 Conclusion and Discussion

In this study, an approach to mapping the biophysical sensitivity of agrosystems in the central Sahel based on the magnitudes of changes in six biophysical indices was proposed. The spatial correspondence between the biophysical sensitivity classes obtained by testing four machine learning models and the land-cover and land-use units suggests a spatial variability in biophysical sensitivity strongly related to land-cover type. The highest biophysical sensitivity is obtained in cropland and is relatively low in other types of land use. Nevertheless, to refine the conclusions of this study, statistical analyses are necessary.

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CA-ANN Simulation Modeling Approach for Urban Spatial Dynamics with Future Projections, and Its Environmental Impacts on Karachi (Pakistan) Based on GIS and RS Data Analytics

Shaker ul Din and Kayoko Yamamoto

Abstract

Urban sustainable development in developing countries faces multifaceted socioeconomic and environmental challenges arising from sluggish economies, population growth, environmental degradation, unemployment, and the proliferation of slums. Recent advancements in urban growth simulation models, such as Cellular Automata with Artificial Neural Networks (CA-ANN), have proven effective due to their simplicity, flexibility, and ability to incorporate spatiotemporal dynamics. In the context of Karachi, Pakistan, the spatiotemporal trends of land use features driven by rapid urbanization have become a critical concern, impacting socioeconomic and environmental well-being. This study follows three main stages: Land Use Classification: Remote sensing imagery was used with a semi-automatic classification plugin (SCP) method. Future Prediction: The Modules of Land Use Change Evaluation (MOLUSCE) prediction model simulated future land cover changes. Monitoring and Interpretation: Change identification and outcome analysis were carried out. Findings indicate an upsurge in the built-up region and a deterioration in other landscapes over historical and projected periods. The accuracy of land cover classification exceeded 90% in 1990, 2000, 2010, and 2020. Notably, the built-up area extended from 245 km^2 in 1990 to 682 km^2 in 2020, accompanied by reductions in grassland, rocky terrain, bare soil, water bodies, and mangroves. Projections suggest a further 561.93 km^2 increase in built-up area by 2050, whereas other features are projected to decrease. Irregular urban growth has led to the proliferation of slums in the city center, reflecting Karachi's sluggish economic development. Urgent action is needed to address unplanned urban growth and mitigate environmental impacts. It is recommended that the authority take immediate action for proper and planned urban growth to ensure sustainable urban development.

Keywords

Cellular automata · Artificial neural network · Modeling · Remote sensing · Spatial dynamics

1 Introduction

In recent decades, there has been an unparalleled and rapid increase in urbanization across the globe, marked by population growth, concentration, and the expansion of urban areas (Sato and Yamamoto 2005). Urban expansion is responsible for the decline in vegetation cover, environmental degradation (Alphan 2003), and arable land loss (Lopez 2001). Similarly, the natural function of the local ecosystem is also seriously affected by land use conversions from rural to urban (Turner 1994). For assessing sustainable urban development, it is important to determine the equilibrium between human activities and ecological functioning (Liu 2005). Studying urban expansion at the regional level requires a manageable approach to analyzing land cover and should provide a timely outcome about the changes in the landscape. Thus, advanced tools and sprawling quantitative methods are the need of the hour (Hofmann et al. 2006). In recent years, there has been a widespread application of remote sensing satellites, and unmanned aerial vehicles (UAVs) are extensively used for data acquisition. Therefore, the utilization of remote sensing offers current spatial dynamics information that can be utilized to extract, investigate, and simulate land use dynamics effectively. Nevertheless, the modeling and simulation of land use dynamics is necessary despite its intricacy (Yang 2016). The urban land use models are

S. ul Din (✉) · K. Yamamoto
Graduate School of Informatics and Engineering, The University of Electro-Communications (UEC), Tokyo, Japan
e-mail: shaker.uldin@go.wt-jdpsr.jp

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employed to simulate, investigate, and forecast potential scenarios of land use dynamics under different circumstances in future and are categorized into different groups. The cellular automata (CA) method still stands as a computational tool that can simulate the evolution process by connecting a complex structure to a series of basic rules. CA's ability to simulate metropolitan expansion, land use spatial dynamics, and population growth has proven to be effective in modeling multi-layered geographical processes (Feng 2011). The study aims to develop a **CA-ANN simulation model** to predict urban growth in Karachi from 1990 to 2050. By integrating **GIS and RS data**, it will assess environmental impacts and propose sustainable planning strategies for the city.

2 Study Area

The city, formerly the capital and currently the economic hub of Pakistan, boasts a population of 20.382 million, as reported in the recent census 2023. It ranks as the 12th largest urban agglomeration globally, as per data from Wikipedia (2023). However, this rapid population growth has brought forth a host of environmental and socioeconomic challenges. These include inadequate urban planning strategies, air pollution concerns, health epidemics, and the proliferation of squatter settlements (Khan and Khan 2019). The city's geographical coordinates lie between latitude 24° 45′ N and 25° 15′ N, and longitude 66° 37′ E and 67°37′ E, as seen in Fig. 1.

3 Materials and Methods

The study utilized remotely sensed images. A total of four Landsat images and a Digital Elevation Model (DEM) were collected. These remote sensing images were acquired in 1990, 2000, 2010, and 2020 with path 152 and rows 42 and 43.

Methods: Commonly, various image classification approaches exist. In this study, an algorithm, namely the Semi-Automatic Classification Plugin (SCP), was applied to classify each land use feature to reach an acceptable kappa coefficient and overall accuracy. To perform an unbiased accuracy evaluation, ground truth points (GTP) were gathered from the four Landsat images in the study area using a method of stratified random sampling. Google Earth was utilized to carry out ground verification within the study region to validate the accuracy of the GTPs for each land use feature. The Modules for Land Use Change Evaluation (MOLUSCE) plugin was used for simulation. In the MOLUSCE plugin, there are four different models present for transition potential modeling; Of these, an Artificial Neural Network was used with a Cellular Automata (CA) combination for this study.

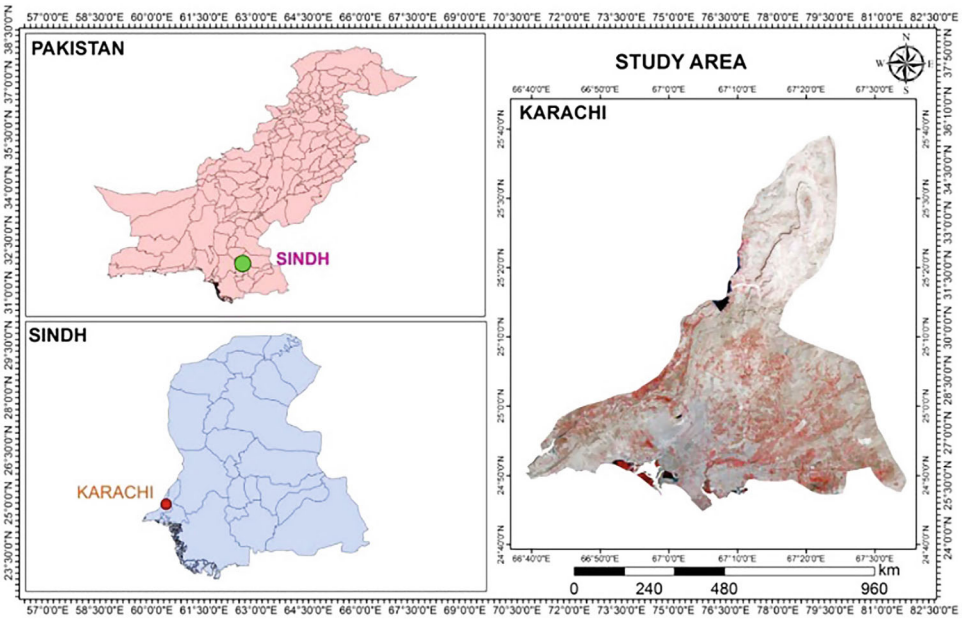


Fig. 1 Study region map

4 Results

4.1 Accuracy Assessment

The evaluation of accuracy indicated that the findings were extremely reliable. The accuracy percentage for all six categories in the four classification results was greater than 87%. The general precision and Kappa index concurrence in the years 1990, 2000, 2010, and 2020 exceeded 94.38 and 0.90, respectively (refer to Table 3). It is worth mentioning that the accuracy for the built-up area exceeded 92.58 and 98.78, respectively.

4.2 Spatiotemporal Dynamics

The obtained results regarding the spatial dynamics of Karachi show interesting facts. The results regarding the transition of land cover classes demonstrate that the built-up area has increased by 423.73 km^2 in the last three decades, from 258.52 to 682.25 km^2 due to the conversion of 214.14 km^2 of rocky bare, 107.97 km^2 of bare soil, 104.47 km^2 grassland, 10.39 km^2 of waterbody, and 0.19 km^2 of mangrove forest. During the analyzed period, the grassland area showed an increase from 560.91 to 1470.85 km^2 due to conversion from 541.59 km^2 of rocky bare, 494.36 km^2 bare soil, 13.35 km^2 of waterbody, 8.05 km^2 of built-up, and 0.15 km^2 of mangroves. Rocky bare shows a decreasing trend from 1990 to 2020 from 1435.23 to 1023.21 km^2. Its 541.59 km^2, 214.14 km^2 103.61 km^2, 14.23 km^2, and 0.33 km^2 of rocky bare were converted into grassland, built-up, bare soil, waterbody, and mangroves, respectively. From 1990 to 2020, the bare soil area decreased from 1241.68 to 368.40 km^2 converting 103.61 km^2 into rocky bare, 15.47 km^2 into grassland, 2.72 km^2 into built-up, 1.59 km^2 into waterbody, and 0.0009 km^2 into mangroves. The waterbody trend shows a slight increase, and the mangrove forest shows a minimal decrease (Fig. 2).

4.3 Predicted Spatiotemporal Trends for Land Use and Land Cover

Predicted results for the upcoming thirty years from 2030 to 2050 for spatial and temporal dynamics of Karachi revealed interesting outcomes. The overall predicted results indicate steady urban growth in the city for the forthcoming three decades. However, the transformation matrices visibly indicate speedy urban growth in future. The built-up area will mainly expand from all land features. Results reveal the built-up amount will increase by 562 km^2 in the forthcoming three decades from 682.25 to 1244.187 km^2 from the conversions of 419.78 km^2 of grassland, 106.33 km^2 of rocky bare, 40.27 km^2 of bare soil, 39.88 km^2 of water body, and 12.17 km^2 of mangroves (Figs. 3 and 4).

5 Discussion

The study reveals that the built-up increased constantly from 1990 to 2020 and projected results for 2030, 2040, and 2050 also showed a constant increase in the built-up surface. Different patterns indicate diverse urban expansion and growth. According to Bhatta (2010), the urban development patterns in the city can be categorized into three types: (1) leapfrog expansion, (2) in-fill expansion, and (3) linear expansion. The continuous population growth and increase

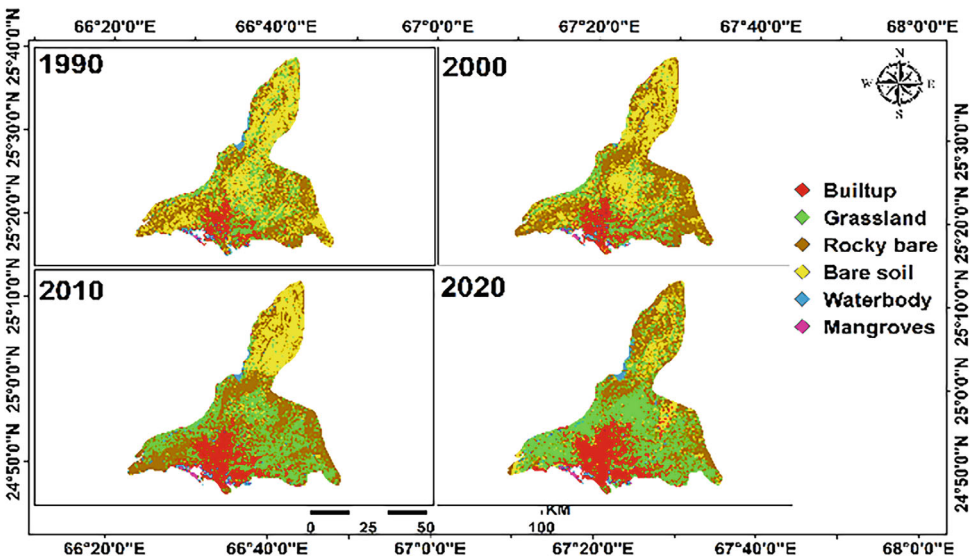


Fig. 2 Land use maps 1990, 2000, 2010, and 2020

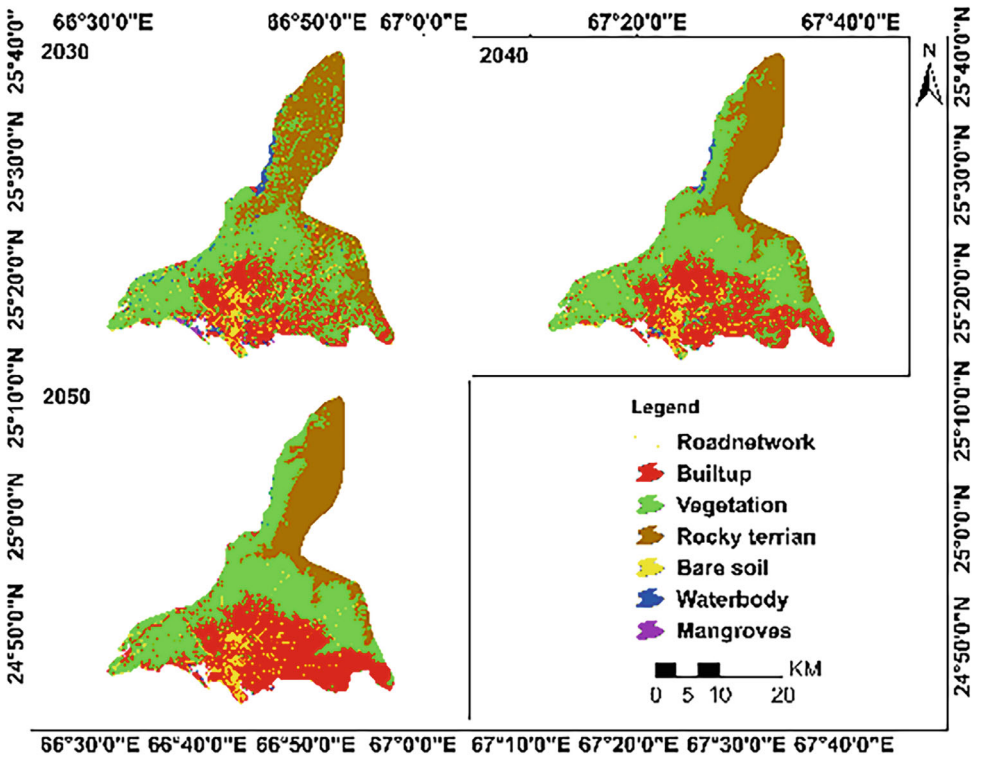


Fig. 3 Land use maps 2030, 2040, and 2050

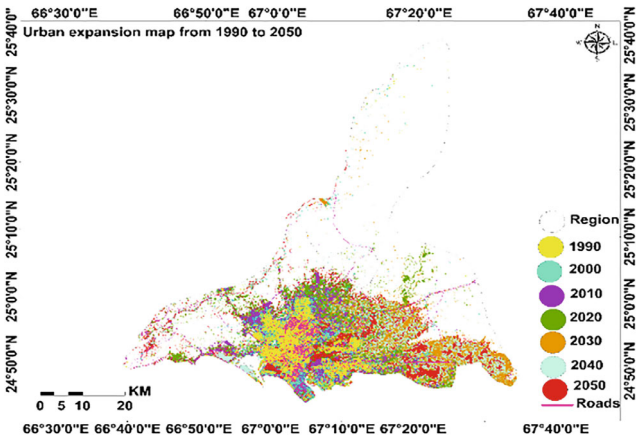


Fig. 4 Built-up area growth from 1990 to 2050

in vehicles and manmade structures have posed many environmental challenges. According to a recent 2023 census report, Karachi's population crossed 20 million. Because of the continuous population increase, the size of slums has also expanded. Presently, there are approximately 400 slums in Karachi, accommodating 40–60% of the city's residents (Thaver 1990). CA models for urban areas have both benefits and drawbacks. Urban CA models' quick development is largely due to their simplicity. Another advantage of urban CA models is their adaptability to different applications. Flexibility, however, may cause confusion and difficulties for users if there is no universally accepted definition of transition rules. It can be difficult to strike the ideal balance between standardization and flexibility as well as between simplicity and realism. The amount of input data that is gathered for various models can vary significantly in terms of data requirements. The software that could be used to create generic urban CA models in the past was extremely constrained and difficult to use; users were frequently forced to redesign or change their models to suit their needs. Future thermal conditions could also be impacted by urban patterns, as a dispersed city can reduce mean UHI intensity while imposing more thermal loading at the regional scale than more compact spatial areas. Assessing the temperature variations caused by urbanization is essential, especially in big cities, as the resulting climate changes can significantly decrease comfort levels and lead to the accumulation of pollutants in urban street canyons, ultimately impacting the health of residents. Consequently, aside from monitoring temperature fluctuations in urban regions, it is imperative to also consider evaluating the impact of changing land-use trends, regional traffic and transportation patterns, as well as meteorological factors on the dispersion of pollutants at detailed spatial scales.

6 Conclusions

This research study aimed to examine historical variations in land cover spatial dynamics and to forecast future urban extension patterns in Karachi through remote sensing and geoinformatics techniques. The results of the study indicated a significant increase in built-up area over the past three decades, from 258.51 km^2 to 682.18 km^2, and the projected outputs for the future also unveiled intriguing findings for the period from 2020 to 2050; over the next thirty years, urban areas could potentially double from 682 to 1244 km^2. The results also revealed that machine learning approaches, such as Cellular Automata-Artificial Neural Network (CA-ANN), can process multispectral satellite imagery more efficiently and can deliver significant urban simulations with a high percentage of accuracy. This research output can also support countries in achieving the Sustainable Development Goals (SDG) by 2030, particularly in developing countries.

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Recent Land Use Land Cover Change Tendencies in Continental Portugal: Are They Sustainable?

Luís Quinta-Nova

Abstract

The Land Use Land Cover (LULC) pattern is fundamental to the structural framework of landscapes, playing a key role in effective landscape management. Additionally, the growing impact of human activities on the ecological environment has become a significant concern. This study aimed to investigate the relationship between human disturbance intensity and the configuration and quality of landscape patterns. The objectives were to analyze the spatiotemporal dynamics of landscape changes and human disturbance associated with land-use changes in Continental Portugal from 1990 to 2018 and to examine how landscape change trajectories relate to human disturbance and naturalness metrics, assessing their potential as sustainability indicators. Landscape configuration was evaluated by using various land-use metrics, including Mean Patch Size, Mean Shape Index, Total Edge, and Mean Patch Fractal Dimension. These metrics were derived from LULC data obtained from the Corine Land Cover databases (1990, 2006, and 2018). Patch and landscape-level metrics were calculated for 163 quadrats of 25 km^2 each, covering the country, using the Patch Analyst plugin in ArcGIS 10.8. The Hemeroby Index (HI) was used to quantify the degree of human-induced disturbance in the landscape. Correlation analysis was performed to identify statistical relationships between changes in landscape metrics and HI. The results revealed a negative correlation between the Total Edge metric changes and human disturbance, suggesting that greater landscape complexity corresponds to lower disturbance levels. These findings support using landscape metrics as indicators of human disturbance, aligning with previous research. Integrating structural and quality indicators can provide valuable insights for planners and decision-makers, aiding in analyzing regional land-use trends and supporting sustainable landscape management.

Keywords

GIS · Landscape pattern · LULC change · Sustainability

1 Introduction

The impact of human activities on the structure and functionality of landscapes is an increasing concern, making its monitoring a key focus and essential area of research in landscape ecology (Geri et al. 2010; Li et al. 2017). Some scientific studies have focused on the spatial variability of disturbance resulting from human action and its relationship with the differentiation and evolution of landscape patterns (Szilassi et al. 2017; Wu et al. 2021).

To attain sustainability, strategies must account for multiple dimensions, including environmental, social, and economic factors across different temporal and spatial scales (Villeneuve et al. 2017). Understanding how societies utilize and manage land to achieve specific land use outcomes is essential. Therefore, adopting a holistic approach to land use—incorporating integrated sectoral policies and targeted policy instruments—necessitates various compromises (Vulevic et al. 2022; European Environment Agency, 2019).

The pattern/process paradigm suggests that ecological processes are influenced by landscape patterns, and landscape structure metrics serve as effective tools for measuring these patterns, reflecting the spatial configuration of the landscape mosaic (Wrbka et al. 2004; Liu et al. 2020). Landscape metrics tools support landscape planning and management decisions by offering a comprehensive view of landscape structure.

L. Quinta-Nova (✉)
School of Agriculture, Polytechnic University of Castelo Branco, Castelo Branco, Portugal
e-mail: lnova@ipcb.pt

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They assess the quantification of the arrangement and content (diversity and abundance) of a landscape, as well as the spatial arrangement (features, placement, or orientation of patches) of its components (Forman 1995).

Also, the Hemeroby index (HI) has been used in different studies (e.g., Szilassi et al. 2017; Wu et al. 2021; Jalas 1955) to quantify the changes in landscape structure and function caused by human activities (Sukopp 1976). There is a direct proportional relationship with a positive sign between the degree of hemeroby and the level of disturbance and transformation of the most disturbed landscape due to human causes (Tian et al. 2020).

Environmental and spatial indicators are essential for assessing the impact of human activities on landscapes and ecosystems. They support decision-making, facilitate ecological monitoring, and guide the development of effective landscape management policies that promote sustainable development.

The aim of this study is (1) to analyze the spatiotemporal dynamics of landscape in Continental Portugal between 1990 and 2018, and to relate it to the implementation of a set of agri-environmental measures resulting in a growing extensification of production systems following Portugal's entry into the EU, which resulted in the implementation of the reform of the CAP (Common Agricultural Policy) in 1992; and (2) to explore the link between LULC change trajectories and anthropic disturbance/naturalness metrics, highlighting how trends in landscape pattern changes can serve as indicators of sustainability.

2 Materials and Methods

2.1 Study Area

The study area encompasses the entire mainland Portugal, which covers an area of 89,073 km^2 and is located in the western part of the Iberian Peninsula. Mainland Portugal has a population of 10,352,042, with over 60% residing in the metropolitan areas of the two major cities, Lisbon and Porto.

2.2 Methodology

The Corine Land Cover databases (CLC 1990, 2006, and 2018) were used to derive values for various landscape indices. Landscape-level and class-level metrics were quantified across 163 quadrats, each covering 25 km^2, forming a grid spanning Mainland Portugal. Landscape metrics were computed using the Patch Analyst extension within ArcGIS 10.8. Land-use and land-cover (LULC) classes were converted into a hemeroby seven-point scale, spanning from ahemerobic (no human influence) to metahemerobic (completely altered biocenosis). Based on that classification, an average value was then calculated for each 25 km^2 grid cell.

We proceed to the quantification of the structure of the landscape using a set of landscape metrics. The selection of landscape metrics was guided by several criteria: (1) they should effectively represent and define the dimensions of spatial pattern characteristics; (2) they should be easily calculable and nonredundant; and (3) they should have been previously used in relevant similar studies.

Metrics describing patch area distribution, such as Mean Patch Size (MPS), characterize the area allocation among patches at both class and landscape levels. The Mean Shape Index (MSI) represents the average patch structure within the landscape and indicates landscape fragmentation. Total Edge (TE) includes all edges in the landscape, and it measures the configuration of the landscape. Mean Patch Fractal Dimension (MPFD) quantifies the level of complexity of a landscape (McGarigal and Marks 1995).

The correlation between landscape metric values' temporal change and the changes in Hemeroby index values was assessed using IBM SPSS Statistics 22 software. The Shapiro-Wilk test was first applied to test the variables' normality. However, the nonparametric Spearman's correlation coefficient was used since most variables do not follow a normal distribution (Sokal and Rohlf 1969).

3 Results and Discussion

In the studied period, the increased LULC categories were seminatural areas, artificial surfaces, pastures, and waterbodies, while forest and agricultural areas. The transitions from forest to seminatural areas correspond to 35% of all LULC changes in Portugal, with a significant amount of agricultural land also changing to seminatural areas (14% of total changes). The change from other LULC classes to seminatural areas corresponds to 54% of total changes in the country in the studied period.

The reduction of agricultural land was low due to the gain in surface mainly from the forest (15% of total changes) but with losses to urban growth (6% of total changes). The increase in urban areas was relatively low (8% of total changes).

The country's average Hemeroby index value remained stable during the study period. In 1990, the index value was 3.88 ± 0.42, then slightly increased to 3.90 ± 0.42, 3835 ± 0.759 in 2006, and maintained at 3.90 ± 0.41 in 2018. This corresponds to a β-euhemerobic level, which indicates moderate to high human impacts.

The LULC and Hemeroby Index change trajectories identified in Portugal between 1990 and 2018 are presented in Fig. 1.

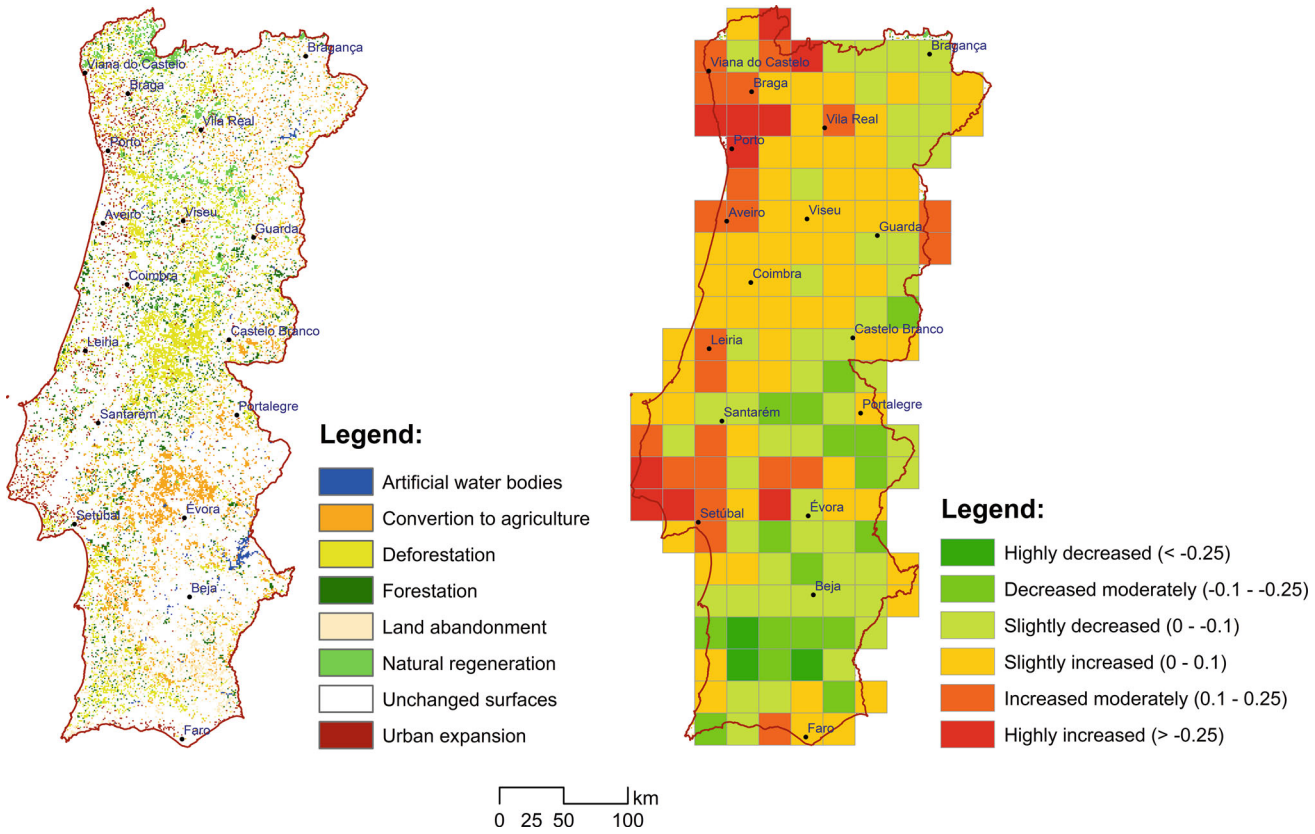


Fig. 1 LULC and Hemeroby level trends for 1990–2018

Based on the analysis of changes in the LULC, the main alteration in use corresponds to the reduction of the forest area (35.9% of the total alterations), followed by the conversion to agriculture (20.6%). Land abandonment and urban expansion also have some expression corresponding to 14.5% and 13.7%, respectively.

The reduction in forest area was due to the larger forest fires that occurred in 2017 in the central region of Portugal, while there was, on the other hand, a significant increase in forest area in the other regions. Also, the conversion into agricultural areas corresponds to the implementation of the irrigated area of the Alqueva Reservoir, with the installation of olive groves in intensive and super-intensive modes in the Alentejo region.

By analyzing the changes in the Hemeroby index value between 1990 and 2018 (Fig. 1), we observed that the level of naturalness increased in 58% of the studied areas, while it decreased in the remaining.

Concerning the variation in the average values of landscape metrics, TE, MSI, and MPFD values increased during the 28 years, indicating an increase in landscape complexity. Conversely, the MPS value declined, indicating a reduction in patch size (Fig. 2).

The results of the analysis conducted to examine the correlation between the Hemeroby index change and the LULC pattern indexes show that Total Edge (TE) exhibited a moderate negative correlation with the Hemeroby index ($\rho = -0.438$, $p < 0.01$). This suggests that complex landscapes are associated with lower levels of hemeroby. No significant correlation was found between the Hemeroby index and the other metrics.

4 Conclusions

This study conducted a comprehensive analysis using GIS-based spatial techniques and spatial pattern metrics to examine LULC change trajectories and their impact on sustainability in Continental Portugal.

Landscape metrics and the Hemeroby Index are essential tools for analyzing LULC changes and validating findings from previous studies in various countries. A combination of structural and hemeroby indicators of landscape patterns can support planners and decision-makers in assessing regional trends and developing policies to minimize human impacts on ecosystems.

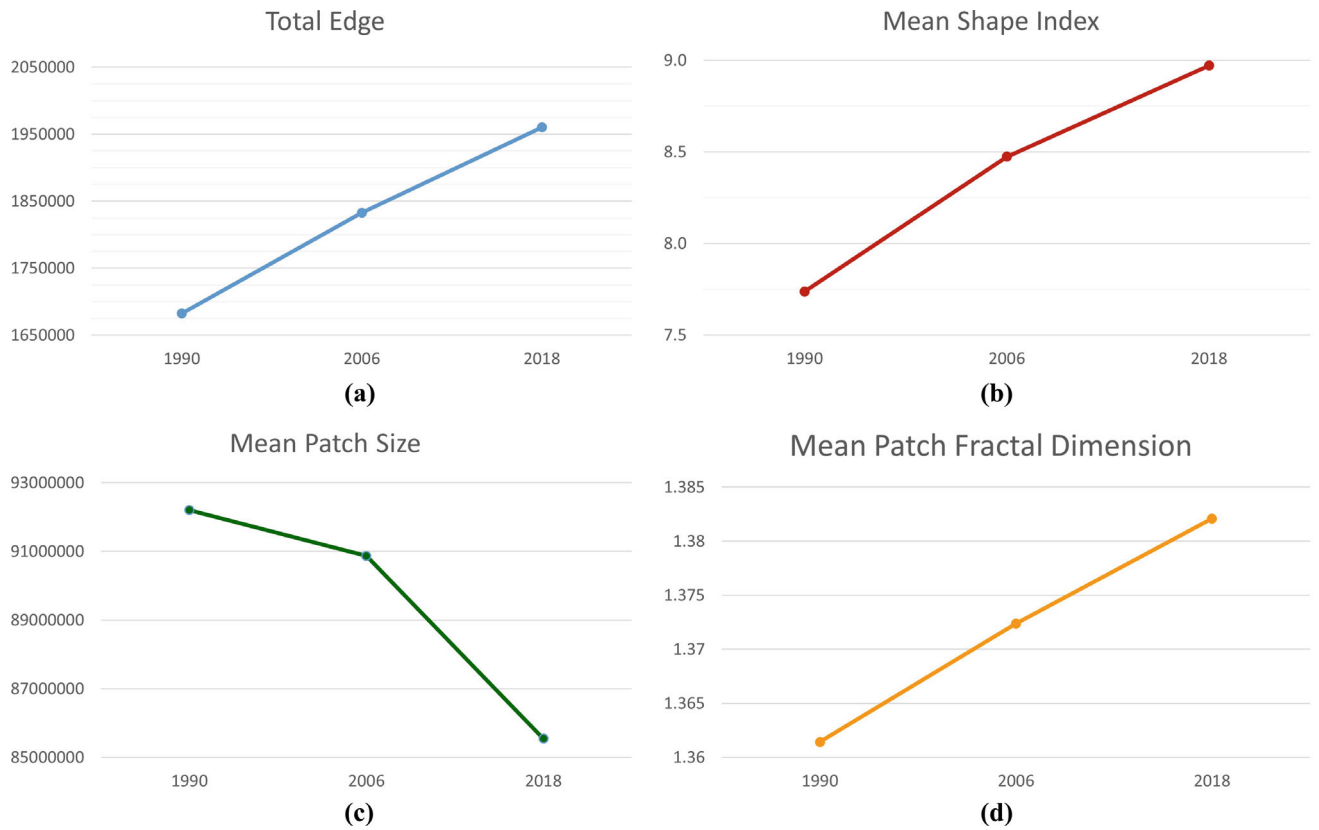


Fig. 2 Change in landscape pattern indices values between 1990 and 2018: **a** total edge; **b** mean shape index; **c** mean patch size; **d** mean patch fractal dimension

The results obtained from quantitative and qualitative LULC metrics can be incorporated into a nationwide system to monitor the execution of spatial plans and their effects on land systems.

This approach would give decision-makers intricate insights into the transformations unfolding across the territory at varying scales. Over time, this continual assessment of indicators would facilitate a comprehensive understanding of the changes occurring in LULC patterns, allowing for a more informed analysis of the impact on the environment and a basis for effective policy formulation and planning.

Acknowledgments This work is supported by Portuguese national funds from the FCT Foundation for Science and Technology, I.P., within the GEOBIOTEC Project UIDB/04035/2020.

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Predicting Sea Surface Temperature along Morocco's Atlantic Coast Using LSTM and Satellite-Derived Data

Hanae Belmajdoub, Siham Zaguir, and Khalid Minaoui

Abstract

Understanding the temporal and spatial distribution of sea surface temperature (SST) along Morocco's Atlantic coast is of paramount importance due to its significant role in the interaction between the ocean and the atmosphere. Accurate monitoring and forecasting of SST in this region are crucial for addressing climate change, mitigating disasters, and preserving marine ecosystems. In this study, we employ long-term memory (LSTM) techniques to predict SST along the Moroccan Atlantic coast, encompassing both short-term and long-term forecasts. The prediction task is formulated as a time series regression problem, where the LSTM architecture is the primary component. The network architecture consists of two main layers: an LSTM layer and a ConvLSTM2D layer. The ConvLSTM2D layer captures spatial and temporal dependencies within the SST time series, while the LSTM layer focuses on modeling long-term memory. These layers together allow the network to learn patterns and relationships in the SST data. The ConvLSTM2D layer is followed by batch normalization layers to improve the model's stability and convergence. Finally, the LSTM layer is connected to a Conv3D layer, which generates the final output. To evaluate our model's performance, we utilize a comprehensive dataset of satellite-derived SST available on the web site http://www.esrl.noaa.gov/psd/. The dataset covers the region along the Northwest African coast, spanning from 20° N to 36° N and 4° W to 19° W. It employs a global grid of 0.25° latitude multiplied by 0.25° longitude, resulting in a grid size of 63 × 63. By leveraging this high-resolution satellite-derived SST database, we aim to provide accurate predictions for SST along Morocco's Atlantic coast. Through rigorous experimentation, we determine the optimal configuration of the LSTM architecture. The effectiveness of our model is then confirmed by assessing the accuracy of SST predictions in Morocco's coastal seas. By employing LSTM-based prediction techniques and utilizing the satellite-derived SST dataset, we strive to contribute valuable insights into the SST dynamics along Morocco's Atlantic coast. This knowledge can facilitate informed decision-making in climate adaptation, disaster management, and marine ecosystem conservation efforts.

Keywords

Sea surface temperature · LSTM · Prediction · Satellite-derived data

1 Introduction

Sea surface temperature (SST) is of considerable importance in the Earth's energy balance system, indicating the temperature of seawater and its central role in interactions between the Earth and the atmosphere. Covering three quarters of the globe, the oceans have a considerable influence on biology and climate. Accurate prediction of SST is essential for ocean weather forecasting, environmental protection and other purposes. Forecasting remains a challenge, paticularly in coastal waters, due to the uncertainties involved. SST forecasting methods fall into two categories (Patil et al. 2016): physicsbased methods (numerical models) and data-driven methods, which aim to learn SST models directly from available data. Various learning techniques, including linear regression (Kug et al. 2004), support vector machines (Lins et al. 2010) and neural networks (Patil et al. 2016), have been applied in these data-driven frameworks. This

H. Belmajdoub (✉)
LRIT Lobaratory, FSJES-Souissi, Mohammed V University, Rabat, Morocco

S. Zaguir · K. Minaoui
LRIT Laboratory, Faculty of Sciences in Rabat, Mohammed V University in Rabat, Rabat, Morocco

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study uses Long Term Memory (LSTM), a recurrent neural network, to predict SST, addressing the challenges associated with gradient problems. The model integrates ConvLSTM2D and Conv3D layers to capture complex spatial and temporal patterns in SST data. The study focuses on SST regimes along the Atlantic coast of Morocco.

2 Methodology

The surface of the ocean, a dynamic and complex system, is typically analyzed by partitioning it into a series of discrete grids, each defined by unique latitudinal and longitudinal coordinates. Within each grid cell, SST values are recorded at regular intervals, assembling into a three-dimensional grid that encapsulates both spatial and temporal dimensions. The forecasting of SST within this 3-D grid represents a substantial challenge due to the intricate interactions of atmospheric and oceanic phenomena. This study focuses on predicting future SST values by capturing the sequential relationships inherent within the SST dataset, employing advanced neural network architectures specifically designed for handling spatio-temporal data.

2.1 Long Short-Term Memory

To address the temporal aspect of SST prediction, we utilize the LSTM architecture, renowned for its ability to model long-range dependencies within time series data. Unlike traditional RNNs, LSTMs are adept at avoiding the vanishing gradient problem, making them particularly suitable for tasks requiring the understanding of long-term temporal relationships. It processes a sequence of input and output pairs $\{(x_t, y_t)\}^n{}_{t=1}$ at each time step. At the current time step, using the pair (x_t, y_t), the LSTM cell takes the new input x_t and the hidden vector h_{t-1} from the previous time step, generating an estimated output $\hat{y}_t$, alongside new hidden vector h_t and memory vector m_t. This feature is crucial for our study, given the nature of SST data, which exhibits dependencies over varying temporal scales. The structure of an LSTM cell is illustrated in Fig. 1.

2.2 ConvLSTM2D

The ConvLSTM2D layer merges the principles of CNNs and LSTM networks. It extends LSTM's capabilities by integrating convolutional operations, allowing for the concurrent modeling of spatial structure and temporal dependencies (see Fig. 2). This fusion is particularly advantageous for SST prediction, as it adeptly captures relationships between adjacent grid points over time and space.

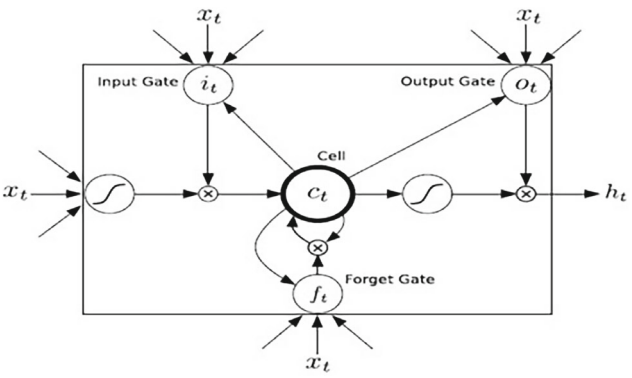


Fig. 1 Structure of LSTM cell [4]

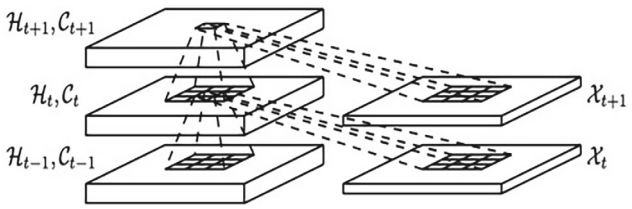


Fig. 2 Inner structure of ConvLSTM

2.3 3D Convolution

The Conv3D layer plays a crucial role in the proposed model for SST prediction by incorporating both spatial and temporal relationships. It extends the concept of 2D convolutions to include the temporal dimension as well. By convolving a 3D receptive field with the input, the Conv3D layer considers neighboring grid points in both spatial and temporal dimensions, enabling it to capture the intricate patterns and trends present in the SST time series data.

2.4 Network Structure

Figure 3 showcases the ConvLSTM-3D network's architecture, which is meticulously designed to leverage the combined strengths of ConvLSTM2D and Conv3D layers, addressing the unique challenges of SST prediction. The network begins with ConvLSTM2D layers, each followed by batch normalization to promote stable learning across the spatial and temporal dimensions of the data. This progression toward a Conv3D layer allows for an integrated analysis, synthesizing the extracted spatial and temporal features into accurate SST forecasts. The choice of this architecture is grounded in its proven effectiveness in handling complex spatio-temporal data, aligning with the inherent characteristics of SST variations.

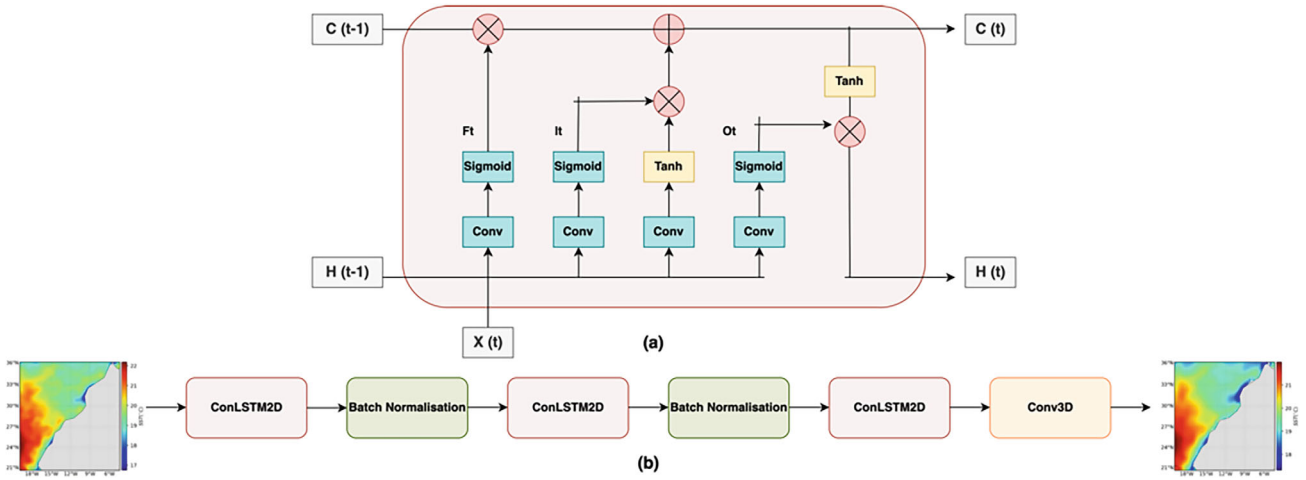


Fig. 3 **a** ConvLSTM2D architecture; **b** network architecture

3 Results and Discussion

3.1 Study Area and Data

Our dataset includes a total of 15,256 days of SST images, providing a comprehensive understanding of SST variations over time in the specified region for the period from September 1981 to December 2022. Figure 4 shows an example of these products that are used in this work.

3.2 Experimental Setup

The approach focuses on enhancing SST prediction through an ConvLSTM-based model. A key challenge lies in determining the optimal historical observation length for predicting future SST values, striking a balance between accuracy and computational efficiency. The model architecture features a tailored input layer followed by three progressive ConvLSTM2D layers, incorporating larger filter sizes and BatchNormalization with ReLU activation for stability. The architecture culminates in a Conv3D layer using sigmoid activation for final predictions. The model is thoughtfully compiled with MAE loss and the Adam optimizer. Evaluation metrics encompass MSE and RMSE, supported by early stopping and learning rate reduction to prevent overfitting. Training involves predefined batches and epochs, using both training and validation datasets. Data division entails utilizing 1981–2018 data for training, 2019–2022 data for validation and testing, and 2023 data for comparison. The approach's effectiveness is measured against three regression models (SVR, MLPR, LSTM-FC Hybrid Network), emphasizing RMSE's importance, particularly area average RMSE for accurate spatial predictions.

3.3 Results and Discussion

In the analysis of SST data from Morocco's Atlantic coast, our experiment benchmarked the ConvLSTM-3D network against three other regression models—SVR, MLPR, and LSTM-FC. The study aimed to predict one-day and three-day SST values. According to Table 1, our experimental setup and results highlight the ConvLSTM-3D network's superior performance in predicting SST values, as evidenced by its significantly lower area average RMSE compared to traditional regression models and even a hybrid LSTM-FC network. This superiority is attributed to the network's intricate design, which is specifically tailored to capture the dynamic spatio-temporal relationships inherent in SST data.

Table 1 shows the results of one day and three days prediction. The boldface items in the table represent the best performance, i.e., the smallest area average RMSE. It can be seen from the results that the ConvLSTM-3D network achieve the best prediction performance.

For a more detailed overview, Fig. 4 illustrates the network's predictions against actual SST measurements at a specific location over a three-day period in 2023. This comparison vividly demonstrates the network's high precision in forecasting SST, with minimal discrepancy between predicted and actual values. The advantages of the ConvLSTM-3D network lie in its exceptional precision in

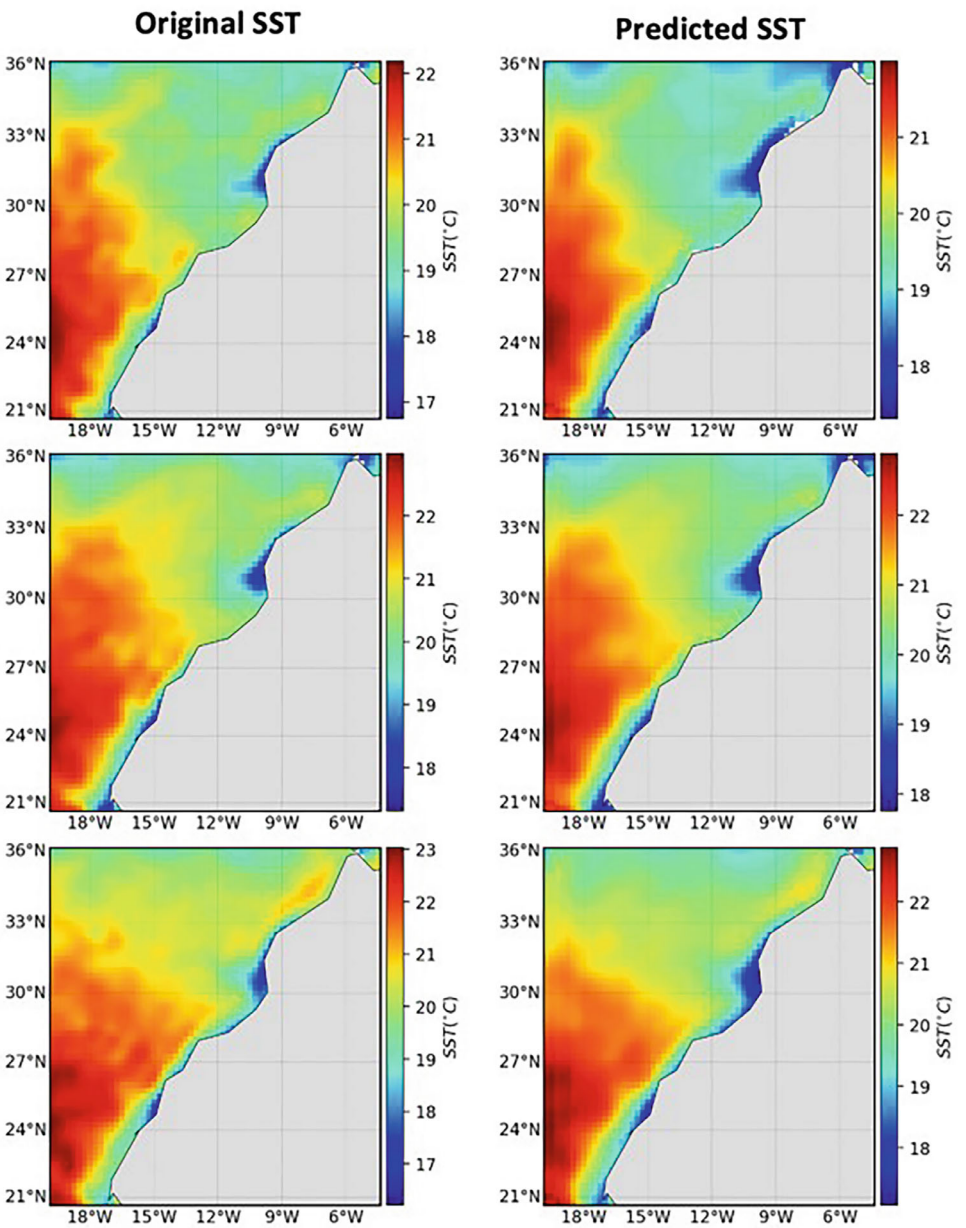


Fig. 4 SST three-day prediction at one location using ConvLSTM-3D network

Table 1 Table prediction results (AREA AVERAGE RMSE) on the Morocco's Atlantic coast SST dataset

Methods	One day	Three days
SVR	0.3998	0.6158
MLPR	0.6633	0.8215
LSTM-FC	0.0767	0.1775
ConvLSTM-3D network	**0.0028**	**0.0214**

short-term SST predictions, which is critical for effective climate modeling and disaster response planning. However, the network may have limitations, such as potentially higher computational requirements compared to simpler models, and its performance might vary for longer-term predictions.

4 Conclusions

In conclusion, our study has introduced an LSTM-based ConvLSTM-3D model that shows great promise for SST prediction on Morocco's Atlantic coast. This model stands out for its accuracy in both short-term and extended forecasting, which can significantly contribute to climate change adaptation and the safeguarding of marine ecosys-

tems. Future work will aim to enhance the model's efficiency and extend its forecasting prowess across different regions, with the incorporation of diverse environmental indicators to bolster its accuracy and utility in broader climate-related applications. Moving forward, our research will explore strategies to optimize the network's computational efficiency without compromising its predictive accuracy. Additionally, extending the model to accommodate longer-term predictions will be a key focus, aiming to broaden its applicability for climate research and operational forecasting.

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A Google Earth Engine Approach for Wildfire Damage Assessment in the National Park of Talassemtane (NPT) Using Comparative Analysis of Normalized Burn Ratio (NBR) Index from Multitemporal Sentinel-2 Imagery

Ali Azedou, Said Lahssini, Nizar Troudi, and Aouatif Amine

Abstract

Burned area mapping provides valuable insights that underpin effective fire management. Spatiotemporal quantification of the extent of burned areas affords an indication of fire severity and potential resulting ecological disruption. In the present study, burned area was analyzed for multiple districts within the National Park of Talassemtane (NPT) from 2016 to 2022 using Google Earth Engine's (GEE) cloud computing capabilities. The Normalized Burn Ratio (NBR) index was calculated for the pre-and post-fire Sentinel-2 imagery for 28 wildfire events. Results indicated substantial interannual variability in burned surface area in the study region from 2016 to 2022, ranging from 50 to over 213 hectares. Moreover, significant differences in burned area across rural municipalities were noted. The rural municipalities of Tassift, Bni Selmane, and Al Oued experienced the majority of burned area, with Tassift alone accounting for over 60% of the total. The burned surface area ranged from a few hectares in some districts to over 458 hectares in Tassift, indicating uneven fire risk and impact across the region. Analysis of climate data for the region revealed that years with higher average annual temperatures (about 16.94 °C) and lower relative humidity (63.69%) tended to have more burned area, suggesting climate is a primary driver of wildfire activity. The produced burned area maps provide indispensable identification of fire-prone areas by revealing locations that tend to experience the most frequent and/or severe fires, aiding targeted fire prevention and management. Further investigation of potential drivers such as climate variability and changes in fire management strategies may elucidate the underlying factors shaping the observed burn patterns.

Keywords

Remote sensing · Natural hazard · Susceptibility mapping · Cloud computing

1 Introduction

Wildfires pose significant challenges to ecosystem integrity and human well-being around the world (Boegelsack et al. 2018; Wang et al. 2021; Xu et al. 2020). Effective fire management requires understanding fire occurrence patterns and activity over space and time (Hiers et al. 2003). Spatiotemporal quantification of burned areas via remote sensing provides critical insights into fire activity, severity, and recurrence patterns (Chhabra et al. 2022). Such analyses can identify fire-prone regions and reveal potential biophysical and anthropogenic drivers of fire risk.

The detection of burned areas in remote sensing has primarily relied on spectral changes between pre-and post-fire imagery. Several vegetation indices sensitive to changes in vegetation cover have been widely used (Kumar et al. 2022; Zeng et al. 2022), including the NBR (Weber and Yadav 2020; Chasmer et al. 2017; Tariq et al. 2021), which exploits reflectance in the near-infrared and shortwave-infrared portions of the electromagnetic spectrum. More recently, time series analyses of vegetation indices and machine learning approaches have further improved burned area mapping at finer spatial and temporal resolutions.

A. Azedou (✉) · A. Amine
National School of Applied Sciences, Ibn Tofail University, Kenitra, Morocco
e-mail: aliazedou@gmail.com

A. Azedou · S. Lahssini
National School of Forestry Engineering, Salé, Morocco

N. Troudi
Laboratory of Sedimentary Basins and Petroleum Geology (SBPG), Geology Department, Faculty of Sciences of Tunis, University of Tunis El Manar, Tunis, Tunisia

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Climate is a primary driver of wildfire activity (Aldersley et al. 2011), with factors like temperature, precipitation, and humidity influencing fire ignition, spread, and severity. Higher temperatures favor fire ignition by lowering fuel moisture and increasing evapotranspiration, while lower precipitation and humidity decrease fuel moisture over longer timescales. Climate change is projected to further exacerbate wildfire risk in many regions through more extreme heatwaves, droughts, and seasonal aridity (Ruffault et al. 2020).

The current study employed remote sensing and geospatial analyses to map and investigate burned areas within the National Park of Talassemtane (NPT), Northern Morocco, between 2016 and 2022. Specifically, Normalized Burn Ratio (NBR) indices were calculated from pre-and post-fire Sentinel-2 imagery to delineate burned areas. The objectives were twofold: (1) to characterize spatial and temporal variation in burned area within and across municipalities in the park, and (2) to explore potential climate drivers of observed burn patterns. The resultant burned area maps highlight districts that tend to experience frequent and/or severe fires, which may aid the development of targeted management interventions and fire prevention strategies tailored to local conditions within the park.

2 Methods

2.1 Burned Area Detection and Analysis

A 10% cloud masking was applied to the Sentinel-2 image collection to mask obstructions from cloud and cloud shadow pixels. The pixel quality band was used to mask out cloud and cirrus pixels based on specified thresholds. Composite images for the pre-and post-fire periods were generated by mosaicking the cloud-masked images within each time period. Images that intersected the study area boundary were filtered from the collection and clipped to the region of interest.

Burned areas were mapped using the Normalized Burn Ratio (NBR) index derived from the near-infrared and shortwave-infrared bands of the Sentinel-2 imagery. It was computed using the following equation:

$$\mathrm{NBR} = \frac{(\mathrm{NIR} - \mathrm{SWIR})}{}(\mathrm{NIR} + \mathrm{SWIR}),$$

where NIR is the reflectance in Band 8 and SWIR is the reflectance in Band 11.

The index was calculated separately for pre-and immediate post-fire acquisitions (within 2 weeks) for 28 wildfire events. The differenced Normalized Burn Ratio (dNBR) was then computed by subtracting the pre-fire NBR from the post-fire NBR. Annual and cumulative burned area maps at 10 m spatial resolution were produced for the period 2016–2022. Burned area statistics were derived for each year and each rural municipality by calculating the number of pixels and corresponding hectares within each class. The percentage of total burned area accounted for by each class was also determined. Climate data spanning 2016–2022 were extracted and annual statistics including mean, maximum, and minimum temperature and precipitation were calculated.

2.2 Climate Data Analysis

Annual temperature, precipitation, and relative humidity data spanning 2016 to 2022 were obtained from the MERRA-2 reanalysis dataset produced by NASA (Global modeling and assimilation office and Pawson 2015). MERRA-2 provides temporally continuous measurements of climate variables derived by assimilating observations into a numerical weather assessment model.

3 Results

3.1 Burned Areas

Figure 1 shows the calculated burned areas over the years and across the rural counties. Burned area within the study region varied considerably from 2016 to 2022. The highest burned surface occurred in 2019 (213 ha), while the lowest (50 ha) was recorded in 2017. Total burned area over the 7-year period was 743 ha. Burned surface generally declined after the peak years of 2018 and 2019, though moderate fire activity continued through 2022. *The results show considerable spatial variability in burned area across municipalities. Tassift municipality suffered the most fire impacts, incurring over 458 hectares and representing over half of the total burned surface from 2016 to 2022. In contrast, some municipalities experienced minimal fire activity.*

3.2 Spatial *and Temporal Assessment* of Burned Areas

The high-resolution burned area maps produced (Fig. 2) help identify *fire-prone districts to mitigate wildfire risk.* The *concentration of burned area within a few* municipalities *points to spatial clustering of fire risk and highlights the need for targeted fire management strategies tailored to high-risk zones to mitigate future fire occurrence.*

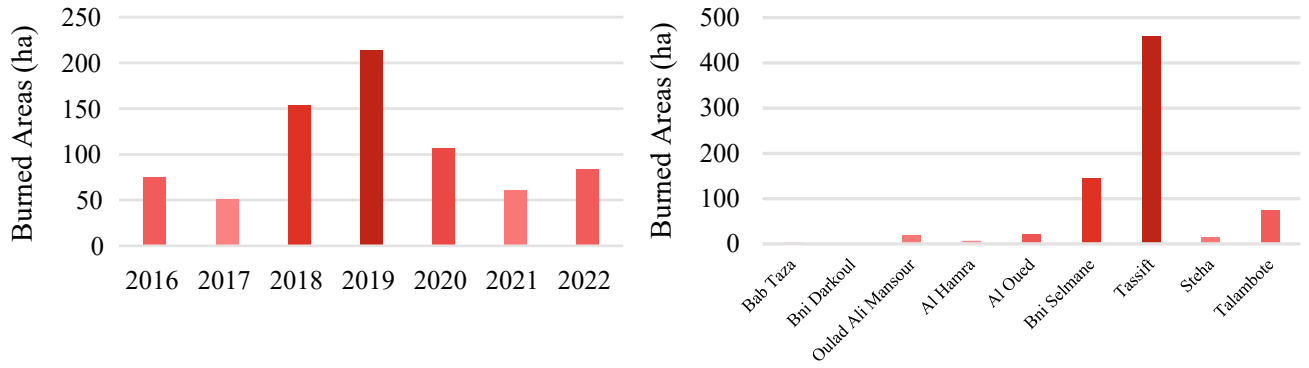


Fig. 1 Burned area surfaces in the TNP by year and rural counties from 2016 to 2021

Fig. 2 Spatial distribution of burned areas in the National Park of Talassemtane over years and rural areas from 2016 to 2021

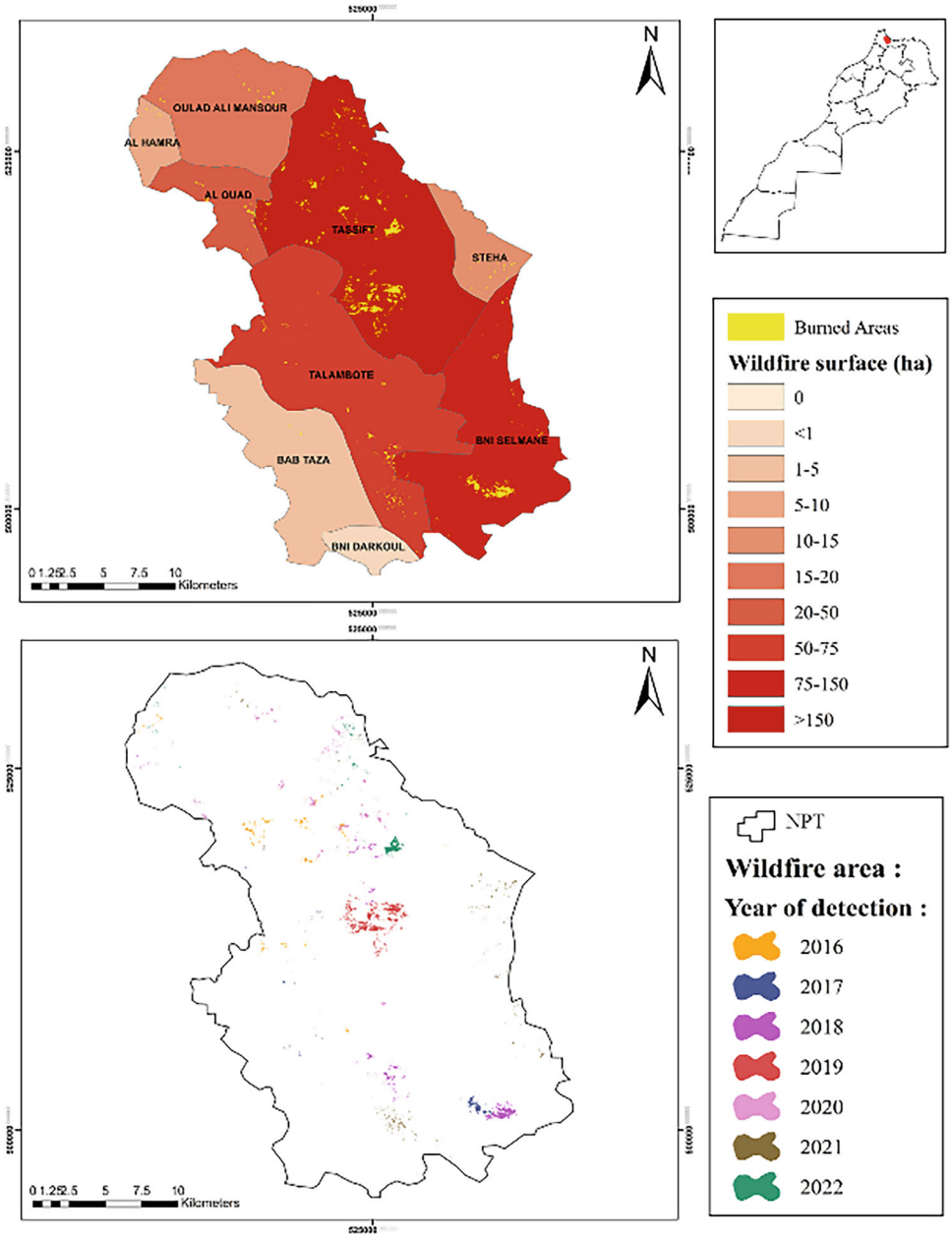


Table 1 Summary of climate variables for the TNP, 2016–2021

Year	Precipitation (mm/day)	Temperature at 2 meters (C)	Relative humidity at 2 meters (%)
2016	2.7	16.41	67.06
2017	1.63	16.92	63.69
2018	4.03	15.26	72.06
2019	1.73	16.45	64.62
2020	2.12	16.94	66.69
2021	2.06	16.7	67.81

3.3 Climate Data

The mean annual temperature across the study period (Table 1) from 2016 to 2021 ranged from 15.26 °C to 16.94 °C, with little variability between years. Slightly higher temperatures in the order of 16.4–16.9 °C were observed in 2016 and 2019–2020. Relative humidity exhibited slightly more variation, fluctuating between 63.69 and 72.06%. The lowest humidity occurred in 2017 and the highest in 2018. With regard to precipitation, annual totals varied from 1.63 mm/day in 2017 to 4.03 mm/day in 2018. The years 2016 and 2019–2021 received intermediate precipitation in the order of 1.7–2.7 mm/day.

4 Discussion

The results demonstrate substantial spatial and temporal variation in burned area within the NPT from 2016 to 2022. Some municipalities experienced frequent and severe fires, while others were relatively unaffected, pointing to heterogeneous fire risk across the park. Climate variables such as temperature and humidity also exhibited interannual differences that correlated with the extent of burned area. Years with warmer and drier conditions tended to have more extensive wildfires, indicating climate is a primary driver of fire activity in the park. The uneven fire patterns suggest complex interactions between local vegetation, terrain, human factors, and climate that vary across municipalities. The high-resolution burned area maps produced can aid in developing tailored fire management strategies for high-risk zones. Continued monitoring of burned area together with ongoing climate assessments would be valuable for detecting changes in fire regimes over time.

The findings of a linkage between climate and fire activity align with previous research demonstrating climate is a major control on wildfire regimes (Mueller et al. 2020; Hidayati et al. 2020). With rising global temperatures and more frequent droughts projected under climate change, fire activity and burn severity are expected to worsen in many regions (Bilbao et al. 2020). Studies have found climatic warming is already driving increases in the size and frequency of forest fires, as well as extending wildfire seasons (Juang et al. 2022). Consequently, organizations like the Intergovernmental Panel on Climate Change (IPCC) have highlighted the threat of climate change to ecosystems and communities from more extreme fire weather and activity (Jia et al. 2019). The results of the current study reaffirm the value of continued landscape and climate monitoring for developing proactive adaptation measures to mitigate worsening fire risk under global warming.

5 Conclusions

The study found considerable spatial and temporal variability in burned area within the NPT from 2016 to 2022. Tassift municipality suffered the most severe wildfires, incurring over 60% of the total burned surface area. Climate variables were associated with observed burn patterns, indicating climate is a primary driver of fire occurrence. The results highlight specific fire-prone districts and potential climate drivers to inform targeted fire management strategies. Continued monitoring and adaptation strategies will be critical to mitigate worsening fire risk under future climate change.

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Satellite Climate Data for Hydrometeorological Analysis in Data-Scarce Regions

Yassine Hammoud, Fatima-Zahra Tabyaoui, Youssef Allali, Soukaina Jaydawi, and Abderrahim Saadane

Abstract

Access to reliable hydrometeorological data is crucial for effective climate and water resource management. This study evaluates the utility of raw TerraClimate datasets as a complementary data source for estimating hydrometeorological variables in regions with limited data availability, focusing on the Meknes Plateau and Middle Atlas Causse region, characterized by a Mediterranean climate and karst plateaus. Through linear regression analysis, bias assessment, and correlation coefficient calculations, satellite-derived measurements are compared with gauge station observations. Results indicate a satisfactory correlation between TerraClimate data and gauge station observations for precipitation values, with coefficients of determination (R^2) ranging from 0.26 to 0.94 (average of 0.81). Temperature estimates demonstrate high R^2 values averaging 0.99 for all stations. However, challenges arise in estimating actual and potential evapotranspiration, with R^2 values ranging from 0.69 to 0.95, and biases indicating underestimation across stations. While precipitation and temperature estimations exhibit high accuracy, caution is required when interpreting evapotranspiration variables due to persistent biases. Root-mean-square error (RMSE) and mean absolute error (MAE) analysis reveals moderate to significant prediction errors, emphasizing the need for further refinement in data processing techniques. Overall, TerraClimate datasets offer valuable insights for hydrometeorological estimation in data-scarce regions like the Meknes Plateau and Middle Atlas Causse. These findings underscore the potential of satellite data for informed decision-making in climate and water resource management. However, addressing regional-specific biases and improving evapotranspiration estimation accuracy are essential for enhancing the reliability of satellite-derived data in such contexts.

Keywords

TerraClimate · Hydroclimate · Meknes plateau · Middle Atlas Causse · Data-scarce

1 Introduction

Access to accurate and comprehensive hydrometeorological data is fundamental for climate research and sustainable water resource management. However, many regions around the globe face challenges in data collection, notably due to inaccessible terrains and the scarcity of ground measurements. In these contexts, data from satellites represent a promising solution for estimating key hydrometeorological variables. This study focuses on evaluating the potential of these data to complement traditional ground-based measurements in estimating essential hydroclimatic variables such as precipitation, temperature, evapotranspiration, and runoff.

In Morocco, a growing water crisis, exacerbated by the effects of climate change, is raising increasing concerns. Rising temperatures and decreasing precipitation significantly impact the country's water resources (Cherif et al. 2023; World Bank Group 2022a; World Bank Group 2022b). However, meteorological data collection, particularly in mountainous regions like the Middle Atlas Causse and the Meknes Plateau, remains a major challenge due to limited data coverage (Hanchane et al. 2023a).

Faced with these challenges, the use of satellite data is emerging as a promising alternative to address the lack of ground-based data (Hanchane et al. 2023a). Despite their potential, products such as TerraClimate remain underutilized in Morocco (Hanchane et al. 2023a). This study aims to eval-

Y. Hammoud (✉) · F.-Z. Tabyaoui · Y. Allali · S. Jaydawi · A. Saadane
Centre of Water, Natural Resources, Environment, and Sustainable Development (CERNE2D), Faculty of Sciences, Mohammed V University, Rabat, Morocco
e-mail: yassine.hammoud@um5r.ac.ma

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uate the effectiveness of TerraClimate datasets in complementing observed ground data, especially for key hydrometeorological variables. Comparing raw TerraClimate (Abatzoglou et al. 2018) data with observations will help better understand hydroclimatic trends in the study region and highlight any discrepancies between the two data sources.

This research is part of an effort to fully exploit the potential of TerraClimate products to enhance understanding of hydroclimatic processes. By analyzing the reliability of TerraClimate data compared to ground-based measurements, it will contribute to strengthening assessment and management capacities of water resources in the region, while also opening new perspectives for the use of these data in other geographical contexts facing similar challenges.

2 Methodology and Materials

2.1 Study Area

The Middle Atlas Causse and the Meknes Plateau, located between the South Rif Fault and the Middle Atlas Range, cover 9100 km^2. The former is karstic limestone, while the latter is lacustrine. Their climate is sub-humid mountainous with precipitation ranging from 300 to 600 mm and temperatures between 12 and 16 °C. They belong to the Sebou watershed, the most important in Morocco (Daguin 1927; Lepoutre et al. 1967; Amraoui 2005; Bentayeb and Leclerc 1977).

2.2 Data Collection

Hydroclimatic data from 1971 to 2001 were collected from eight spatially distributed meteorological stations in the study area (Fig. 1): Aguelmam Sidi Ali, Azrou, Azzaba, Chelihet, Dar El Arsa, El Hajeb, Ifrane, and Meknes. The Sebou Hydraulic Basin Agency (ABHS) and the Provincial Directorate of Agriculture (DPA) of Meknes provided precipitation and temperature data. Evapotranspiration (actual and potential) and runoff were estimated from these data, along with the crop coefficient Kc, determined using the equation generated by Runtunuwu (Runtunuwu 2006) based on NDVI values. Monthly data from the TerraClimate dataset, which has a spatial resolution of approximately 4 km, were also utilized. A detailed analysis was conducted to compare data from individual meteorological stations with corresponding Terr-

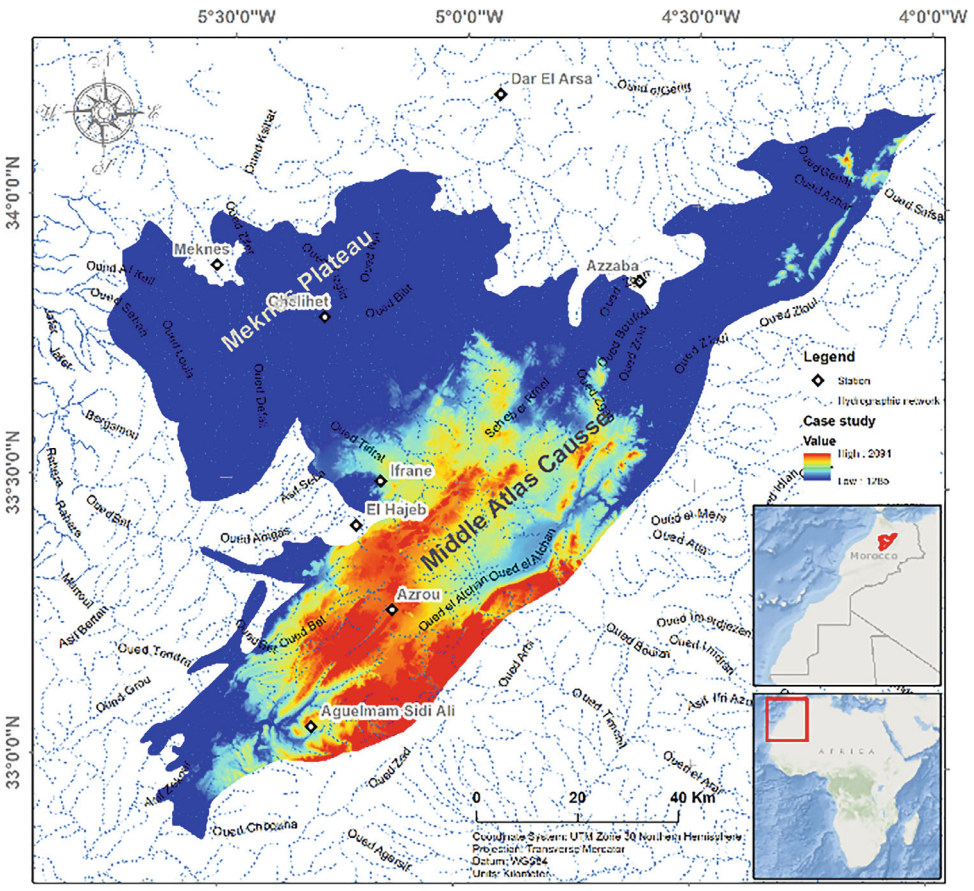


Fig. 1 Geographical setting of Meknes Plateau and Middle Atlas Causse

Table 1 Comparison of monthly interannual averages of observed hydrometeorological variables with TerraClimate raw data products for the period 1971–2001

Variable	PCC	Bias	RMSE	MAE
Precipitation	0.92	− 3.69	15.37	11.55
Temperature	0.99	− 1.29	1.44	1.31
aET	0.96	1.09	9.82	7.31
pET	0.99	− 14.74	17.04	15.02
Runoff	0.98	0.22	5.48	2.55

aClimate data, evaluating the consistency of the latter with ground-based measurements (Solaimani and Ahmadi 2024).

2.3 Data Preparation

Data preparation involved reviewing the quality of precipitation and temperature data, followed by filling gaps by calculating the average of interannual monthly precipitation. To detect and correct heterogeneities, data series homogenization was performed using double-sum analysis and a correlation estimator. Potential evapotranspiration was estimated using the Thornthwaite (Thornthwaite and Mather 1955) equation, while actual evapotranspiration (aET) was calculated based on potential evapotranspiration (pET) and the crop coefficient Kc. Runoff was estimated using the Tixeron-Berkaloff (Tixeront 1950; Berkaloff 1951) formula based on annual precipitation and potential evapotranspiration.

2.4 Data Evaluation

A statistical regression analysis was conducted to assess the reliability of TerraClimate datasets compared to measured data, using metrics such as the Pearson Correlation Coefficient (PCC), the Nash-Sutcliffe Efficiency Coefficient (NSE), the Root Mean Square Error (RMSE), the Mean Absolute Error (MAE), and Bias (BIAS).

3 Results and Discussion

The comparison between raw TerraClimate data and meteorological station observations reveals moderate correlation for various parameters. In the study region and over the entire study period, precipitation shows an average PCC of 0.92, with minimal errors of 15.37 mm/month for RMSE and 11.55 mm/month for MAE, while temperature measurements exhibit even stronger correlation, with a PCC of 0.99 and minimal errors.

Both actual evapotranspiration (aET) and potential evapotranspiration (pET) also show high correlations, although TerraClimate tends to slightly overestimate both aET and pET compared to observations.

For runoff, TerraClimate generally aligns well with observed values, although there may be some discrepancies.

Although some minor divergences persist, they do not significantly affect the overall reliability of the information derived from TerraClimate datasets for hydrometeorological variables.

The results obtained already demonstrate moderate reliability of raw TerraClimate data without the application of any correction, which places them ahead of other studies that rely on satellite-derived estimates, where larger discrepancies are often observed. On average, raw precipitation data from TerraClimate exhibit a correlation coefficient of 0.92 with ground measurements, with a slight bias of −3.69. In comparison, Al-Sheradeh's (Al-Sheriadeh and Al-Sharman 2024) study reveals varied performance for other monthly products such as TRMM 3B43, with PCCs ranging from 0.83 to 0.95 and biases reaching up to −13.07, and PERSIANN-CDR with PCCs ranging from 0.69 to 0.88 and biases reaching up to −45.2. On the other hand, Hanchane (Hanchane et al. 2023b) showed in their study that TerraClimate raw data are quite accurate in estimating monthly precipitation in most stations during the rainy season but struggle to capture summer precipitation (Table 1).

The following graphs (Fig. 2) show interannual monthly trends (between 1971 and 2001) for all parameters studied at the level of the study region.

4 Conclusion and Perspective

In conclusion, the evaluation of raw TerraClimate datasets reveals a strong correlation with meteorological station observations for a range of hydrometeorological parameters. However, minor divergences persist, highlighting the need to apply corrections before directly using these data. These results underscore the importance of further research to develop appropriate correction methodologies, while continuing to assess the performance of corrected data in different geographical and climatic contexts.

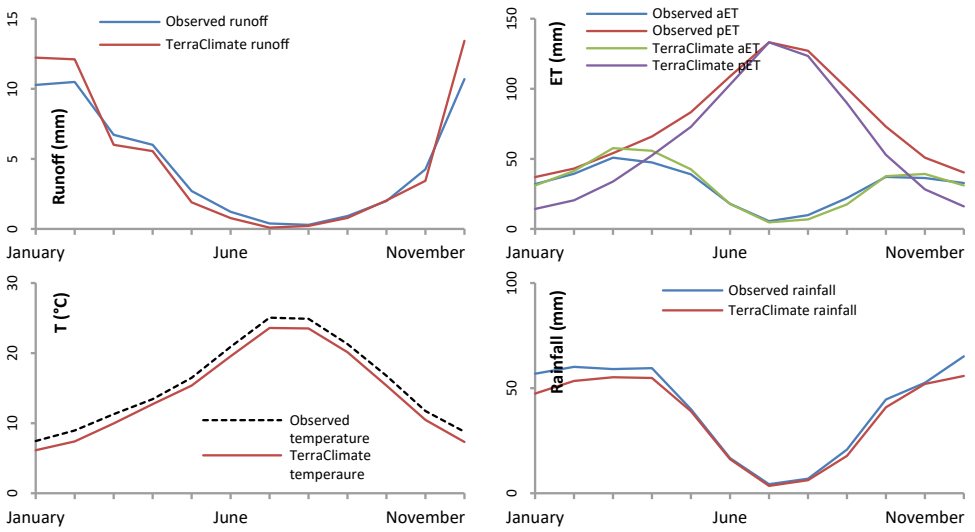


Fig. 2 Comparison of monthly interannual averages of observed hydrometeorological variables with TerraClimate raw data products for the period 1971–2001

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Microtopography Reconstruction for Agriculture 4.0 Purposes: Assessment of UAV-Photogrammetry and UAV-Lidar Procedures and Benchmarks

Federico Barbieri, Francesco Ioli, Lorenzo Rossi, and Carlo Iapige De Gaetani

Abstract

In the framework of the so-called Agriculture 4.0, the use of geomatics techniques like unmanned aerial vehicles (UAV) photogrammetry is a common practice to determine high-resolution digital terrain models (DTMs), typically needed for surface water flow modeling and subsequent resource management optimization tasks. In this framework, spatial resolution, accuracy, and consistency of input DTMs are critical factors for successful analyses. On the other hand, requirements on the quality of the survey products must be met while adopting standardized practices, commercial-grade equipment and easy-to-use processing tools and workflows. The aim of this work is to carry out an assessment of different technologies for deriving high-accuracy DTMs by UAV-photogrammetry or UAV-lidar, comparing the results achievable with mid to high-level equipment and defining best survey practices for soil/land digital modeling in a modern agricultural context. A field of about 24 ha, composed of different land plots at different stages of preparation for the incoming sowing season, was used as a test site. Different surveys were simultaneously conducted with equipment ranging from a DJI Phantom 4 RTK to a DJI Matrice 300 RTK. The latter was equipped with both a DJI ZenMuse P1 full-frame camera and a DJI ZenMuse L1 Lidar. Topographic-grade GNSS was used to measure on-ground targets, to be used either as ground control points or check points, and about 300 points with 30 m grid spacing. A comprehensive assessment is discussed, while also considering practical and on-field challenges (field operations, time-consuming tasks, ease of use, skills and experience requirements) and investigating the capability of reaching a target centimetric accuracy in the determination of the DTM. Preliminary results show that the target quality of the obtained DTMs at microtopographic scale is achievable also with less sophisticated equipment, provided that a skilled and experienced processing workflow is carried out. Moreover, proper planning of field operations is crucial for achieving successful results. The frontier of geomatics techniques for Agriculture 4.0 tasks looks toward the use of low-end technology but, at the same time, it clarifies the need for skilled and experienced operators to avoid the risk of misleading or poor-quality results.

Keywords

Drones · Structure-from-motion · Lidar · Smart agriculture · Microtopography

1 Introduction

The term "agriculture 4.0", related to the "fourth agricultural revolution", dates back 2015 and refers to the impact of sensors, satellites, digital technology, and robotics on precision farming applications (Frankelius et al. 2019). In this sense, the use of drones and Unmanned Aerial Vehicles (UAV) is nowadays a common practice. In the general framework of surface water flow modeling and water management optimization, the use of geomatics techniques like drone-based photogrammetry and LiDAR (Light Detection And Ranging) surveying are standard solutions to determine high-resolution Digital Terrain Models (DTMs) at micro-topography level. A better specification of what is intended for "high-resolution" and "microtopography level" is often a hard task, as well as determining the minimum accuracy requirements of the final products. In fact, there are several examples of studies sharing the general field of research in water flow modeling but targeting more specific investigations like surface runoff pathways deter-

F. Barbieri · F. Ioli · L. Rossi · C. I. De Gaetani (✉)
Politecnico di Milano, Milan, Italy
e-mail: carloiapige.degaetani@polimi.it

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mination, hydrological connectivity, geomorphometry, stagnation phenomena detection, drainage networks design or irrigation optimization (Thomas et al. 2017; López-Vicente and Álvarez 2018; Tarolli et al. 2019; Pijl et al. 2019; Straffelini et al. 2021; Costabile et al. 2023) that rely on DTMs with very different spatial resolutions (ranging from few to several tens of cm) and accuracies (usually at centimetric level, although this information is often not well specified). The aim of this work is analyzing the process of surface roughness modeling from the geomatics perspective, defining realistic geometric benchmarks to be used as reference in different fields of applications for surface water flow modeling and hydric resources optimization purposes. The objective is clarifying the main challenges, constraints and opportunities of using geomatics techniques for surface digitalization while considering also practical aspects like equipment cost, easiness of use, required level of expertise and to provide indications with practical implications to obtain high-resolutions DTMs. This paper presents the preliminary results of such investigation, currently ongoing.

2 Methods

The whole investigation is founded on relative comparisons of DTMs, DEMs (Digital Elevation Models), and point clouds obtained by photogrammetric processing of images acquired by different equipment, as well as by drone-based LiDAR. Different processing techniques were considered to simulate different surveying strategies requiring different levels of expertise, both at the field level and in processing capabilities. In particular, a DJI Phantom 4 RTK and a DJI Matrice 300 RTK (equipped with a DJI Zenmuse P1 full-frame camera or a DJI Zenmuse L1 LiDAR) were used for the investigation. As this paper is a report of the preliminary results, the focus will be on the tests carried out with the DJI Phantom 4 RTK only.

The assessment was performed based on a fixed benchmark accuracy and spatial resolution of the surface models equal to 5 cm, assuming this to be a reasonable limit able to describe the roughness of the soil for water flow modeling and agricultural applications. As a test field, an agricultural district of about 24 ha composed of different land plots at different stages of preparation for the upcoming sowing season was used. Three consecutive flights at an average flight altitude of 120 m with a Ground Sample Distance (GSD) of about 3.3 cm were required to cover the whole test field, acquiring more than 400 images. On-ground targets to be used either as Ground Control Points (GCPs) or Check Points (CPs) in the photogrammetric process were surveyed by geodetic RTK GNSS (with an accuracy of a few centimeters). Figure 1 shows the spatial distribution of the targets used as GCPs and CPs.

Moreover, the position of the camera projection centers of the images was observed (with an accuracy at the decimeter level) by the RTK GNSS receiver mounted onboard the drone. To simulate different drone quality and cost levels, different solutions were computed. The former solution A1 uses the data observed by the onboard RTK GNSS, while the latter solutions (A2 and A3) neglect them. In this way, we simulated the presence or not of an RTK GNSS receiver onboard the drone, therefore simulating the usage of lower-cost equipment. Table 1 summarizes the different processing strategies and options, while Fig. 1 shows the spatial distribution of the targets used as GCPs and CPs in the two cases.

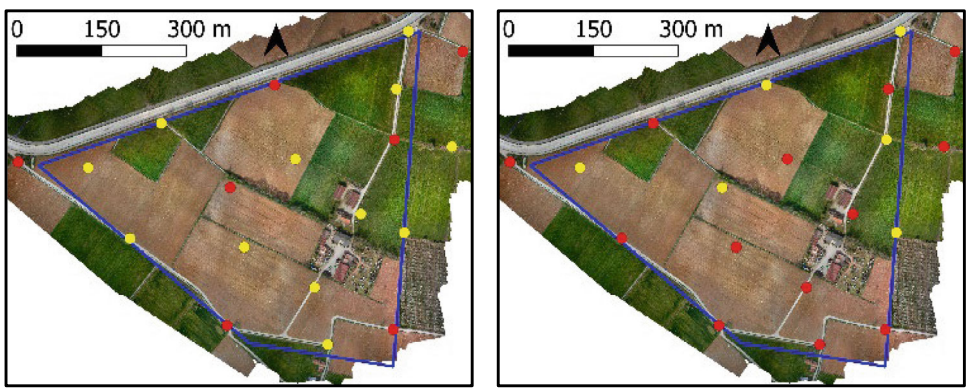


Fig. 1 Distribution of GCPs (red dots) and CPs (yellow dots) for solution A1 (left) and solutions A2–A3 (right), considering (or not) the presence of an onboard RTK GNSS receiver

Table 1 Summary of the equipment, surveying, and processing modes to be compared

ID	Camera calibration	Onboard RTK GNSS	No. GCPs	No. CPs
A1	Self-calibration	Enabled	7	12
A2	Self-calibration	Disabled	13	6
A3	Fixed, inherited from A1	Disabled	13	6

Photogrammetric processing was carried out with the Agisoft Metashape v1.8.2 software package.

3 Results and Discussion

Statistics on the residuals on the considered GCPs and CPs provided an initial assessment of the quality of the obtained models. In particular, the Root Mean Square (RMS) of the residuals has been considered, showing a value at the 1 cm level for the GCPs (in all three cases) and values ranging between 2.7 cm (A1 case) and 4.4 cm (A2 and A3 cases) on CPs.

As a second comparison, the differences between DEMs obtained in A1, A2, and A3 cases were computed to evaluate: a) the impact and benefits carried by the presence of the onboard RTK GNSS receiver, and b) the effect of camera self-calibration without an onboard RTK GNSS receiver. Figure 2 presents the aforementioned differences.

Figure 2a highlights the importance of the RTK GNSS positioning device onboard the drone. With respect to the GNSS aided solution A1, both A2 and A3 DEMs present different systematic biases of the order of some centimeters, directly related to the way with which the survey flight plan was designed. In fact, bands are visible and aligned with the flight strips, as well as a small tilt in the NW-SE direction is present. If such differences might be neglected at single plot scale (i.e., area smaller than 1 ha), they could affect the water flow modeling results at district scale (i.e., area of tens of ha). Figure 2b show that the availability of camera projection center positions from onboard RTK GNSS improves also the quality of camera calibration. In fact, comparing solution A1 with A3 definitely shows an attenuation of the systematical effects, reducing the difference with respect to A1 below the benchmark accuracy of 5 cm. This improvement could be also reached by a dedicated procedure for the camera calibration before the flight. Figure 3 reports a vertical cross-section of the differences between solutions. Again, the differences show that using a reliable camera calibration improves the final accuracy even without an onboard RTK GNSS receiver, being the differences between A1 and A3 almost a constant value with variability below the target accuracy. On the other hand, working without an onboard RTK GNSS receiver and exploiting camera self-calibration (difference between A1 and A2) may lead to mismodeling comparable or larger with respect to the benchmark tolerance, then impacting the further processing depending on the reliability of the digitalized surface.

4 Conclusions

In this work, we reported the preliminary results of an investigation on the capabilities of geomatics techniques based on drone surveys of surface roughness digital modeling. The focus of the paper has been on the results obtained by means of a photogrammetric survey carried out with commercial-grade equipment and different processing options, thus simulating different operative scenarios. A fixed benchmark accuracy and DEM resolution of 5 cm were defined, assuming that the computed DEM may serve for further processing in the field of surface water flow modeling. Moreover, the size of the test field was selected at the district level (tens of ha) to take into account practical implications typical when operating in the framework of "Agriculture 4.0". With such geometrical constraints, we highlighted that although typical statistical indices on GCPs and CPs were better than the target benchmarks in all the different operative scenarios, the analyses

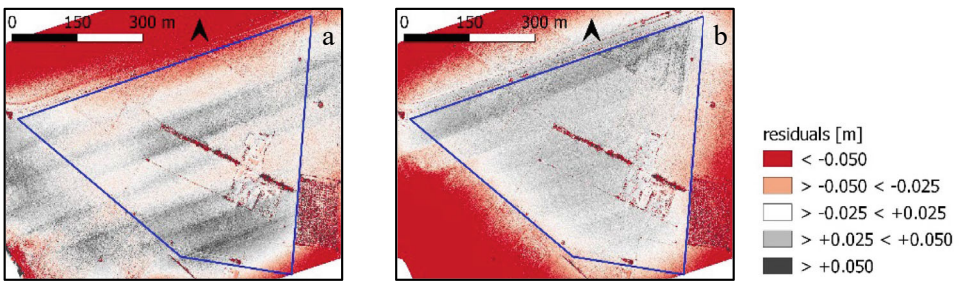


Fig. 2 DEM differences considering A1–A2 (left) and A1–A3 (right)

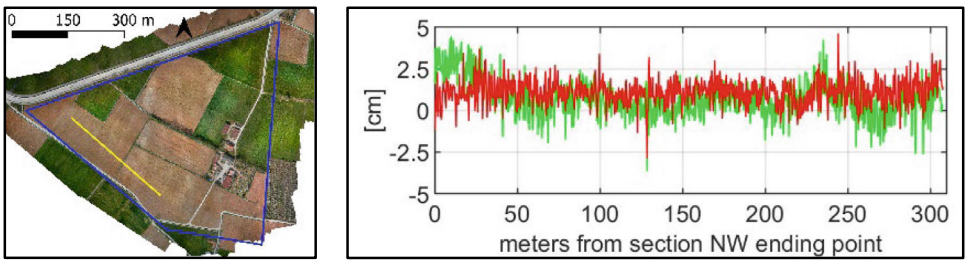


Fig. 3 Profile along a sample cross-section (yellow line in the left plot). Residuals of comparisons A1–A2 (in green) and A1–A3 (in red)

of the residuals between the produced DEMs showed that the agreement was far from being acceptable for the target of surface water flow modeling. Systematic effects that might be negligible at a single-plot scale may not be negligible at the district scale since they could potentially affect the reliability of produced DEMs and consequently of water flow modeling results, for instance for irrigation management optimization purposes.

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Climatic Micro-zonation of Naples (Italy) Through Landsat and Machine Learning

Daniela Flocco, Ester Piegari, and Nicola Scafetta

Abstract

Naples, in Southern Italy, is densely populated and severely impacted by several environmental risks associated with meteorological conditions. Because of the city's varied topography, meteorological hazards vary significantly across its territory. Heatwaves have become more common over the last decade; the creation of thermal maps would aid in understanding the different hazards within the city and provide the community with more precise information on the associated health concerns. In this study, we use Landsat data to find locations with comparable temperature anomalies throughout the year. We then use a machine-learning technique to detect seasonal similarities. We discovered that our approach aids in the identification of low-quality data and the formation of geographical clusters with similar temperature anomalies.

Keywords

Urban areas heatmaps · Hierarchical clustering · Heat waves and health risk

1 Introduction

Densely populated areas have the potential to be affected by many environmental risk factors. In the event of flooding or heatwaves, i.e., heavily urbanized areas suffer greater damage compared to less urbanized ones, as a direct consequence of the number of people and goods involved in the hazardous event. Naples has a population of about 3,000,000 people and an average density in the metropolitan area of about 2700 inhabitants/km^2 that reaches peaks of 20,000 inhabitants/km^2 in the historical center and over 10,000 inhabitants/km^2 in some municipalities around the volcanic complexes of Somma-Vesuvius and the Phlegraean Fields.

Previous studies have used model data to classify cities in terms of thermal comfort and adaptation strategies (Bassolino et al. 2021; Calama-González et al. 2022) and to integrate Automatic Weather Station data with remote sensing data (Nikoloudakis et al. 2020). Here we aim to create a climatic micro-zonation applying machine learning tecniques to Landsat temperature anomalies, to produce maps that can help the forecast and the impact of heatwaves, which can benefit the population in terms of being informed on areas which are more likely to pose a health risk related to higher-than-average temperature. Furthermore it can provide useful information for energy efficiency over a large area, which we aim to achieve through a cluster analysis of the area of study.

2 Materials and Methods

2.1 LANDSAT Data

We used Landsat 8 data to retrieve land surface temperatures (LST). We choose images for the year 2016 with a maximum cloud cover of 10%, but when a month of data was missing, we raised the cloud cover threshold until at least one image per month was available. A total of fourteen images (two for July and August), were found to be suitable for our purposes. The data were provided by SMS Engineering, and downloaded from the USGS website, and the surface temperatures were calculated using a script implemented in GoogleEngine. Landsat 8 is known to have an error of ± 2 °C (Cook et al. 2014; Jiménez-Muñoz et al.

D. Flocco (✉) · E. Piegari · N. Scafetta
Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse (DiSTAR), Scuola Politecnica e delle Scienze di Base, Università di Napoli Federico II Complesso Universitario di Monte S. Angelo, Naples, Italy
e-mail: daniela.flocco@unina.it

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2014), when using absolute temperature values, but here we use land surface temperature anomalies.

2.2 Hierarchical Clustering

We choose to use hierarchical clustering to classify our high-resolution Landsat surface temperature data and to interpret them in terms of area at higher-than-average health risk and of level of energy consumption.

Clustering is a type of unsupervised machine learning that separates data into groups with homogeneous characteristics and eliminates any subjective, biased interpretation in this process (Zhang et al. 2022; Murtagh and Contreras 2017). Agglomerative hierarchical clustering is a method of clustering analysis aimed at building a hierarchy among groups of similar data (clusters). It is a bottom-up approach that starts by treating each data point as a single cluster and then merges them step by step based on similarity until a single cluster containing all the elements is formed (Murtagh and Contreras 2017).

3 Results

3.1 Surface Temperature Anomalies

Maps of LST and of LST anomalies show that the metropolitan area of Naples is generally characterized by higher temperatures than the rest of the area considered. This is especially evident when Fig. 1 shows temperature maps and the corresponding geo-referenced thermal anomalies for months representing summer and winter respectively (August and December).

3.2 Cluster Analysis

A hierarchical clustering has been applied to the 14 Landsat images of thermal anomalies gathered for the year 2016. The dataset is represented in the form of a heatmap in Fig. 2a, where individual values of the temperature anomalies are represented by colors. The rows of the heatmap describe pixel areas, while the columns specify the investigated

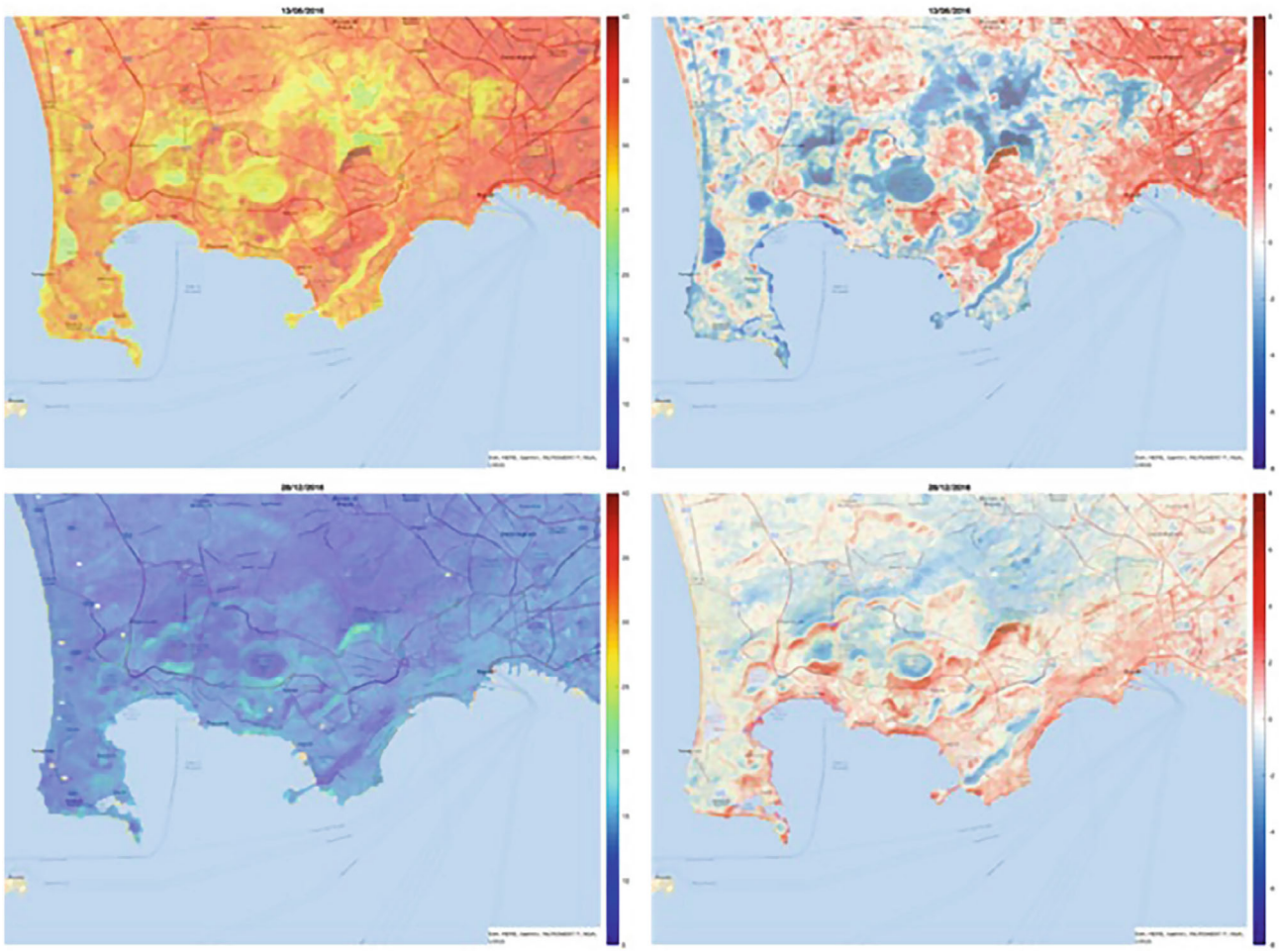


Fig. 1 Example of Landsat surface temperature in August and December 2016 (top and bottom left), and their anomalies on the right

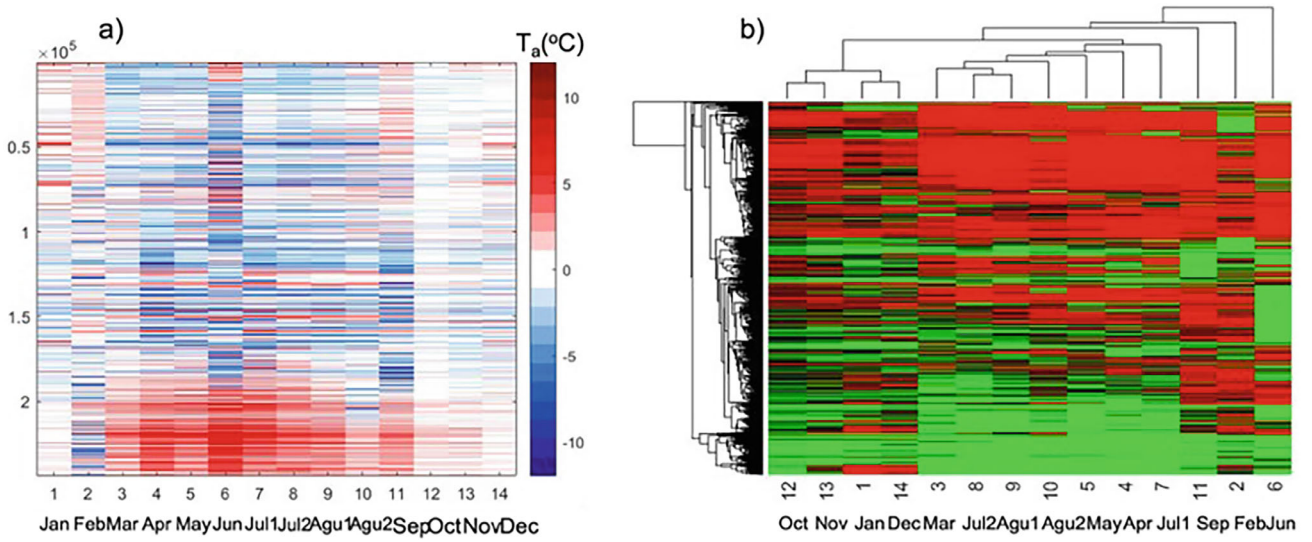


Fig. 2 Cluster analysis of the 2016 dataset. **a** Heatmap of the temperature anomalies. **b** Heatmap and dendrograms that show the results of the cluster analysis. Red and green colors represent values above and below the mean, respectively. The mean values are in black

months. To better investigate possible spatial and temporal correlations of temperature anomalies, we performed an agglomerative hierarchical clustering analysis using the Statistics and Machine Learning Toolbox of MATLAB R2023a.

Figure 2b shows the results of the cluster analysis in both the graphical representations of the heatmap and dendrograms. Months presenting the highest similarities are the columns grouped to the left, and at the top, the corresponding roots of the dendrogram are the lowest. The vertical lines indicate the clusters, while the horizontal lines connecting the clusters indicate the level of distance at which the clusters come together.

The three colors of the heatmap, black, red, and green, represent values of the mean and values above and below the mean, respectively. Here, we focus on the cluster tree on the top that shows similarities among the months. We notice that on the right end, three clades have just one leaf (x-axis 11, 2, and 6, Fig. 2b). These three chunks are completely separated from all the others and can be interpreted as outliers: the cluster analysis applied is able to automatically identify noisy data, as actually the presence of clouds affected the quality of the temperature data corresponding to these three months (11 = September; 2 = February; 6 = June). Winter months (chunks 12 and 13 and 1 and 14) are the closest link, characterized by similar spatial behavior in temperature anomalies. The next closest link is that between chunks 8 and 9 related to the summer months July and August.

4 Discussion

Our hypothesis is that some areas, regardless of the season, will show temperature anomalies of the same sign: for example, we expect that the more densely populated and cemented areas will have positive temperature anomalies, while inland or more "green" areas will be characterized by negative temperature anomalies.

During summer, the northern internal area of the city of Naples (e.g., Via Foria) becomes significantly warmer than the coastal areas of the city, which may increase the risk of heat-related mortality and other health hazards in such locations (Scafetta et al. 2017). Regardless of the clearly different absolute value, it is noted that qualitatively the anomaly maps follow similar patterns. In particular, the positive anomalies in the center of Naples and the negative ones north of the Camaldoli are evident.

The results of the clustering show similarity in the winter months, with December and January being the most similar. The months of June and November were the most dissimilar from the others because of the low quality of the images in terms of high cloud cover. One of the long-term goals of our study is the automatization of the acquisition and processing of Landsat images; therefore, this result gives us confidence that the clustering algorithm would damp images of low quality and not good enough for our purposes. Unsupervised algorithms may struggle to capture the complex spatial and temporal variations in vulnerability, potentially overlooking

critical patterns in different locations and time periods, but the high spatial resolution of the LANDSAT data counteracts this issue. Further work using a longer time series is planned.

5 Conclusions

The area of Naples is a densely populated and topographically complex one: its hilly terrain and coastal location as well as temperature gradients across different elevations can result in microclimates within the metropolitan area, with cooler temperatures at higher elevations and warmer conditions in low-lying areas (Scafetta et al. 2017).

Landsat data offer synoptical, high-resolution data that help to identify zones that present higher health risk during heatwave events due to typically higher-than-average temperatures. Accurate information on health risks related to heatwaves in the area of Naples is essential for protecting public health, developing effective adaptation strategies, and fostering community resilience in the face of increasing climate-related challenges. Our study extends to suburban areas, since they may exhibit different population density patterns compared to the city center. We also find that our methodology is capable of discarding low-quality input data (i.e., high cloud coverage).

Future work will include the use of advanced statistical analysis to classify the area of Naples and divide the area of study into high-, medium-, and low-health-risk areas and areas of high and low energy consumption required to reach a good level of comfort in housing and offices.

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Recent Evolution of High Alpine Areas: Multi-sensor Optical Satellite Imagery Analysis in the Monte Rosa Massif, Western Alps

Fabrizio Troilo, Pietro Di Sopra, Paolo Perret, Luca Mondardini, Niccolò Dematteis, and Daniele Giordan

Abstract

In recent years, both mountaineers and researchers have documented an increased degradation of high-altitude glacierized areas, leading to processes such as permafrost thawing, increased rockfall activity, and expansion of rock outcrops. Even though the high-altitude portions of large glaciers do not show significant local mass loss in the accumulation zones, the adjacent areas reveal important changes under the present context of climate change. Pilot studies have been performed, but more data from different massifs and regions are needed to better understand these phenomena. We carried out our study on a pilot area in the Monte Rosa massif, where field observations indicated a probable fast evolution of degradation processes. The analysis of rock outcrop areas was performed between 2017 and 2022. Semi-automatic classification of free-access Sentinel-2 (10 m resolution) images and manual digitization on commercial Pléiades (0.5 m resolution) imagery have been compared. Our study shows an increase in rock outcrop areas in high-altitude environments. Both datasets show similar results coherent with literature data. The higher resolution of the Pléiades dataset, resulting in a superior accuracy of the analysis, revealed that out of a total analyzed area of 28.09 km^2, the areas of rock outcrops increase by 10% in 5 years. The use of medium-resolution multispectral imagery to document the aforementioned geomorphological process has proven effective in showing the very fast shrinking of glacial areas during the study period. Still, an extension to a regional scale is needed to better define those dynamics and their recent evolution. A possible exacerbation of the processes due to the warm summer of 2022, which falls within the study period, has to be considered. Furthermore, the evolution in the next decades still remains uncertain, and high-mountain processes of the Alpine environment, such as the one outlined in the present study, have to be better observed and understood. Nevertheless, our work shows that rapidly evolving trends exist and should be monitored.

Keywords

Glacier · Ice · Remote sensing · Climate change · Permafrost

1 Introduction

The aim of this paper is to investigate the evolution of glacier surfaces and rock outcrops in recent years using satellite imagery in high-altitude Alpine terrain. The study is focused on the Monte Rosa Massif, a high-Alpine area covering approximately 150 km^2, located on the Italian-Swiss border, culminating with Dufour Peak (4635 m a.s.l.). The area, where field observations indicated a probable fast evolution of degradation processes, is characterized by the widespread presence of glaciers, seracs, and ice walls, also known as ice aprons (Ravanel et al. 2023). Repeated photographs of the area of study show macroscopic changes of rock outcrops at very high altitude (Fig. 1). To better understand this phenomenon, we analyzed satellite imagery and historical orthophotographs of the Monte Rosa Massif.

F. Troilo · P. Di Sopra (✉) · P. Perret · L. Mondardini
Fondazione Montagna sicura (FMS), Courmayeur, Italy
e-mail: pdisopra@fondms.org

F. Troilo · N. Dematteis · D. Giordan
Italian National Research Council, Research Institute for Geo-Hydrological Protection (CNR-IRPI), Torino, Italy

F. Troilo
Università di Pavia, Dipartimento di Scienze della Terra e dell'Ambiente, Pavia, Italy

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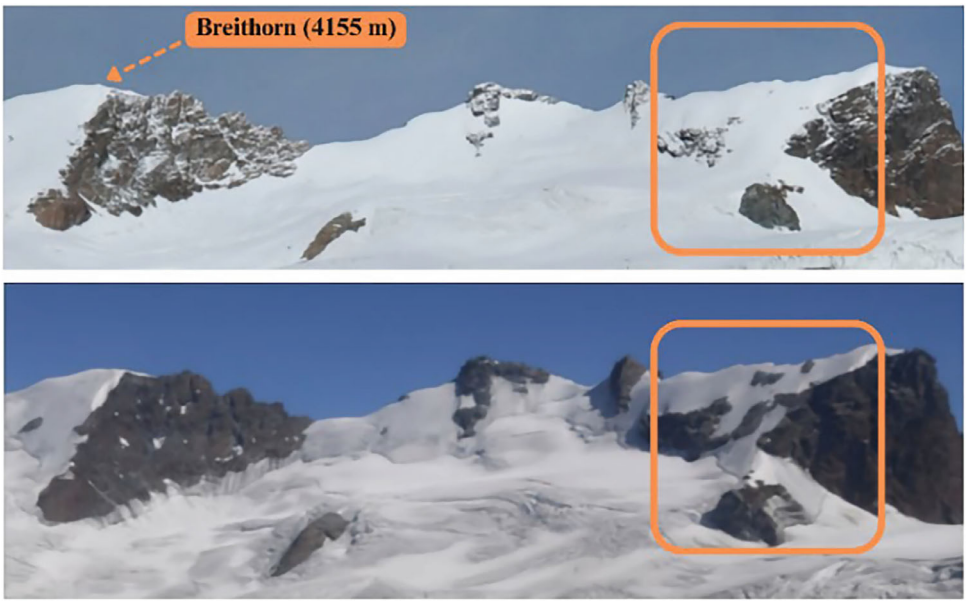


Fig. 1 The eastern ridge of the Central Breithorn peak (4155 m a.s.l.) shows changes in the areal extension of rock outcrops. Photographs from 04/10/2017 and 26/07/2022 (Fondazione Montagna Sicura archive)

2 Materials and Methods

A multitemporal and multisensor approach was chosen for this study. We analyzed distinct datasets: (i) AIRBUS Pléiades (0.5 m spatial resolution) optical imagery acquired on 15/08/2017 and 18/09/2022; (ii) freely available European Space Agency Sentinel-2 (10 m spatial resolution) optical imagery captured on 19/07/2017 and 15/07/2022; (iii) historical aerial orthophotos acquired in 1999 and 2005 by the Autonomous Region of Aosta Valley covering the Italian territory only. The added value of analyzing two distinct datasets, having spatial and temporal coherence, resides in the possibility to compare the results obtained by using freely available medium-resolution imagery with expensive high-resolution imagery as well as cross-validating the semi-automatic and the manual mapping methods. To focus exclusively on high-altitude areas, we defined an Area of Interest (AOI_f) using the NASA SRTM DEM, encompassing elevation bands above 3700 m a.s.l. The analysis of Pléiades imagery involved manual digitization performed by a trained technician using QGIS software, with a scale of 1:1000 (Fig. 2). We applied the same methodology to map rock outcrops on historical orthophotos. Sentinel-2 images were processed through a semi-automatic classification on ESA SNAP software, using band combinations and ratios as outlined by Paul et al. (2016). We classified as rocks those pixels that satisfied the equation proposed by Paul et al. (2016):

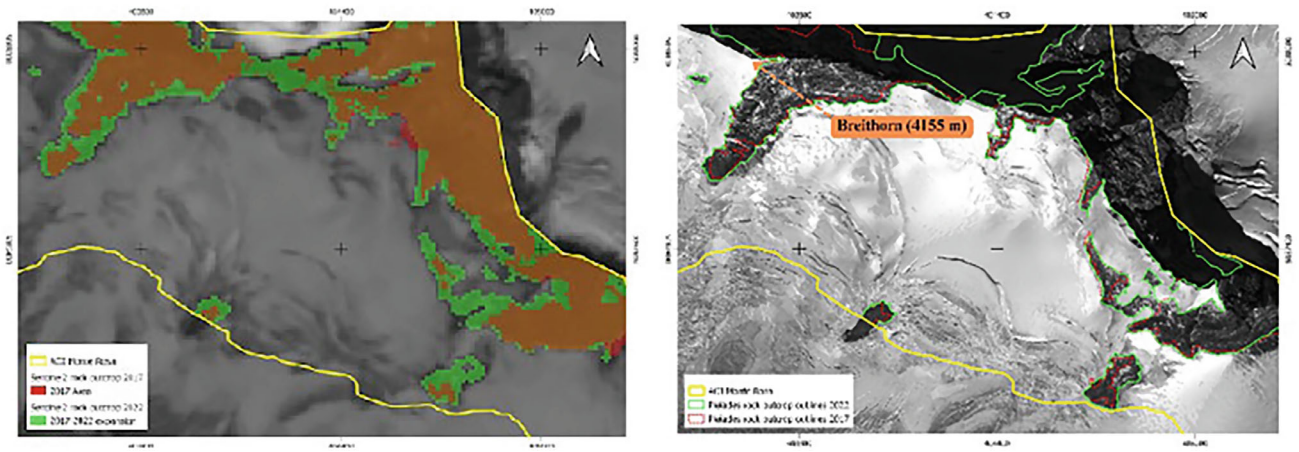


Fig. 2 Satellite imagery of the areas shown in Fig. 1. The left panel shows the semi-automatic classification of rock outcrops from Sentinel-2 imagery, while the right panel displays the manual classification on Pléiades imagery (2017 vs. 2022)

$$(B04/B11) < 3.00 \text{ AND } B02 < 0.11, \quad (1)$$

where B02, B04, and B11 are the blue, red, and SWIR bands, respectively.

3 Results

The multi-temporal image dataset between 2017 and 2022 was analyzed with two different approaches. On one hand, we explored the feasibility of multispectral Sentinel-2 satellite imagery semi-automatic classification, in order to: (i) avoid time consuming manual digitization of perimeters for future studies and (ii) free availability of 3–5 days satellite revisit time. On the other hand, we manually digitized the highest resolution Pléiades imagery as well as the orthophotos from 1999 and 2005.

The analysis of the areal changes between 2017 and 2022 was conducted on the whole cloud-free areas of the AOI_f (28.09 km^2) while, to ensure spatial coherence from the year 1999, we reduced the AOI_f to a subset of 17.54 km^2 (AOI_s). We then measured areal changes of rock outcrops in the AOI_s, obtaining a total rocky area of 3.440 +/− 0.040 km^2 in 1999 in contrast to 3.884 +/− 0.045 km^2 in 2022 (Table 1). The rocky areal extent increase from Pléiades images resulted in 0.453 +/− 0.187, while that from Sentinel-2 was equal to 1.576 +/− 1.099. Finally, we compared the differences between manually digitized mapping and semiautomatic classification on the AOI_f above 3700 m (Table 2). Differences between Sentinel-2 and Pléiades were estimated at − 7.6% +/− 3.0% for 2017 and 12.2% +/− 4.2% for 2022.

Table 1 Temporal evolution of rock outcrops extension (1999–2022) by manual digitization

Year	Area (km^2)	Difference from previous measure (km^2)	Difference from t_0 (km^2)
1999	3.440 +/− 0.040	/	/
2005	3.578 +/− 0.042	+ 0.138 +/− 0.082	+ 0.138 +/− 0.082
2017	3.533 +/− 0.041	− 0.045 +/− 0.083	+ 0.093 +/− 0.081
2022	3.884 +/− 0.045	+ 0.351 +/− 0.086	+ 0.444 +/− 0.085

Table 2 Differences between the mapping based on Pléiades and on Sentinel-2 imagery

Year	Pléiades area (km^2)	Sentinel-2 areas (km^2)	Difference Sentinel-2/ Pléiades (km^2)
2017	5.063 +/− 0.093	4.705 +/− 0.471	- 0.358 +/− 0.546
2022	5.516 +/− 0.094	6.281 +/− 0.628	+ 0.765 +/− 0.722

Errors during the manual digitization can mostly arise from: (i) variations in manual picking of pixels, (ii) differences in snow cover conditions and (iii) local geometric distortions linked to the orthorectification process. Manual mapping accuracy (i and ii) was estimated in 1% of the calculated area, as the interpretation of rock outcrops was supported by high quality dataset, previous terrain knowledge and the analyst's expertise in photo interpretation (Paul et al. 2013). Errors linked to geometric distortions were estimated according to Millan et al. 2019. The Sentinel-2 mapping accuracy imagery was considered to be between 2 and 5% as described by Paul et al. (2016).

4 Discussion

The present study demonstrates the possibility of an ongoing variation in the degradation trends of the high-altitude cryosphere, potentially leading to an increased rate of expansion of high-altitude rock outcrops. The analysis of the manual mapping on Pléiades and historical imagery shows a substantial steadiness of the areal extension of rock outcrops. By contrast, between 2017 and 2022, we registered a + 10% increase in rock outcrop area (Table 1). In 2017, the semi-automatic mapping shows an underestimation of the total rock outcrop area of 0.358 km^2. While in 2022, the same comparison shows an overestimation of 0.765 km^2. This considerable variability is likely to be caused by the difference in the acquisition dates. Only two images were available from the Pléiades archive; therefore, the most suitable image match had to be found in terms of date similarity, shadows, cloud and snow cover. Finally, the trade-off among all these parameters led to the selection of a July 2017 Sentinel-2 acquisition. However, this image still had a considerable amount of seasonal snow cover on the rock outcrops, resulting in a misclassification of rocky areas as snow/ice zones. Similar errors were detected on the completely snow-free 2022 Sentinel-2 image, where misclassification of dirty/debris-covered ice was mainly caused by rockfall and ice darkening. These areas could be correctly classified as glacier/ice zones by the analyst's trained eye but cannot be distinguished from rock outcrops by the semi-automatic classification.

5 Conclusions

A 10% expansion of high-altitude rock outcrops in the Monte Rosa massif is detected in the present study between 2017 and 2022, while analysis of historical data showed an overall steadiness until that point. The comparative methodology showed that, for this type of study, the use of Sentinel-2 could be adequate on a decadal time-scale

comparison when the imagery is acquired in very similar conditions of snow cover, rockfall activity and lighting. In the present climate change scenario, with unprecedented rates of warming and possible Altitude-Dependent Warming effects (Pepin et al. 2015), the highlighted trend should be monitored in the future, as an exacerbation of the phenomenon seems possible in the next decades. Although the present study identifies an increased rate of expansion of high-altitude rock outcrops, future measurements, on a longer time scale, are required to confirm the findings of this study.

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A Framework for Urban Green Areas Assessment Using Remote Sensing and Geographic Information Systems Technologies

Carolina Salvo and Alessandro Vitale

Abstract

The conservation and improvement of the socio-environmental functions of urban green areas (UGAs), such as microclimate regulation, air purification, surface water runoff, and recreational functions, represent one of the goals of sustainable urban development. This objective can be reached by implementing suitable UGAs planning and management strategies, which can be defined starting from a complete and integrated assessment of the quality of the UGAs' service delivered within urban contexts, which depends on the availability, accessibility, and quality of these spaces. Using a methodology that combines RS and GIS technologies, the research aims to quantitatively analyze the availability, accessibility, and quality of UGAs in real time by suggesting proper policies and actions to improve urban and environmental quality from a quantitative perspective. The developed methodology, characterized by a structured information management system, is tested and validated on a case study. The results reveal that the UGA quality of service provided in the case study is very low and highlight valuable insights in the definition of adequate guidelines to support decision-making on the challenging objective of incorporating suggested actions within urban plans, making sustainability goals achievable.

Keywords

Urban green areas · Remote sensing · Geographic information systems · Geospatial analysis · Sustainable urban development

1 Introduction

The increasing population in urban areas represents a big challenge for cities' sustainable and green development (Brom et al. 2023). It threatens the provision of UGAs in urban areas, which puts pressure on natural ecosystems in cities (Haaland and van Den Bosch 2015; Gupta et al. 2012). Therefore, the conservation and enhancement of UGAs are a primary goal of urban area planning policies.

UGAs are vegetated areas in urban environments and include parks, open spaces, green squares, residential gardens, and urban forests. UGAs are the most valuable ecosystem service providers in cities since they are involved in many biophysical activities that contribute to the well-being of humans and the environment. Therefore, the planning and management of UGAs to preserve and enhance these ecosystem services are essential in creating sustainable, livable, and resilient urban areas. In this regard, the knowledge of the baseline condition of UGAs' quality of service in urban areas is of great significance for efficient greening planning policies.

Recent technological advances can support urban planners in mapping and assessing UGAs' quality of service in urban areas as it consents to synthesizing information resources (Shahtahmassebi et al. 2021). Spatial information retrieved from various sources, especially those obtained through RS technologies (Francini et al. 2023), can be gathered, processed, and visualized with GIS tools to get valuable information about the quality of UGAs' services.

The authors propose a framework to support UGAs' service planning. This study aims to present a decision support tool for assessing the UGAs' service quality at the urban scale by employing RS technologies and geospatial analysis. The objectives of this paper are the following: (1) to present a framework for the assessment of UGAs' quality of service considering crucial quality aspects of UGAs such as the provision, quality, and accessibility to this service; (2) to provide

C. Salvo (✉) · A. Vitale
University of Calabria, Rende, CS, Italy
e-mail: carolina.salvo@unical.it

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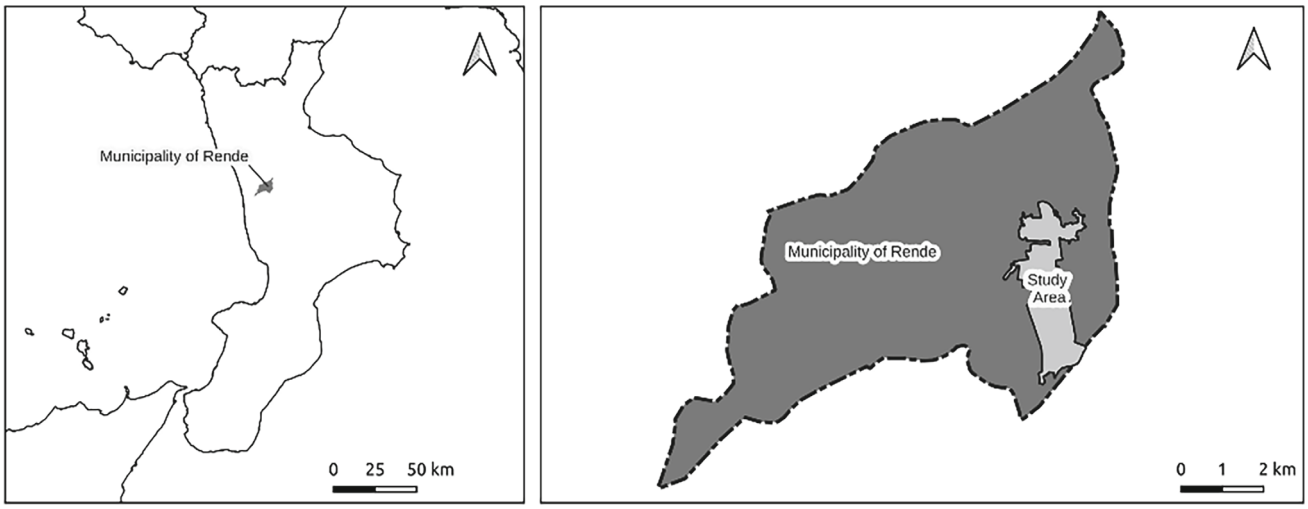


Fig. 1 Study area

an attempt of integration between RS data and GIS tools in the context of UGAs planning, and management; and (3) to test the developed framework on a case study to verify its validity.

2 Materials and Methods

The framework is tested on an urban area of the municipality of Rende (Fig. 1). Rende involves different settlement areas, such as Roges, Commenda, Quattromiglia, Arcavacata-Santo Stefano, Saporito, and Surdo. This study investigates the high-density settlements of Roges, Commenda, and Quattromiglia.

The framework of the methodological approach is depicted in Fig. 2.

The authors identified UGAs' geometry using the European Space Agency's (ESA's) WorldCover product retrieved from the Google Earth Engine (GEE). GEE is a free-to-use platform for geospatial dataset analysis and visualization, and it is available for research, education, and nonprofit use (Amani et al. 2020). The ESA WorldCover product provides a world land cover map for 2021. It is based on Sentinel-1 and Sentinel-2 data and is characterized by a resolution of 10 m. The code to identify the LULC map for the case study is available at the following link: https://code.earthengine.google.com/34580f89ad9c5b52d1ba8e92ada469fa. To map the public UGAs within the study area and perform the analysis

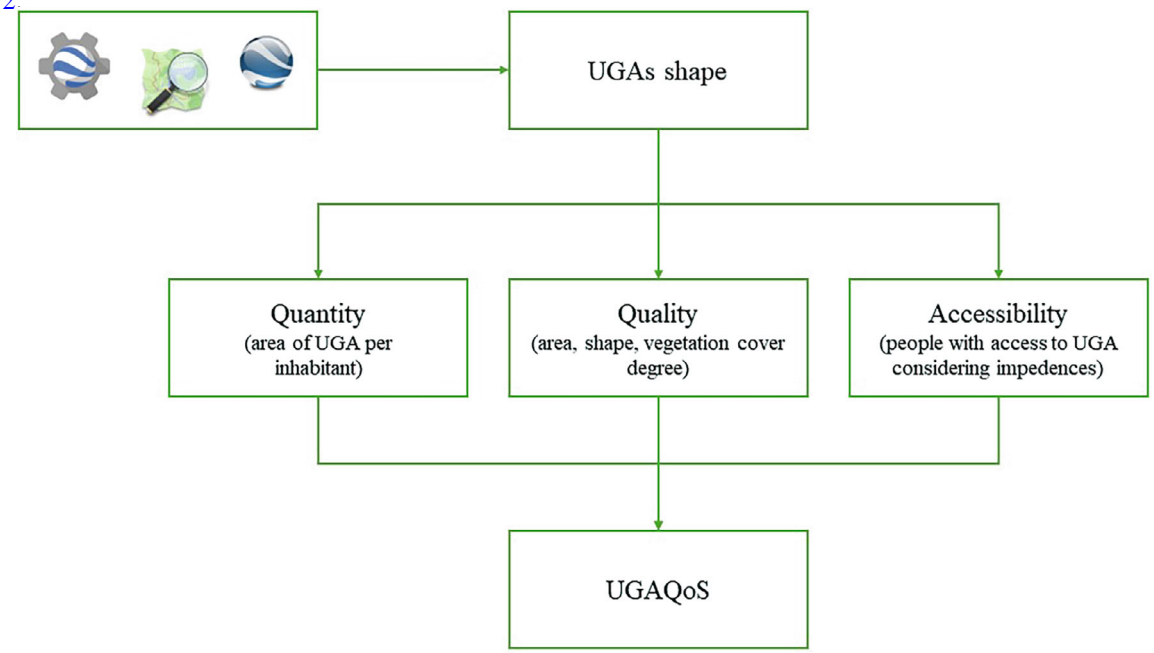


Fig. 2 Methodological framework

of the UGAs' service quality, the authors defined that UGAs included tree cover and grassland. The authors extracted these classes from the LULC map and refined the UGAs' geometry surveying OpenStreetMap (OSM) and Google Earth Pro (GEP) products.

After defining the UGAs' shape, the quality of UGAs' service is evaluated at the census tract level through an index, the urban green areas quality of service (UGAQoS), which is related to the quantity, quality, and accessibility of UGAs.

The quantity of UGA's service relies on the provision per inhabitant of such spaces, and it is assessed as the total area of UGAs and the number of inhabitants in each census tract.

The quality of the UGAs' service offered to citizens is evaluated by considering the specific characteristics of the UGAs available in the study area. These characteristics include the area, shape, and degree of vegetation cover of these spaces, which are assessed at the UGA level first and then at the census tract level through a weighted mean. The shape is set using the (McGarigal 1995) formulation, while the vegetation cover degree is assessed by extracting the statistics of vegetation coverage density detected by (Copernicus 2018).

The accessibility of UGAs is evaluated by considering the people within the census tract who have access to one UGA or multiple UGAs. The accessibility measure is performed by considering the effective path traveled by people. Specifically, the authors reduced the total distance of 300 m defined by the World Health Organization (WHO) by considering the material and immaterial impedances along the route, such as intersections, street slopes, and the percentage of older people with more difficulties traveling along the path, following what proposed by (Vitale et al. 2016).

The authors employed the tools and functions in the QGIS environment to assess the indicators of quantity, quality, and accessibility to UGAs at the census tract level, normalized them through the min-max standardization method, and aggregated them to obtain the UGAQoS index. Then, the authors defined five classes of evaluation: very low (0–0.20), low (0.20–0.40), medium (0.40–0.60), high (0.60–0.80), and very high (0.80–1).

3 Results

After identifying the UGAs' geometries and evaluating their quantity, quality, and accessibility, the authors assessed the quality of UGAs within the study area (Fig. 3).

The results are numerically summarized in Table 1, which presents the area and number of census tracts falling in each defined evaluation class.

The results reveal that the overall level of UGAs' service in the study area is low. None of the census tracts shows a very high level of UGAs' quality of service. Only two census tracts (57 and 141) have a high level of UGAs' quality of service, while 6 (29, 31, 51, 139, 152, and 155) show a medium level. Census tracts 34, 39, 47, 58, 67, 140, and 144 have a low level, while all the others 42 have a deficient quality of UGAs service. In terms of area, the case study is characterized by a very low level of UGA quality of service for 243.52 ha.

Table 1 Numerical results from UGA quality of service

Class	Area (ha)	Number of census tracts
Very high	0	0
High	9.71	2
Medium	48.16	6
Low	63.21	7
Very low	243.52	42
Total	364.60	57

4 Discussion

The results drawn from the analysis of the quality of service provided by UGAs in the urban area of Rende reveal that UGAs' service quality is scarce. None of the census tracts fall in the very high class, and many fall in the very low classification level. The low quality of service of UGAs in the case study is not only related to their limited provision and accessibility but also their poor quality.

UGAs' service is a crucial aspect of city planning and development, as UGAs and their management and maintenance contribute significantly to the livability and well-being of citizens. The methodology proposed in this study consents to quantify UGAs' service quality and compare the urban blocks by considering the level of UGAs' service that characterizes them.

Integrating such a decision support tool within urban planning practice would be significantly crucial for many geographical regions, including the Middle East and North Africa (MENA) and Mediterranean (MED) regions, where urbanization is rapidly increasing, and the preservation and the promotion of green spaces within cities are becoming increasingly important to tackle many urban challenges such as air pollution, urban heat islands, and loss of biodiversity (Madbouly 2009; Clemente et al. 2022).

The results demonstrated that UGAs' quality and accessibility are crucial questions to evaluate in the UGAs' service planning and management. UGAs should be accessible to all residents, regardless of their socioeconomic status and location in urban areas. High levels of accessibility to UGAs are better if linked to sustainable means of transport, such as public transport, walking, and cycling, and encourage physical activity, relaxation, and social interactions. Also, the quality of UGAs' service, in terms of size, shape, and diversity of UGAs, has great significance. Various sizes of UGAs,

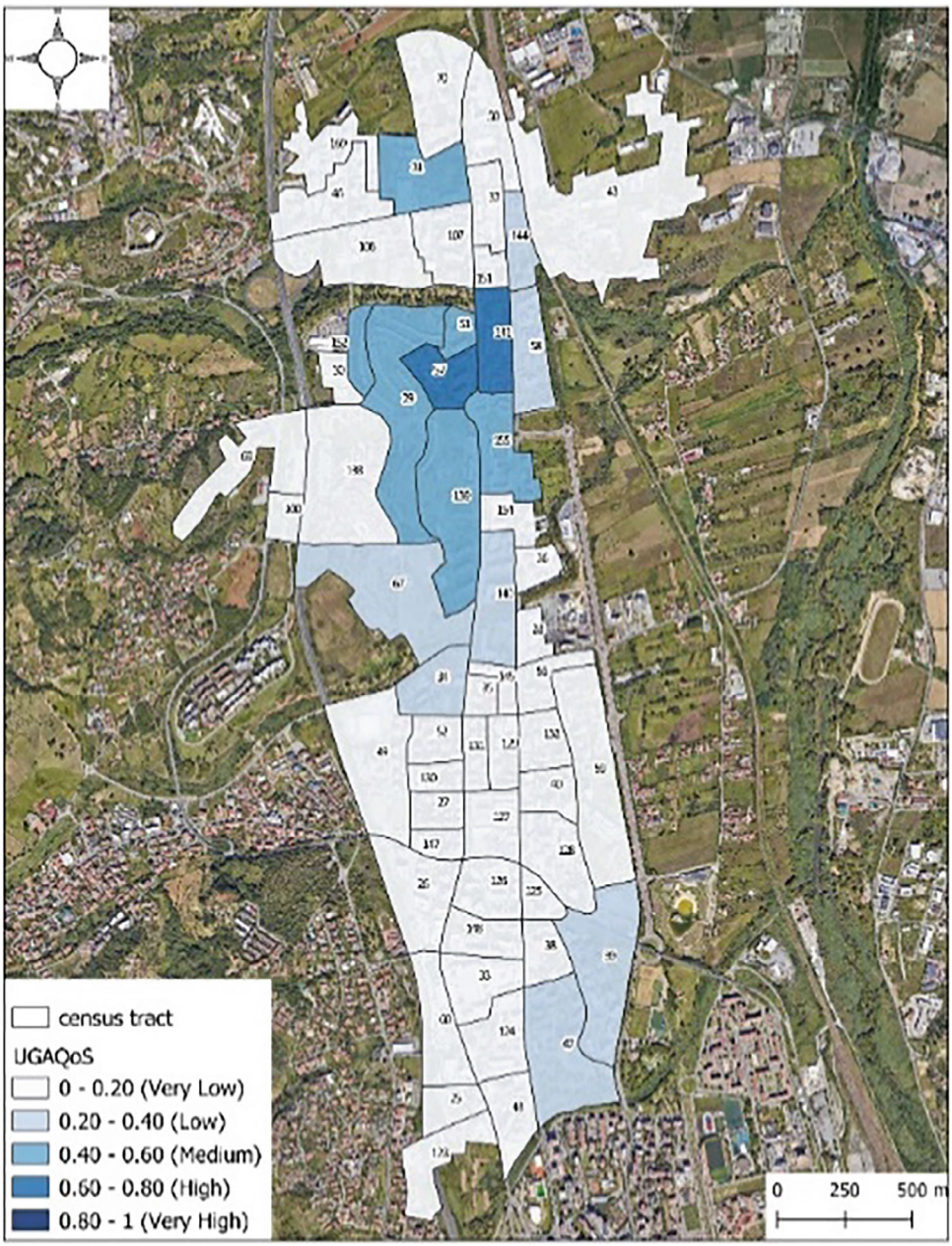


Fig. 3 UGAs' service quality assessment

from pocket parks to urban forests, and the variety of these spaces in terms of the type of vegetation cover, presence of facilities, and amenities, such as playgrounds, sports courts, picnic areas, seatings, and walking and cycling paths, improve the UGAs usability from different groups of people, who may have various interests and social needs.

Data about the presence of equipment and amenities is challenging to find. An in situ analysis can provide valuable information about this crucial aspect. Also, having data about the biodiversity and urban ecology value of these spaces could enhance the quality and appropriateness of this study since UGA service in urban areas should also contribute to the local biodiversity and provide habitats for plant and animal species.

5 Conclusions

This study demonstrated that RS technologies coupled with GIS are practical tools for quantitatively evaluating the quality of UGAs' services, considering their provision, quality, and accessibility, and, therefore, operationally supporting urban planning in building more sustainable and liveable cities.

This study attempts to analyze UGAs' quality of service within urban areas. It demonstrates that quality is a complex concept encompassing accessibility, provision, design quality, and community engagement. A well-designed and well-maintained network of UGAs contributes to a higher quality of life for city residents and enhances the overall

quality of the urban environment and its environmental integration.

Further research should focus on integrating other quality aspects of UGAs' services in the proposed assessment framework by exploiting RS capability and giving the proposed study more social implications.

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Optical Sensor-Based Estimates of Biomass for Tropical Rain Forests of Acre State, Brazil, with Lidar Equivalent of Ground Truthing

Zalak Vyas and Vibha Patel

Abstract

Evaluating the effects of deforestation and climate change and understanding carbon cycles needs accurate estimation of aboveground biomass (AGB) in tropical rainforests. Optical remote-sensing-based techniques have been widely used for AGB estimation due to their cost-effectiveness and broad coverage. However, the accuracy of these estimates can be limited, especially in complex forest ecosystems. This study aims to improve AGB estimation in the tropical rainforests of Acre State, Brazil, by integrating optical sensor data with Lidar measurements as a reference. Because of its remarkable temporal precision and capacity to identify flames in far-off places, Moderate precision Imaging Spectroradiometer (MODIS) multispectral data provides valuable insights into vegetation characteristics. The purpose of using MODIS as compared to Landsat is its temporal resolution. Moreover, this study has incorporated Lidar measurements over selected sample plots to obtain accurate forest structure and AGB measurements. Spatial differences of MODIS and Lidar data are addressed using scaling techniques. Lidar data was the reference against which the optical sensor estimates were compared and calibrated. To establish a strong link between the optical sensor data and AGB, the study utilized statistical modeling techniques such as adaptive boosting and Random Forest. The models were trained using the optical sensor and Lidar data as reference. The trained models were then used to estimate AGB across the study area. Results demonstrate that the AGB estimation process is significantly improved with accuracy (86%) and Mean Absolute Error (1.5), particularly in rainforest ecosystems. Lidar measurements, like tree height and diameter at breast height (DBH), are utilized to predict aboveground biomass (AGB). The work extends the use of remote sensing to estimate aboveground biomass (AGB) in tropical rainforests, namely in the Acre State of Brazil. The integration of optical sensor data with Lidar-referenced data enhances the ability to accurately monitor and assess aboveground biomass, aiding in effectively managing and conserving these critical ecosystems.

Keywords

Aboveground biomass · Remote sensing · Lidar · Forest ecosystems · MODIS

1 Introduction

In a natural environment, like grassland, forest, scrubland, or tundra, a wildfire, commonly referred to as a forest, bush, or vegetation fire, is characterized as any spontaneous and uninvited ignition or burning of plants that utilizes organic combustible and spreads according to ecological factors such as temperature, relative humidity, precipitation, wind, and topography (https://www.un-spider.org/category/disaster-type/forest-fire). There are three conditions, i.e., fuel, oxygen, and a heat source (source of ignition), that can cause a wildfire to burn (https://www.un-spider.org/category/disaster-type/forest-fire).

The process of gathering data from remote locations is known as remote sensing. Broadly, we can say sensors can be categorized based on sensor type, i.e., Optical (Multispectral, Hyperspectral), Radar (Synthetic Aperture Radar: SAR, PALSAR), Lidar. There are various Earth observation satellites like Landsat, MODIS, AVIRIS, etc. This paper focuses on MODIS. Each element on the Earth has a specific spectral

Z. Vyas (✉)
Gujarat Technological University, Ahmedabad, Gujarat, India
e-mail: zalakvyasce@gmail.com

V. Patel
Vishwakarma Government Engineering College, Gandhinagar, Gujarat, India

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signature. Satellite sensors record spectral information in the form of reflected or backscattered energy. By comparing this energy with spectral signature, one can identify a particular object on the Earth surface.

Remote sensing data as an input and machine learning algorithms as a process improve predictions about the behavior of environmental systems. Machine learning includes a variety of algorithms, from which I have chosen, MLR, GB, XGBoost, DT, RF, because Brazilian forests are tropical regions and studies suggest that for such regions adaptive learning algorithms give better approximation of biomass (Souza et al. 2013).

For estimation of various environmental parameters and physical characteristics, different Vegetation Indices (VI) are available. The Leaf Area Index (LAI), Normalized Difference Vegetation Index (NDVI), Modified Soil-Adjusted Vegetation Index (MSAVI), and so on. One of the most useful spectral vegetation indicators for monitoring aboveground biomass and crop development dynamics is the Normalized Difference Vegetation Index (NDVI), which measures photosynthetically active plant biomass. NDVI can be calculated by taking the ratio of difference of NIR and Red band and the result is divided by sum of NIR and Red Band.

2 Methods and Materials

2.1 Method by Synergy of Satellite Data with Machine Learning in Wildfire Observation

Remote sensing and machine learning together can give the best results for biomass estimation. Following is the general flow that one can practice.

(i) Identify study area and gather ground truth data.
(ii) Acquire Earth observing satellite images from platforms that provide images such as USGS, Earth data, and Copernicus.
(iii) On acquired satellite image, perform preprocessing if required.
(iv) Employ an array of models, including allometric equations, regression, geostatistical, and nonparametric models.
(v) Validate results generated by applying various models with Ground Data.

2.2 Ground Truth Data Description

The four forest locations in the eastern region of Acre, Brazil, that are covered by this data collection are Humaita, Bonal, Transacreana, and Catuaba. It includes identifying species and making observations of diameter at breast height (DBH).

The dataset contains burned area in 2005 and 2010. In October and December of 2017, surveys were carried out. The dataset has spatial resolution of multiple points and temporal resolution of one-time samples of desired area. According to the geographic area, bounding box values for regions of interest are − 68.147738, − 67.281765, − 9.754178, and − 10.083254 as western longitude, eastern longitude, northern latitude, and southern latitude, respectively. Results of the survey are mentioned in the paragraph below. Specific results are shown in Sect. 3 Results.

Nine 500-m segments (S1-S9) having three 50-by-50-m plots were present in the Bonal region. Plots for sampling were set up 500, 300, and 500 m from the edge of the forest. In the same region, three 50-by-100-m plots were set up on another segment. Eight 50 km × 50 m plots were divided into two segments (a total of four sites in each segment) inside the Catuaba area, supervised by the Federal University of Acre, and is a preserved woodland area. There were six 50 m × 100 m plots in the Humaita area; two were on private land in a scattered forest area, and the other four were within a Federal University of Acre conserved forest area.

2.3 Satellite Dataset Description

At the site of Acre, Brazil, South America, the Moderate Resolution Imaging Spectroradiometer (MODIS) captures data at 10-day intervals, with a temporal resolution of every 5 days, and achieves a pixel resolution of 250 m.

Lidar data for this paper is acquired from the Project named Carbon Monitoring System (CMS) which is available on ORNL DAAC of Earth data by NASA (Mummoorthy et al. 2019). Lidar point cloud processing may produce Digital Elevation Models (DEM), Digital Surface Models (DSM), and Canopy Height Models (CHM) from point clouds, which are representations of Lidar data. From the Canopy Height Model (CHM), Height of Tree and Radius are calculated, which will be useful to calculate allometric equation for Estimation of Biomass. By processing Lidar data, each site location contains approximately 4500–5000 trees. Height typically ranges from 138.670 to 223.480. The study used allometric equations derived from the LBA-ECO LC-02 Biophysical Forest Measurements dataset for Acre, Brazil (1999–2002) (Selhorst and Brown (2014); Gao et al. (2018), available from the ORNL Distributed Active Archive Center.

3 Results

For Performance evaluation, the following statistical measures are used: Pearson Correlation, R-squared, RMSE.

Two variables can be correlated using Pearson correlation analysis. In the current situation, NDVI and AGB are linked. The result is a value of roughly 0.86, indicating a strong positive correlation between aboveground biomass (AGB) and the Normalized Difference Vegetation Index (NDVI).

The standard deviation of the residuals (prediction mistakes) is called the Root Mean Squared Error, or RMSE. XGBoost has the lowest RMSE in the given scenario compared to other algorithms, at approximately 7.93.

The difference between the "true" value and the measured value is the measurement error, which is stated as the Mean Absolute Error (MAE). In the current case, the MAE for XGBoost is 1.66, which is good compared to other methods.

A model is considered to have the best estimate capacity when its R-Squared value is greater and its error parameters are smaller.

4 Discussion

The outcome implies that the model using XGBoost performed more efficiently over the one using Random Forest. Selected Parameters have great impact based on type of forest or atmosphere in general like tropical area, boreal area, subtropical area. Results shows that XGBoost has achieved a maximum R^2 score around 86% as compared to other ML algorithms. Similarly, XGBoost has achieved a minimum Error rate around 1.5.

Hypertuning of Model Parameters

The fundamental components of a model are its parameters, which defines its degree of complexity. To optimize or tune the model, the ideal set of parameters must be identified and adjusted.

Optimizing Random Forest

In order to optimize the Random Forest model, we adjust two parameters namely ntree and mtry. Ntree specifies the number of trees to be generated and it stabilizes the error by tuning it to be set at optimum value. We increase ntree in increments of 50, starting from 10 and going up to 1000 for this model. The count of predictor variables that are selected arbitrarily as candidates at each split is controlled by the parameter called mtry. The default value for mtry is used. RF was performed in the spyder IDE of Anaconda 4.12.0 software environment using the module RandomForestRegrssor of Sklearn Ensemble Learning.

Optimizing XGBoost

Optimization of various parameters of XGBoost has been done, that includes nrounds, max_depth, gamma, and learning_rate. Adjusting a parameter in the XGBoost model can impact other values, complicating optimization. In this model, random state is increased from 0 to 100 in steps of 10 keeping other parameters as default value, because they don't affect much to the overall performance. XGBoost was performed in the spyder IDE of Anaconda 4.12.0 software using the module XGBRegressor of XGBoost.

5 Conclusions

This research focused on Eastern Acre, Brazil, to analyze aboveground biomass (AGB) estimation using MODIS and Lidar data with various modeling algorithms such as Multivariate LR, Gradient Boosting, RF, Decision Tree, and XGBoost. The study revealed that parameter optimization significantly influences machine learning methods. XGBoost's performance improved after parameter tuning, with its R^2 reaching 0.88. Machine learning algorithms offer advantages in biomass estimation, addressing issues of underestimation and overestimation. XGBoost notably mitigated these problems, outperforming the Multivariate LR model. Lidar PCD yielded a more accurate AGB calculation when combined with MODIS data. The study highlights the benefits of using both sensors for estimating AGB. Additionally, it emphasizes the high quality and utilization of MODIS and Lidar data, promoting additional research and model development for estimating biomass.

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Toward a Framework Integrating Remote Sensing Techniques and Big Data Tools to Calculate Irrigation Water Requirements in Arid and Semi-arid Regions

Sara Merzoug, Abderrahim Ajakka, Mohamed El Hajji, Youssef Es-Saady, and Zine El Abidine El Morjani

Abstract

Agricultural irrigation is the largest consumer of water, especially in arid and semi-arid regions. Limited water resources in these areas make food production a critically challenging task. Therefore, estimating irrigation requirements is crucial for efficient water resource management and sustainable development. In this context, various standard techniques are commonly employed for estimating water demand such as evapotranspiration, or crop water requirement. In this study, we utilized the coupling Models and Methods of remote sensing and big data for estimating water demand and evapotranspiration in cultivated areas. The objective of this research paper is to bridge the gap between remote sensing, big data, and irrigation management, providing an integrated solution for accurate small-scale irrigation monitoring in real time, and ultimately enhancing irrigation decision-making. The study investigated the following steps: (a) Employing the direct approach, that involves applying the theoretical expression of the crop coefficient (K_c) by dividing the potential evapotranspiration (PET) by the reference evapotranspiration (ET_o). Estimating the ET_o values using the FAO-Penman–Monteith method with appropriate values of meteorological factors, such as air temperature (T_{min}, and T_{max}), solar radiation (R_s), and rainfall, which were ingested using big data tools. (b) Integrating remote sensing techniques to estimate canopy parameters notably leaf area index (LAI) and Fcover (F_c). These factors are derived from high-resolution multispectral satellite images through a scripting interface. The derived LAI and F_c values were then incorporated into our calculation approach. (c) Calculating the required irrigation amount and mapping daily crop evapotranspiration that were represented in an interactive user-friendly dashboard. The results highlight the capabilities of our framework that have been demonstrated in a sophisticated application. The developed application accurately maps daily crop evapotranspiration, and provides users with personalized recommendations on the required irrigation amounts. The interface's main contribution lies in its adaptability in various crop fields with the potential for optimization in different agricultural settings. Overall, the developed framework holds promising potential for significant savings of agricultural irrigation water use through tracing water use efficiency, reducing water stress along with improving crop yield.

Keywords

Irrigation · Irrigation requirements · Crop evapotranspiration · Remote sensing · Sustainable irrigation · Meteorological data · Big data

1 Introduction

Irrigated agriculture persists as a primary driver of worldwide water resource consumption, accounting for approximately 70% of freshwater withdrawals (Mitter and Schmid 2021). In this context, improving irrigation water management using innovative tools is crucial for a sustainable use of water resources. Efficient irrigation necessitates precise

S. Merzoug (✉) · Z. E. A. El Morjani
2GBEI Laboratory, Polydisciplinary Faculty of Taroudant, Ibnou Zohr University, Agadir, Morocco
e-mail: sara.merzoug@edu.uiz.ac.ma

A. Ajakka · Y. Es-Saady
Polydisciplinary Faculty of Taroudant, Ibnou Zohr University, Agadir, Morocco

M. El Hajji · Y. Es-Saady
IRF-SIC Laboratory, Ibnou Zohr University, Agadir, Morocco

M. El Hajji
Regional Center for Education and Training Professions—Souss Massa, Agadir, Morocco

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water application aligned with actual crop water requirements, demanding accurate estimation of evapotranspiration (ET) which is the combined process of water evaporation from the soil and transpiration from plants. However, a lack of proper planning, management, and comprehensive spatiotemporal data on crop water requirements at the field scale presents a significant challenge. Remote sensing has emerged as a powerful tool to address this challenge and improve irrigation management. A significant body of research underscores the importance role of remote sensing in irrigation management and in particular in crop water management. Several studies were based either on surface energy balance (SEB) methods (Allen et al. 2007), or on reflectance-based crop coefficient methods (Heilman et al. 1982; Bausch and Neale 1987). However, the major challenge faced by these models lies in translating the wealth of spectral data into a daily practical irrigation decision. It is therefore necessary to develop enhanced predictions and user-friendly interfaces in order to bridge this gap and fully leverage remote sensing for agricultural water management. One of the most widely utilized methodologies for estimating crop water requirements and devising irrigation schedules at the local scale is the renowned FAO56 approach (Allen et al. 2006) particularly the K_c-analytical method (Menenti Guido and Menenti 1995) which is based on the direct application of the Penman–Monteith equation. The aim of our research is to develop an advanced interface to estimate crop water requirements and irrigation parameters using interface employs the potential of big data tools and remote sensing technologies. The main motivation of this research is to develop a new user-friendly interface to empower the farmers and decision makers with a powerful tool that not only optimizes water usage but also contributes to the resilience and productivity of agricultural systems.

The rest of the paper is organized as follows.

2 Architecture Design

This section provides an overview of the system architecture, which consists of three layers: the data layer, the system layer, and the monitoring layer as illustrated in Fig. 1. These three layers interact with each other to form a workflow. The system is designed to monitor irrigation parameters in real time. The details of each layer are presented in the following section.

2.1 Data Layer

The data layer is responsible for collecting meteorological data from weather stations for calculating reference evapotranspiration (ET_o) employing the use of the FAO-56 Penman–Monteith (FAO-PM) equation, a widely recognized method and tested in many regions of the world. Additionally, satellite data from the Sentinel-2 Hub is used to calculate the Leaf Area Index and Fractional Vegetation Cover.

To assess the interface, weather data were collected from a dynamic web interface called meteoblue. This platform offers a variety of global weather datasets, including NEMS-GLOBAL, a high-resolution global weather model with a 12 km grid spacing, NEMS12, a global weather model with a 12 km grid spacing, designed to provide greater regional detail, NEMS5, a global weather model with a 5 km grid spacing, offering even higher regional resolution and ICON, a global weather model with a variable grid spacing, providing high resolution for specific regions. These datasets are available for any location on Earth every 15 min through their API services. A Python script was developed to facilitate data retrieval, taking as input the latitude and longitude of the field and the output is expected to be a list of weather data for a specific period of time in a certain temporal resolution.

2.2 System Layer

The system layer represents the back-end of the architectural framework. The function of this layer is to process the data received from the preceding layer in its original, unprocessed state. The principal functions of this layer are as follows:

- Calculating potential evapotranspiration (ET_p):

The Penman–Monteith equation is used to calculate potential evapotranspiration (ET_p) using 15-min weather datasets. An alternative approach was developed for the direct calculation of the ET_p (Menenti Guido and Menenti 1995) represents an estimate of the evapotranspiration under ideal conditions, assuming a standardized surface resistance of 70 s m^{-1} and a constant albedo of 0.23. This approach deviates from the traditional reference evapotranspiration (ET_o) calculation, as it incorporates these specific assumptions, hence the term “potential” evapotranspiration.

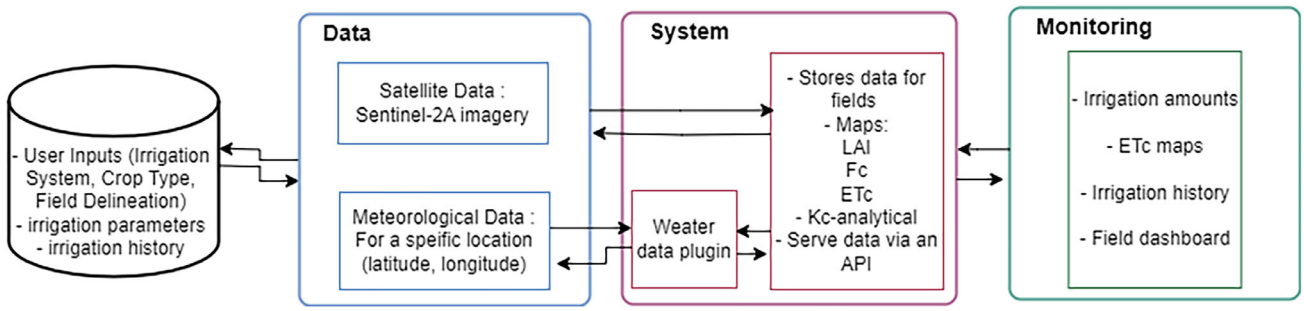


Fig. 1 Diagram of the system architecture

- Calculating Crop Coefficient (K_c):

The crop coefficient (K_c) is calculated using an analytical approach proposed by (Menenti Guido and Menenti 1995), which involves a direct application of the Penman–Monteith equation (Allen et al. 1998). This approach integrates biophysical parameters estimated from satellite images, including leaf area index (LAI), surface albedo (r), and crop height (h_c). It can be expressed as a function of several factors, including:

$$K_c = \mathrm{ET}_{crop}/\mathrm{ET}_o = f\{R_s, T_a, \mathrm{RH}, U_z; r, \mathrm{LAI}, h_c\} \quad (1)$$

where

R_s: solar radiation.
LAI: Leaf Area Index (estimated from satellite images).
h_c: Crop height (estimated from satellite images).
T_a: air temperature.
RH: relative humidity.
U_z: wind speed.
r: Albedo (surface reflectivity, estimated from satellite images).

2.3 Monitoring Layer

The monitoring layer is the user interface of the system. It's tasked to visualize the data processed by the system layer. The data is illustrated in various forms such as graphs, charts and maps in an intuitive dashboard for a better understanding of the field's irrigation status. The graphical user interface (GUI) has been developed using the TypeScript language, together with libraries such as ReactJS, in order to take advantage of its reactivity design and to create reusable components, as well as to handle state. Apexcharts has been employed as a further tool in order to display interactive and user-friendly charts along with Leaflet maps to interact with maps and manipulate polygons. Finally, Axios has been utilized as a library used for fetching data from the back-end.

3 Results and Discussion

The results are illustrated in Fig. 2 which is an interactive website where the farmers are able to input information about their fields including the field's name, the crop type, the irrigation system and to select their weather station as shown in Fig. 2a. Then, the graphs will display the hourly water application and reference evapotranspiration for the current day in a specific field as shown in Fig. 2b. The screen in Fig. 2c illustrates a dashboard that provides more insights of the field. It allows the user to get both a real time and historical weather data, apply water and evapotranspiration. Furthermore, the dashboard gives a bird-eye view of the field and the elements mentioned earlier. The last Fig. 2d represents the front-end of our application which serves as an interface for station technicians to integrate the plugin developed for communication between the system and their database.

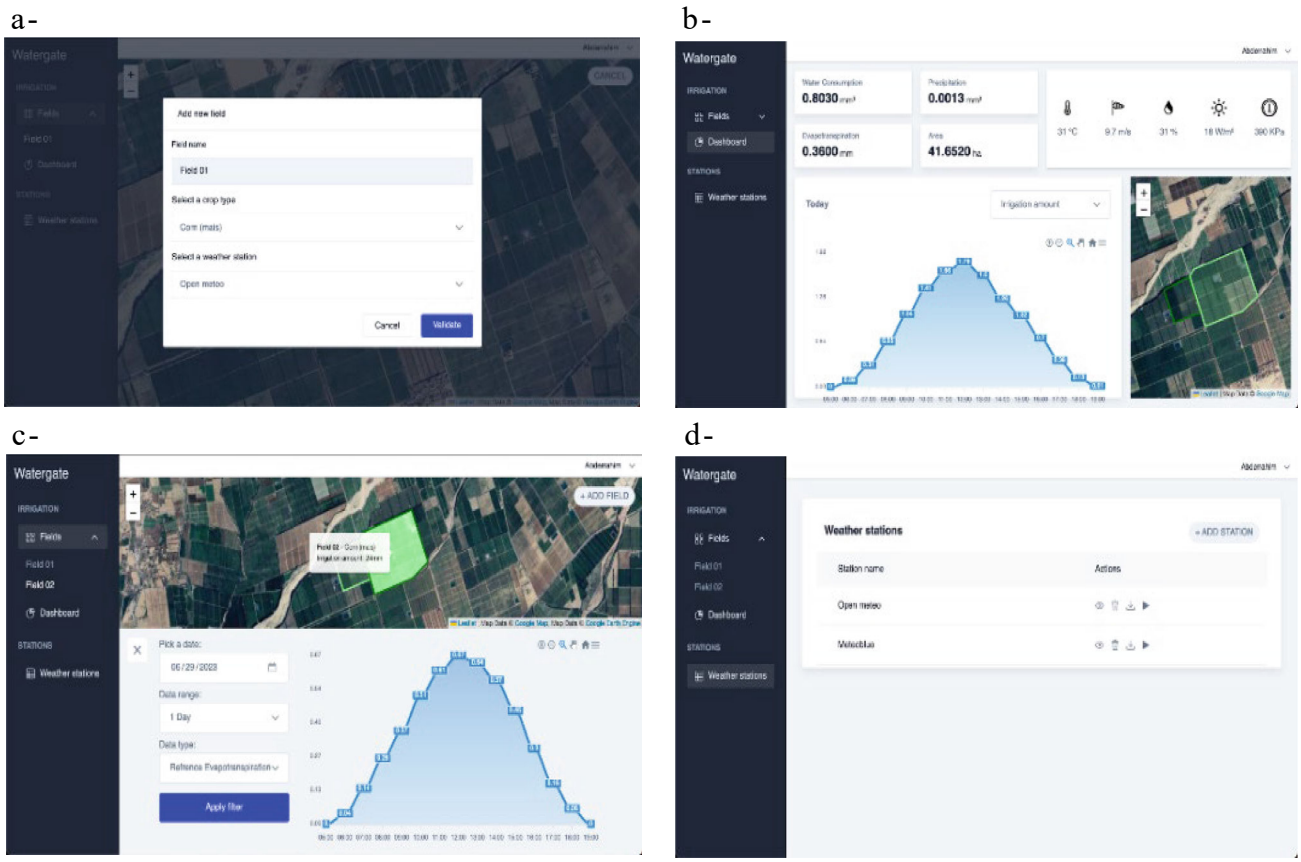


Fig. 2 **a** Adding a field to the system, **b** main screen of the application featuring a map with irrigation information, **c** dashboard screen containing elements, **d** weather station screen with an interface to add more than one station

4 Conclusion

The principal objective of our research is to address the challenges surrounding agricultural water management, particularly in regions with limited water resources. We have successfully developed an innovative solution that combines the realms of remote sensing, big data, and irrigation techniques. This solution generates daily crop evapotranspiration maps and empowers end-users with personalized irrigation recommendations with an intuitive dashboard and user interface that offer promising usability and interactivity, enriching the user experience and ensuring optimal usage. Despite the challenges faced, the system showed notable results, setting a solid foundation for its future applications and development.

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Windmill Site Suitability Using GIS and Remote Sensing

Rahul Gawai, Md. Maruf Mortula, and Tarig Ali

Abstract

In recent years, the use of renewable energy sources has become key to mitigating climate change and reducing dependence on fossil fuels. Wind energy is a promising source of renewable energy, and identifying suitable sites for windmill installation is critical for maximizing its potential. However, it requires understanding the advantages and disadvantages using spatial analysis of many geographic parameters of concern. Geographic Information Systems (GIS) and remote sensing techniques can be used to analyze various factors that influence the suitability of a site for wind energy production. United Arab Emirates (UAE) is a country surrounded by the Arabian Gulf and Gulf of Oman on both sides, having immense potential for wind energy production. However, effective utilization of the potential is key to achieving success in wind energy production. This study focuses on using GIS and remote sensing to identify suitable sites for windmill installation in the UAE. The study area covers the entire UAE, and the data used includes solar power density, wind speed, settlements, transportation network, slope, elevation, land use and land cover, and meteorological data. The study employed various GIS and remote sensing techniques, including multi-criteria analysis, weighted overlay, and suitability mapping. The results of the study show that the UAE has high potential for wind energy production, with several areas identified as highly suitable for windmill installation. The study identified factors such as wind speed, topography, and land use/land cover as important factors that influence the suitability of a site for wind energy production. Overall, this study demonstrates the potential of GIS and remote sensing techniques in identifying 1738.23 square km of land as suitable for wind energy production in the UAE. The results of this study can be useful for policymakers and energy planners in making informed decisions regarding the installation of windmills and promoting the use of renewable energy in the UAE.

Keywords

Windmill · Geographical information system · Remote sensing · Wind energy · UAE

1 Introduction

Wind energy has gained significant attention in recent years as an alternative and sustainable source of energy. The progressive increase of the middle class and their growing incomes, technology-supported urban lifestyles, and appliances are the main factors responsible for doubling of electricity demand in the present decade (Bhide and Monroy 2011). To meet the energy demand, it will be a great challenge to the electrical power sectors (Ahn and Graczyk 2014).

Global installed wind-generation capacity, both onshore and offshore, has increased from 7.5 GW in 1997 to 743 GW in 2020 (Global wind report 2021). Human activities that influence the environment (such as burning fossil fuels and deforestation) will responded by the Earth in various ways such as, acid rain, rise in sea level and climate change the detrimental impacts of traditional electricity production techniques on the environment have necessitated the strategic planning and development of environmentally friendly and sustainable power generation techniques. Given the global scarcity of fossil fuel resources and the resulting damage to the environment, the need to transition to renewable energy (Kartal et al. 2022). One of the critical factors in the successful implementation of wind energy projects is the identification of suitable sites for wind turbines. Site suitability assessment requires the consideration of several factors, including wind speed, topog-

R. Gawai (✉) · Md. M. Mortula · T. Ali
Department of Civil Engineering, American University of Sharjah, Sharjah, UAE
e-mail: rgawai@aus.edu

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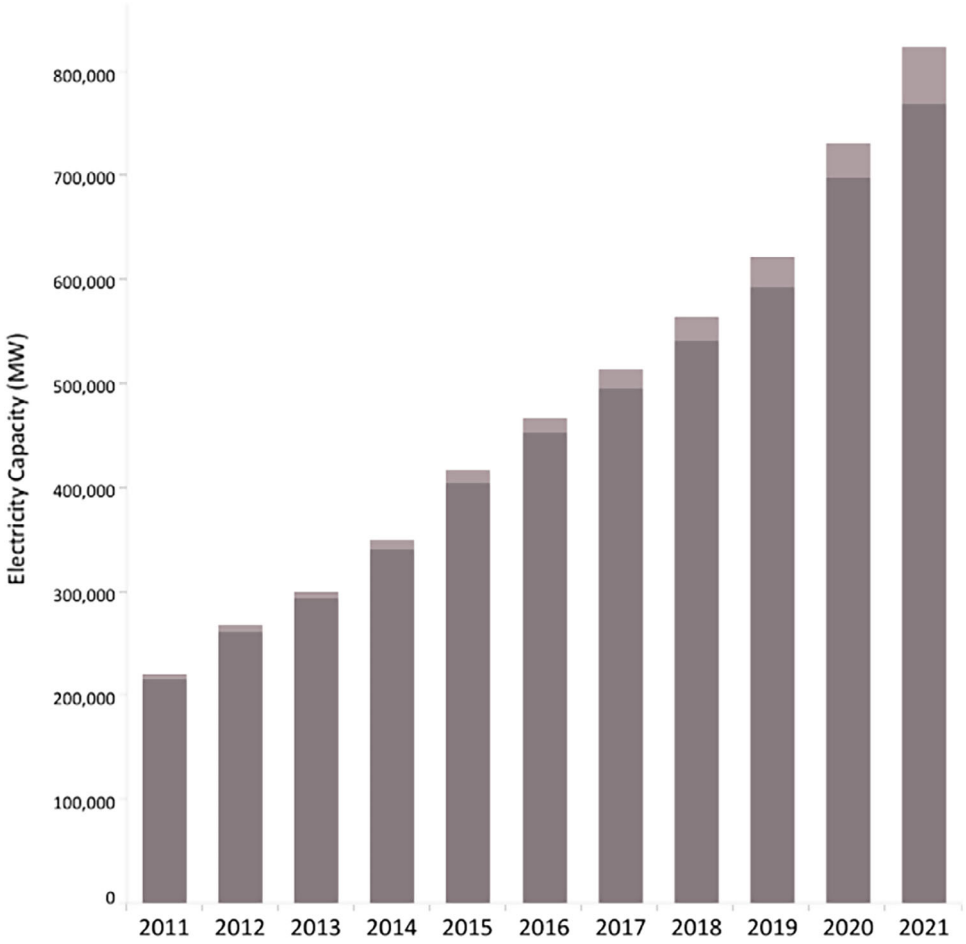


Fig. 1 UAE's wind-generation capacity per year

raphy, land use, and environmental constraints. Geographic Information Systems (GIS) and remote sensing technologies provide valuable tools for evaluating site suitability by integrating and analyzing spatial data (Fig. 1).

There are several technical factors that must be considered to ensure a smooth installation. The decision-making process must account for factors including the ever-shifting wind speed, ease of access, and proximity to existing power systems. Site suitability assessment requires the consideration of several factors, including wind speed, topography, land use, and environmental constraints (Msigwa et al. 2022).

Geographic Information Systems (GIS) and remote sensing technologies provide valuable tools for evaluating site suitability by integrating and analyzing spatial data (Xu et al. 2020). Therefore, it is crucial to use GIS for installation sites to ensure the financial benefits of a wind power plant. Since GIS has the necessary features for modelling multi-criteria analysis, it has been widely used to help find optimal locations for wind farms. Therefore, this study demonstrates the potential of GIS and remote sensing techniques in identifying suitable sites for wind energy production in the UAE.

2 Materials and Methods

The present study uses a variety of datasets that were gathered from various organizations, open sources, and similar literary works and referring to related literature, climatology, topography, and accessibility were identified as the main factors, whereas wind speed, wind power density, slope, land use, proximity to the transmission grid network, roads and residential areas were designated as criteria.

2.1 Study Area

The UAE is made up of seven emirates: Abu Dhabi, Dubai, Sharjah, Ajman, Umm Al Quwain, Ras Al Khaimah, and Fujairah with a total geographical area of approximately 83,600 square kilometers. The country's latitude ranges from 22.6333 ° N to 26.3839 ° N, while its longitude ranges from 51.5833 ° E to 56.3817 ° E.

Table 1 Data source

Data	Data source	Links	Spatial resolution
Wind speed	Global wind atlas	https://globalwindatlas.info/en	100 m
Mean power density	Global wind atlas	https://globalwindatlas.info/en	100 m
DEM	SRTM	https://earthexplorer.usgs.gov/	30 m
Powerline	OSM	https://www.openstreetmap.org/	
LULC	Sentinel ESRI	https://livingatlas.arcgis.com/landcover/	10 m
Roads	OSM	https://www.openstreetmap.org/	

2.2 Data Source and Methods

First step: Identify the constraint thematic layers to eliminate the unsuitable sites, using the integrated tools of ArcGIS Pro 3. Second step: Reclass all the layers' input data into 1 to 9 classes. Third step: Apply the weighted sum overlay approach to assign the relative weight of each criterion. Fourth step: generate the final suitability maps using the weighted overlay tool within the ArcGIS Pro. For the conduct of this study used the following data set mentioned in Table 1.

3 Results and Discussion

The analysis presented in this study covers the entire UAE region and is based on freely available data sources. The analysis utilizes the weighted sum method, a popular approach for assessing site suitability. This method involves assigning weights to various factors or criteria that determine suitability and then summing up these weighted values to rank or categorize sites.

The specific data sources used for this analysis are not detailed in this summary, but they are openly accessible and have been employed to evaluate the suitability of sites for windmill installation across different categories, ranging from the lowest suitable to the highest suitable (Table 2).

Table 1 indicates the land suitability for windmill sites, categorizing it into nine classes based on total land area and the percentage it represents. The categories range from "Lowest Suitable" with 3.48% of the total land (2562.87 sq. km) to "Highest Suitable" with 2.36% of the total land (1738.23 sq. km). Land suitability progressively improves from the lowest to highest categories, with "High Suitable" and "Very High Suitable" classes occupying 13.75% (10,135.39 sq. km) and 10.47% (7718.27 sq. km) of the total land, respectively. These findings provide valuable information for wind energy project planning and indicate the distribution of land suitable for windmill sites within the studied area.

Table 2 Land suitability for windmill sites

Class name	Total land in sq.km	% of lands
Lowest suitable	2562.87	3.48
Very low suitable	5036.87	6.83
Low suitable	7316.46	9.93
Moderately low suitable	9947.73	13.5
Moderately suitable	15095.53	20.48
Moderately high suitable	14162.71	19.21
High suitable	10135.39	13.75
Very high suitable	7718.27	10.47
Highest suitable	1738.23	2.36

The land suitability map generator shown in Fig. 2. After combining all the parameters using the weighted sum and assign the weight according to their intensity lowest suitable to highest suitable map shows the highest suitable lands for the windmill sites is located western and southern part of the UAE while lowest land suitable located eastern and northern part of the UAE it's because most of the settlements located along the Arabian gulf coast. There are few regions where there are moderate stability lands available for the establishment for windmill turbine. There are huge portions located in the western part of the UAE.

4 Conclusions

In conclusion, the analysis of land suitability for windmill sites across the UAE region using the weighted sum method has provided valuable insights. The findings categorize land into nine distinct suitability classes using, ranging from "Lowest Suitable" to "Highest Suitable," based on the available data sources.

This classification offers a comprehensive overview of where wind energy projects are most likely to succeed, considering various factors and criteria. It's important to note that the UAE's diverse geography and environmental conditions have been considered in this assessment. These results can serve as a critical resource for decision-makers, investors, and stakeholders interested in harnessing wind energy in the UAE, guiding them towards the most suitable sites for sustainable and efficient windmill installations. Further refinement and detailed analysis may be required to support the planning and implementation of specific wind energy projects in the region.

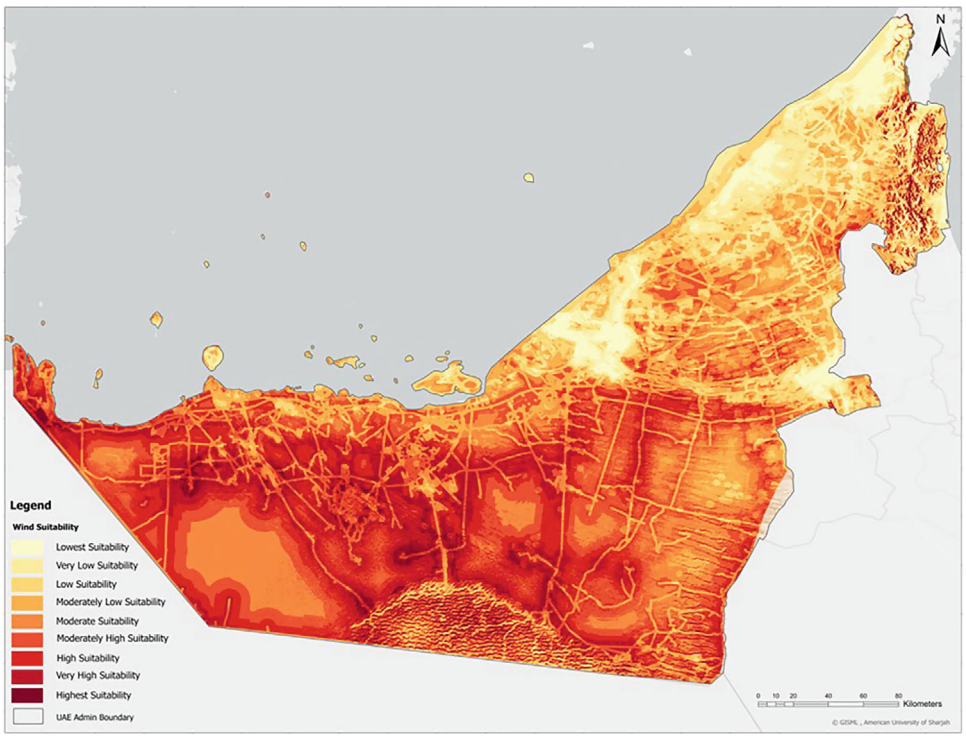


Fig. 2 Windmill site suitability map

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CarboAmazon: System for Mapping Carbon Credit Areas in the Amazon

Izabela C. L. Carvalho, Carlos S. S. Souza, Clayton A. M. Santos, and Celson P. Lima

Abstract

Carbon credits are an important tool for reducing greenhouse gas emissions (GHGs) and promoting environmental protection. By buying and selling carbon credits, companies and individuals can offset their emissions, finance sustainable projects, and support the preservation of vital ecosystems. For carbon credit projects to succeed, it is necessary to identify areas with the potential to capture large amounts of CO_2 and generate credits. Mapping carbon credit zones is a fundamental tool in this process. Area mapping involves the use of technologies such as remote sensing and geoprocessing to assess characteristics of areas of interest, such as vegetation, topography, and land use. Based on this information, it is possible to identify areas with the highest potential for generating carbon credits. The goal of this tool is to apply geotechnologies to the development of methodologies for assessing greenhouse gases and forest carbon stocks. It aims to digitally classify and estimate the carbon stock of reference areas in natural and implanted forests in the Amazon biome through remote sensing. The project also aims to systematize a geographic database with greenhouse gas emissions and carbon stocks of natural and planted forests in the reference areas; apply different digital classification models for native and planted forests; and spatialize the biophysical parameters of native and planted forests through carbon mapping of the studied areas. As a result, technical-scientific impacts stand out, such as the generation of processes and methodologies for estimating forest carbon stocks through remote sensing; results of economic and environmental impact, through the generation of carbon mapping protocols with lower costs than traditional protocols; and impacts on governance, through the generation of a spatially explicit database on greenhouse gases and carbon stocks, supporting government decision-making and public policies for sustainable development.

Keywords

Carbon credits · Greenhouse gas emissions · Remote sensing · Amazon biome · Sustainable development

1 Introduction

The issue of climate change and its global consequences has raised the need for innovative approaches to mitigate greenhouse gas (GHG) emissions and preserve natural ecosystems. Carbon credits have emerged as a strategy that not only contributes to reducing these emissions but also promotes environmental protection and sustainable development. By enabling the buying and selling of carbon credits, companies and individuals can not only offset their own emissions but also finance projects and actions that contribute to the preservation of vital ecosystems, such as the Amazon rainforest (Carbon Credit 2023; Ecossistema De Valor 2023).

The Brazilian Amazon, as one of the world's largest tropical forests, plays a crucial role in capturing CO_2 and regulating global climate (INPE 2023). However, the increasing rates of deforestation and forest degradation in the region pose a significant threat to environmental stability. In this context, the identification and mapping of areas with high potential for carbon sequestration and credit generation become essential

I. C. L. Carvalho · C. S. S. Souza · C. A. M. Santos (✉)
Federal University of Western Pará, Oriximiná, Pará, Brazil
e-mail: clayton.santos@ufopa.edu.br

I. C. L. Carvalho
e-mail: izabela.carvalho@discente.ufopa.edu.br

C. P. Lima
Federal University of Western Pará, Santarém, Pará, Brazil

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to guide conservation and sustainable land use actions (Silva et al. 2005).

This article introduces CarboAmazon, an innovative system for mapping carbon credit areas in the Amazon. The main objective is to use advanced technologies like remote sensing and geoprocessing to identify and characterize areas within the Amazon biome that have ideal conditions for CO_2 capture and, consequently, carbon credit generation. Through the application of various digital classification models, the project also aims to estimate forest carbon stocks in reference areas, both in native forests and planted areas.

To achieve this, the project utilizes data obtained from satellites and drones, which are processed by specialized spatial analysis software. The project also relies on secondary data about land use, climate, and biodiversity in the region. The project's methodology follows the guidelines of the Intergovernmental Panel on Climate Change (IPCC) (IPCC 2020) and the Ministry of Science, Technology, and Innovation (MCTI) (MCTI 2020) for carbon stock and emissions calculations. The project is also built upon previous studies on carbon mapping in the Amazon.

2 Results

The preliminary results of the CarboAmazon project are promising and indicate the potential of this approach for assessing and mapping carbon credit areas in the Amazon. Through the detailed analysis of features such as vegetation coverage, topography, and land use, it was possible to identify regions with a greater capacity for carbon sequestration. Additionally, the use of remote sensing technologies allowed for the acquisition of precise and comprehensive data, contributing to a more thorough evaluation of the areas of interest (EBCF 2023a).

The digital classification of reference areas, both in native forests and planted areas, resulted in reliable estimates of forest carbon stocks. This is crucial for quantifying the potential for carbon credit generation and for planning conservation and sustainable management actions. The spatialization of biophysical parameters through carbon mapping provided a detailed view of the distribution of carbon stocks in the studied areas, aiding in the identification of priority areas for interventions (EBCF 2023a).

A project similar to CarboAmazon is the EBCF Carbon Project (EBCF) (EBCF 2023a; EBCF 2023b). This emissions reduction project was certified in November 2017 and underwent a validation process conducted by the Rainforest Alliance in accordance with international certification standards of the VCS CCB (currently VERRA). The Amazon Rio REDD+ IFM project aims to generate approximately 2.2 million VCUs over a 36-year period. The EBCF carbon project is continually monitored and underwent its first verification in 2017, issuing a total package of 240,000 VCUs for the period from 2013 to 2016. Currently, EBCF is undergoing the second verification for the last 6 years (from 2017 to 2022) and is expected to issue approximately 400,000 VCUs in 2023 (EBCF 2023a; EBCF 2023b).

Similar to CarboAmazon, the EBCF Carbon Project also focuses on carbon credit generation and the sustainable development of riverine communities (EBCF 2023a; EBCF 2023b). EBCF is a Climate Tech company with a Business Environmental Platform fully aligned with the 17 UN Sustainable Development Goals (SDGs). It continuously develops new value chains from environmental and digital products, services, and assets to finance its mission of promoting the preservation of the Amazon rainforest, protecting its biodiversity, fostering the sustainable development of traditional and riverine communities, and reducing CO_2 emissions (EBCF 2023a; EBCF 2023b) (Fig. 1).

Please keep in mind that the CarboAmazon project is currently being developed with the goal of enhancing the scope and extent of carbon credit mapping in the Amazon region. The information shared in this text is preliminary and subject to change as the project advances. Additionally, the project aims to form collaborations with public and private organizations that are committed to ecological initiatives to distribute and utilize the mapping outcomes.

The expectation is that the project can contribute to advancing scientific knowledge about carbon stocks in the Amazon, as well as strengthening public policies aimed at reducing greenhouse gas emissions and promoting sustainable development in the region. The project also hopes to encourage the participation of civil society and traditional communities in natural resource management and the appreciation of ecosystem services provided by the forest.

3 Discussion

The CarboAmazon Project indeed marks a significant step forward in the realm of carbon credit mapping, offering a holistic approach that aligns cutting-edge technology with environmental preservation goals. Leveraging geotechnologies, such as remote sensing, for the identification and evaluation of carbon credit areas is both efficient and effective (ISA 2023; Almeida et al. 2016). The incorporation of digital classification models and the spatialization of biophysical parameters significantly enhance the accuracy and granularity of estimates regarding forest carbon stocks.

One of the most compelling aspects of this project is the remarkable economic and environmental impact it delivers. The ability to generate carbon mapping protocols at reduced costs compared to traditional methods opens up access

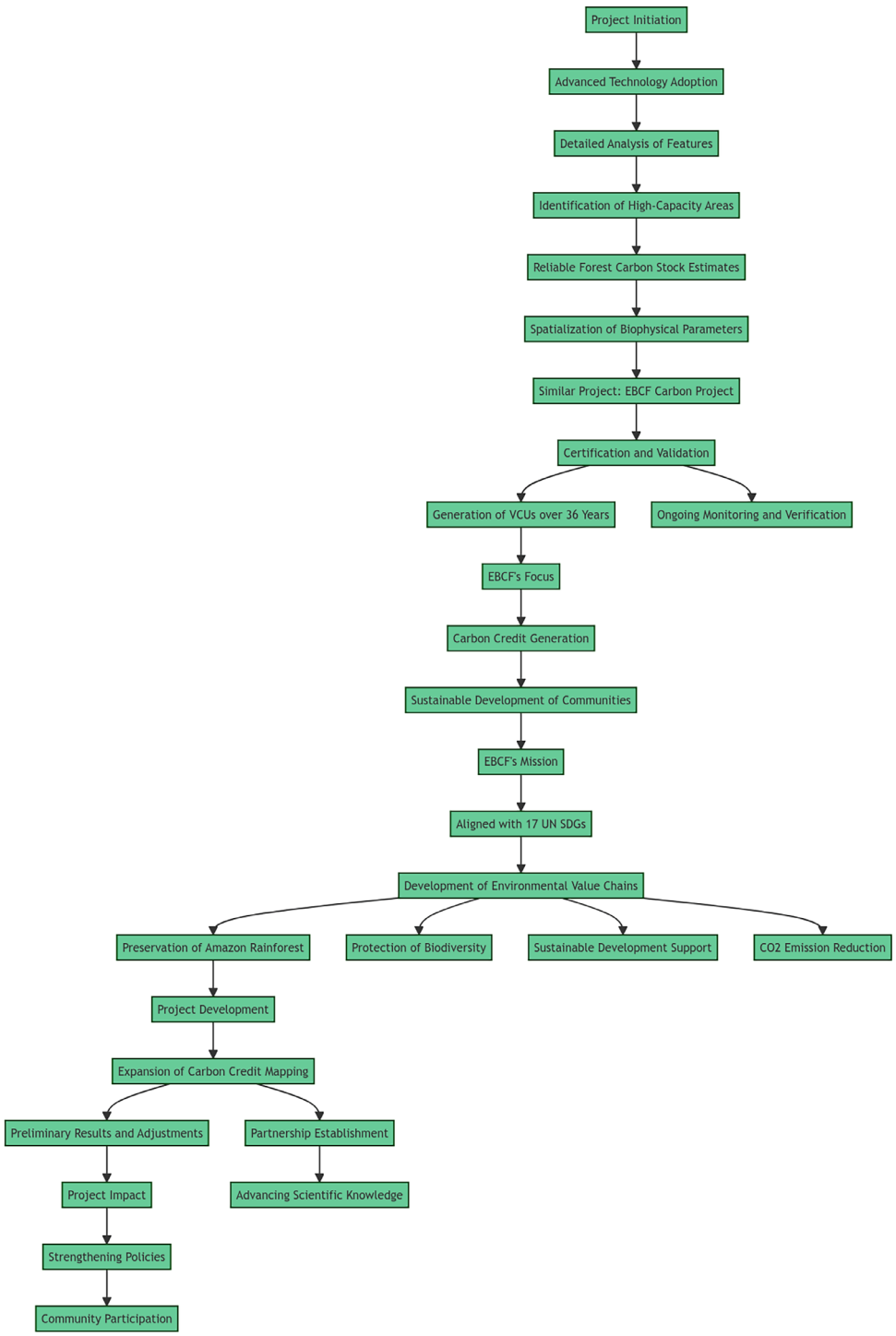


Fig. 1 CarboAmazon project methodology

to conservation and sustainable management tools. This democratization of carbon credit mapping tools is particularly crucial in regions with limited resources, where conservation efforts can face financial constraints.

Additionally, the provision of a spatially explicit database that details greenhouse gases and carbon stocks adds another layer of significance to the project. It serves as a valuable resource for informing public policies and government decisions, aligning them with the goals of sustainable development. By providing comprehensive data, the CarboAmazon Project empowers policymakers and stakeholders to make informed choices that benefit both the environment and the broader community.

In summary, the CarboAmazon Project stands as a beacon of innovation and environmental stewardship, showcasing the potential of advanced technology in addressing critical issues such as climate change and biodiversity conservation. Its cost-effectiveness, accessibility, and data-driven approach make it a valuable tool in the pursuit of a sustainable future.

4 Conclusions

The project emerges as an innovative and comprehensive solution for carbon credit area mapping in the Amazon. Utilizing advanced remote sensing and geoprocessing technologies, the project can identify regions with high potential for carbon sequestration and credit generation. The results achieved, both in technical-scientific aspects and in economic and environmental terms, reinforce the feasibility and relevance of this approach for biodiversity conservation and climate change mitigation.

In this article, we explore the context and motivation behind the project, detail the CarboAmazon system and its methodology, present preliminary results of carbon credit area mapping, discuss the project's impacts and limitations, and conclude with the main contributions and future perspectives of the project. This work aims to provide a comprehensive view of the project, highlighting its potential to transform carbon credit management in the Amazon.

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From Rasters to Social Ecological Gradients over a Research Network

Isabelle Charpentier

Abstract

Open worldwide geographical information databases—landscape, climate, population, vegetation, land cover, practices, and so forth—are frequently mobilized the study of poorly gauged watersheds. More generally, the variety of such databases is an opportunity for collecting information and for evaluating indicators on a common basis. Although the European Long-Term Social Ecological Research (eLTER) network already produced some indicator maps at the level of the European continent, such global representations do not allow for a straightforward local inter-site comparison. This study focuses on the evaluation and the representation of some local indicators for a prescribed set of geographical areas. As a case study, we consider the French long-term social ecological research network, namely Réseau des Zones Ateliers, which conducts action-oriented studies on social ecological systems such as river basins, rural, urban or mountainous territories, or protected areas in Metropolitan France and outside Europe. Besides this general description, it is of prime interest for this network to assess and to bring to light the so-called ecological gradients for the design of new research. Through software engineering, some general workflow is set up from raster extraction to the evaluation of social and ecological indicators. These are mean values for temperature and vegetation index, percentages for land cover and biogeographical regions, or quantiles for population density. Their representation by means of a table of pie charts allows for inter-site comparisons at one glance. Their publication in a data warehouse is also considered. The workflow is operated on 7 of the 15 Zones Ateliers (ZA), yielding 72 pie charts that aggregate about 2500 data on half an A4 page. As expected, some gradients reflecting the diversity in the territories already appear in this table of pie charts. For instance, the results for 2 ZAs (in Brittany) are very similar and come in support to their joint research project on the land-sea continuum. More results will be presented in the extended abstract. The workflow is of general use to get indicators and perform comparisons over a prescribed set of geographical areas (watershed, eLTER sites, protected areas, for instance).

Keywords

Geo-informatics · Raster · Social ecological system · Indicators · Ecological gradients

1 Introduction

Open, worldwide, geographical information databases are an opportunity for the assessment of heterogeneity among a long-term social ecological research (LTSER) network or a federation of protected areas. For instance, monthly gridded variables about climate, population, vegetation, or land cover already provide a coarse but relevant information. According to the number of files and possible indicator values, the provision of both a general workflow and a smart representation mode is necessary to the assessment of social ecological gradients over a LTSER network.

The French LTSER network and the workflow are presented in Sect. 2. Indicators are displayed as pie charts in Sect. 3 for a straightforward inter-site comparison. Advantages and limits are discussed in Sect. 4. A conclusion is proposed in Sect. 5.

I. Charpentier (✉)
ICUBE, Unistra&CNRS, Strasbourg, France
e-mail: isabelle.charpentier@unistra.fr

LTSER-FR ZAEU, CNRS, Strasbourg, France

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2 Settings

The Réseau des Zones Ateliers (RZA) (Bretagnolle et al. 2019) is the French distributed research infrastructure dedicated to social ecological systems delimited by a river basin, some rural, urban or mountainous territories, or protected areas in Metropolitan France and outside Europe. Its 15 Zones Ateliers (ZAs) put emphasis on human-nature interactions and sustainability by means of in situ social ecological observations and action-oriented experimentation.

Although the RZA promotes open science, the current heterogeneity in the observed variables, in the acquisition protocols, and in the data formats in use may restrain inter-ZA comparisons. A quantitative assessment of the so-called ecological is thus of prime importance for the development of new research within the RZA.

Retrieving and compiling heterogeneous data is among the scientific hot issues. For instance, the Long-Term Ecosystem Research network (eLTER) develops some R package called ReLTER (Oggioni et al. 2023) for the extraction of data from publicly available resources to enrich on-site observations. Besides eLTER also produced some indicator maps at the level of the European continent (Wohner et al. 2021). Clearly, such representations do not yet allow for straightforward local inter-site or inter-ZA comparisons.

To go one step beyond, a general workflow ranging from raster extraction to the evaluation of social and ecological indicators is proposed together with a dedicated representation mode. In Fig. 1, the workflow phases are mapped with regards to Findable−Accessible−Interoperable−Reusable (FAIR (Wilkinson et al. 2016)) principles.

Firstly, social and ecological raster data (land cover, population, temperature or vegetation, for instance) should be findable using either a general browser or thematic ones (like NEO for earth observations or DEIMS-SDR for eLTER sites). Secondly, data should be accessible. Data providers offer more or less complex application programming interfaces and file formats. Interoperability is thus an issue. ReLTER solves it by proposing an interface. We download files to ensure repeatability and to limit the number of remote accesses. Thirdly, the Matlab integrated development environment is used to manage the different file formats and to take advantage of TopoToolbox (Schwanghart and Kuhn 2010) in our geographical (GIS) analyses. Fourthly, we design the ModZA software to automate the workflow. This organizes computational loops over the ZAs' list, variables, and dates that crops rasters and generates a large number of sub-rasters. Indicators are then computed as mean values for land surface temperature day (LSTD (Wan et al. 2015)) and normalized difference vegetation index (NDVI (Didan 2015)), percentages for land cover (LC (Zanaga et al. 2021)) and biogeographical regions (BIOG (Biogeographical regions 2016)). Quantiles and a logarithmic scale are used for population density (GPW4 (CIESIN 2018)). Their representation as a table of pie charts allows for some inter-site comparisons. For each ZA and each variable, ModZA generates the indicator set and saves it into a JSON file together with metadata (sources, processes, units, scaling) for the sake of reproducibility. Finally, the dataset is published in a data warehouse following FAIR principles (Charpentier 2023). Throughout the study, additional sites, rasters and indicators were considered to check the robustness of the workflow.

3 Results

Seven 7 Zones Ateliers comprising Alpine (ZAA, Alpes), urban (ZAEU, Strasbourg), agricultural (ZAAR, Armorica; ZAPYGAR, Pyrenees-Garonne), coastal (ZABRI, Brittany) and riverine (ZAL, Loire river; ZAM, Moselle river) systems are considered.

Their limits downloaded from DEIMS-SDR are used to crop rasters (Fig. 2) such as for the BIOG.variable (Fig. 2).

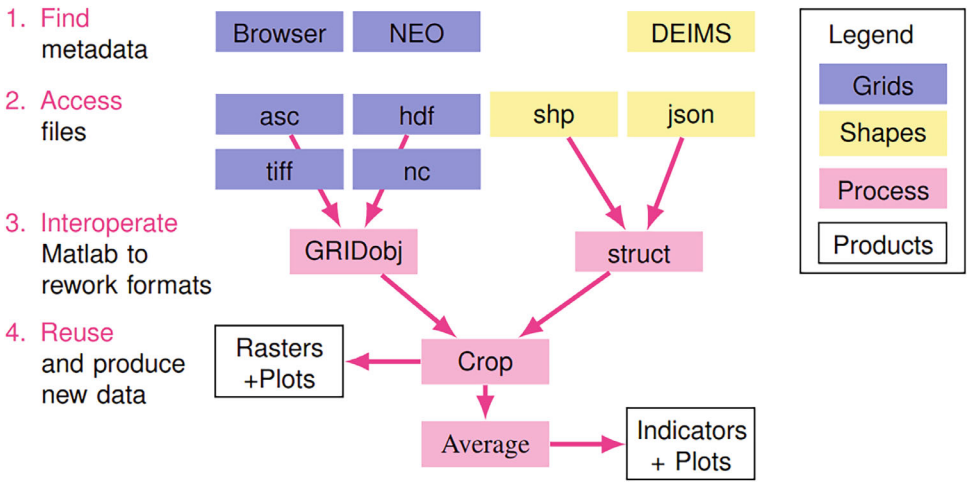
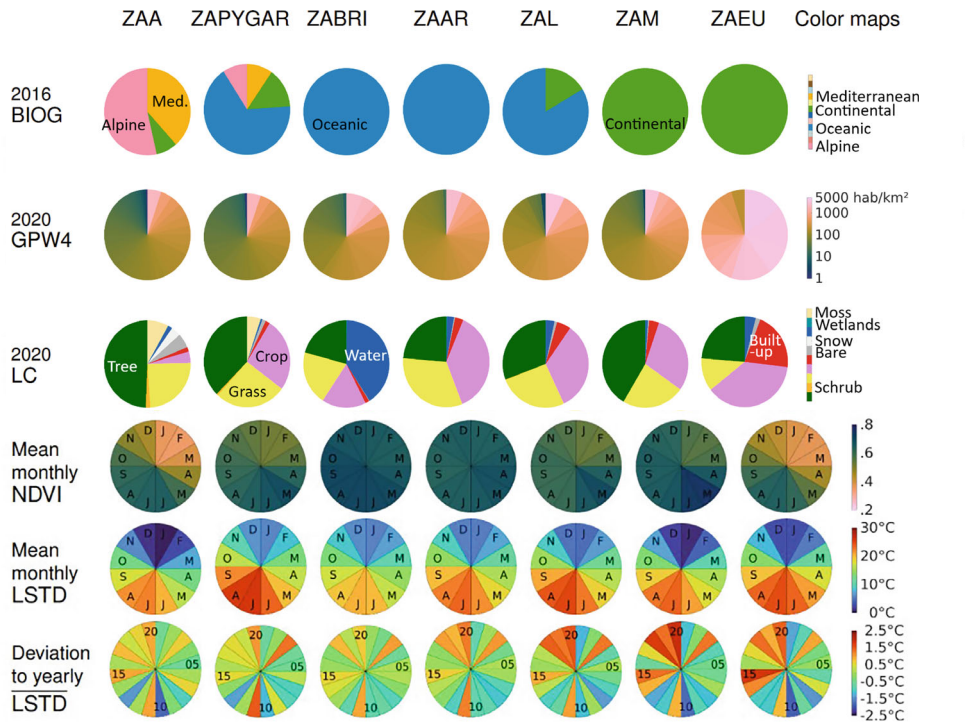


Fig. 1 Methodological workflow used in this study, steps 3 and 4 implemented in Matlab

Fig. 3 Table of indicators



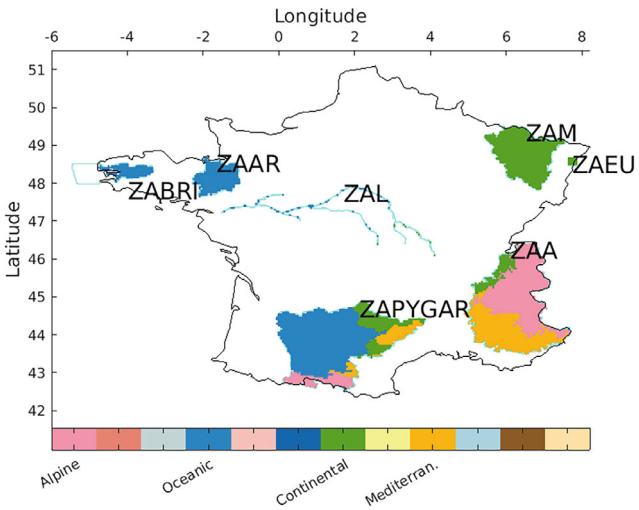


Fig. 2 Crop of the "European Biogeoraphical regions" raster with respect the shape of 7 ZAs

Note that ZAL's polygon corresponds to the Loire River and its tributaries.

From the workflow operated on 7 ZAs and 5 variables we select 42 pie charts plotted in Fig. 3. The BIOG line draws ratios computed from Fig. 2. The GPW4 and LC charts clearly distinguish the urban ZAEU from the other ZAs. Similarly, the ocean part of the ZABRI is well rendered by the land cover variable.

The last 3 indicators describe evolutions of vegetation (NDVI) and land surface temperature (LSTD) on a monthly or a yearly basis. Mean monthly NDVI pies reflect the greenness of the land. Under oceanic ZAAR and ZABRI are the greenest areas all along the year. In a different climate zone, ZAA and ZAEU experience the largest NDVI variations at the same time, but for different reasons. In winter, the Alps are covered by snow while the leafless deciduous trees let visible the urban fabric within ZAEU. The deviations to the yearly mean temperature (last line of Fig. 3) inform on climate variation from 2001 to 2020. The second decade is warmer than the first one for all the ZAs, especially for continental ZAs.

4 Discussion

The concise table or chart of Fig. 3 provides indicators computed on a common basis at the level of a social ecological research network. It can be applied to any other set of geographical areas. Similarly, the workflow and the computer code are implemented for a variety of variables and formats. They may be used to deal with new raster sets as far as data are findable and accessible, and information is available to reuse them.

Some social and ecological gradients reflecting the diversity in the territories appear. For instance, the very similar results for ZAAR and ZABRI (in Brittany) come in support to their joint research project on the land-sea continuum.

To go one step beyond, smaller territories called ZA's sites may be considered. Site indicators allow for a finer capture of the spatial heterogeneity. These local indicators could be evaluated against open ground-based datasets and on-site observations.

The "FAIR"ness of the datasets we used is not satisfied since these are provided without metadata (except for BIOG), even if data was described in technical reports. A FAIR workflow is thus needed to deal with the diversity of variables and protocols and to propose some indicators to a general audience.

5 Conclusions

The FAIRness of the data remains a key complex concern for a scientific research. Although not FAIR within the scientific meaning, open worldwide rasters are usually provided with sufficient information to be reused. To go one step beyond, the heterogeneity in their characteristics is smoothed by implementing a general workflow.

The resulting concise, coarse but informative indicator chart informs on the gradients over the RZA social ecological research network, striving for research and opening science opportunities.

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Assessment of Nearshore Bathymetry Data Using GIS Technique

Şerife Pınar Güvel and Mehmet Ali Akgül

Abstract

Bathymetry mapping has been employed in the construction of underwater facilities, marine structures, ports and water structures, navigation, coastal monitoring and protection, and stream enhancement projects. The acquisition methods of bathymetric data are subject to accessibility, costs, and constraints. The methods used in the preparation of bathymetry maps can be determined in accordance with the purpose and content of the study scope according to their advantages and limitations. The goal of the study is to assess the benefits of geographic information systems (GIS) and its significance in decision-making, particularly in the field of bathymetry. The Anamur Sultan Suyu Stream sea outlet area and its surroundings were chosen as the research area for GIS-supported coastal bathymetry investigation. The Anamur Sultan Stream is located near Mersin, in the Eastern Mediterranean Basin, in Türkiye. In this study, GIS technique was used in three-dimensional modeling of coastal bathymetry to evaluate if there is a closure at the creek's mouth or sand accumulation that prevents the stream from joining the sea. The usefulness of GIS technology in completing a preliminary evaluation of whether a containment structure at the sea's outflow is necessary was also assessed with the findings. The coastal slope was assessed using a 3D model created in a GIS environment to aid in coastal management research. Another purpose of this research is to look into the potential of utilizing GIS techniques to evaluate bathymetry data sets and contribute to bathymetry data management for decision-makers. As a result, it was evaluated that GIS-supported analysis in assessment of coastal bathymetry data contribute decision-making process in coastal management studies.

Keywords

Bathymetry · Geographic information system · Anamur Sultan Suyu Stream · Bathymetry mapping

1 Introduction

Bathymetry is a basic feature of oceans, seas, and lakes and has importance for a wide variety of applications such as physical oceanography, geophysics, biology, or marine researches (Hell et al. 2012). The acquisition methods of bathymetric data are subject to accessibility, costs, and constraints. The methods used in the preparation of bathymetry maps can be determined in accordance with the purpose and content of the study scope according to their advantages and limitations. Bathymetry data is obtained using conventional methods (Güvel 2007) and/or advanced technologies such as remote sensing (Randazzo et al. 2020; Daly et al. 2022). Echo sounder surveying is a frequent underwater mapping technique (García et al. 2016).

Bathymetry mapping has been used in the development of undersea facilities, marine structures, ports, and water structures, navigation, coastal monitoring and protection (Janowski et al. 2022), and stream enhancement projects. Researches on bathymetry topic for investigating underwater topography in lakes (Zhu et al. 2019), in bays (Figliomeni and Parente 2022), in rivers (Wu et al. 2019), in river mouths (Kaboğlu et al. 2018), in dam reservoirs (Ibrahim et al. 2023), in estuaries (Sánchez-Carnero et al. 2013) have been carried out in earlier studies. Several researches on bathymetry for assessment of accuracy of interpolated bathymetry (Amante and Eakins 2016) and for investigation of sediment thickness in dam reservoirs (Güvel et al. 2021) were conducted in previous studies.

The geographic information system (GIS) technique was used in the three-dimensional modeling of coastal bathymetry in this work to assess if there is a closure at the creek's mouth

Ş. P. Güvel (✉) · M. A. Akgül
General Directorate of State Hydraulic Works, Adana, Türkiye
e-mail: pinar.guvel@gmail.com

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or sand buildup that prevents the stream from entering the sea. With the findings, the usefulness of GIS technology in completing a preliminary evaluation of whether a containment structure at the exit to the sea is necessary was also assessed. The coastal slope was assessed using a 3D model created in a GIS environment to aid in coastal management research.

2 Materials and Methods

The Anamur Sultan Suyu Stream sea outlet area and its environment were selected as the study area for GIS-based coastal bathymetry. The Anamur Sultan Suyu Stream lies in Türkiye's Eastern Mediterranean Basin, near Mersin (Fig. 1), and joins into the Mediterranean Sea.

The Eastern Mediterranean Basin is bounded by the Konya closed basin to the north and the Mediterranean Sea to the south. The basin has several types of rivers and stream subbasins that flow straight into the sea. River flow regimes vary throughout the year due to spring, summer, autumn, and winter rainfall regimes, resulting in considerable surface runoff.

The basin has a Mediterranean climate, with dry, hot summers and moderate, warm winters. There are settlements and agricultural fields around the research area.

In recent years, water and land resource planning research has been conducted to aid in accelerating the development of the area. The Sultan Suyu stream is an important source of sediment supply.

3 Results and Discussion

The bathymetry map prepared by echo-sounding was analyzed in a GIS environment. GIS tools were used to generate a 3D model of the research region in order to investigate the spatial changes in the coastal area (Fig. 2). The coastal slope was assessed using a 3D model created in a GIS environment to aid in coastal management research. Bathymetry investigations benefit from the use of GIS techniques in terms of labor and time savings.

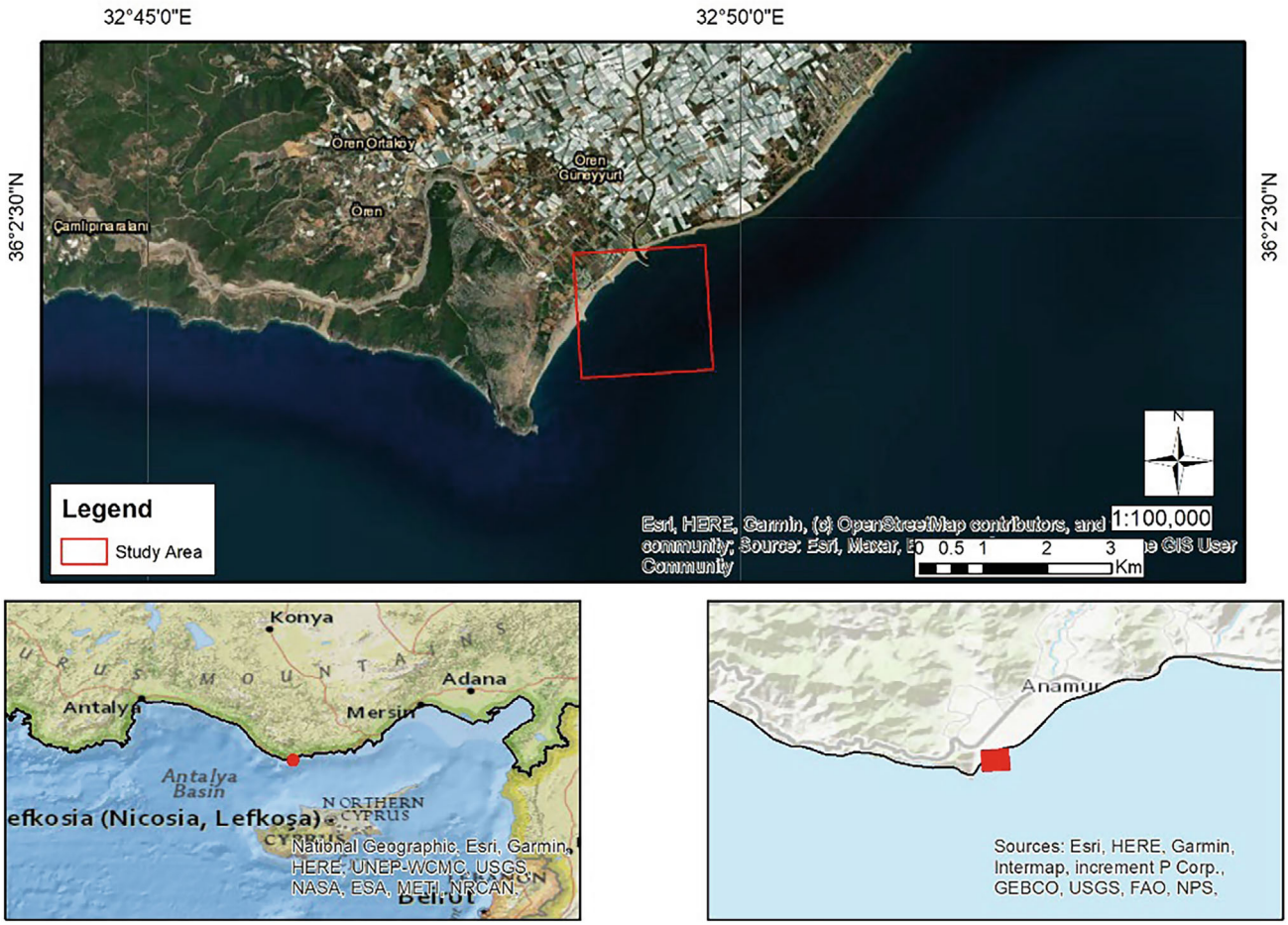


Fig. 1 Location of the study area

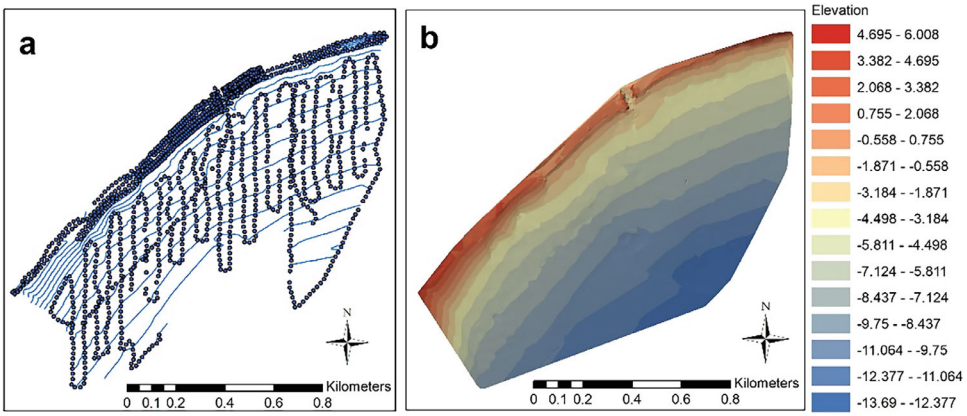


Fig. 2 **a** Bathymetry survey data in the study area, **b** 3D model in GIS environment

4 Conclusions

The benefits of GIS in the field of bathymetry and its usefulness in decision-making are evaluated using Mersin Anamur District Sultan Stream and sea outflow as the research region. This study focused on possibilities for utilizing GIS techniques in bathymetry mapping. It was evaluated that future monitoring works will provide an estimate of suspended particles at the mouth level. It was also assessed that employing GIS techniques to analyze bathymetry data sets benefits decision-makers in coastal management studies.

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Application of SAR Technique to Sentinel-1 Images for Monitoring Tailings Elevation Changes of Abandoned Lakhouat Mine (Siliana, Northwestern Tunisia)

Jihene Nouairi, Ali Azedou, and Mounir Ghribi

Abstract

Mining wastes at the abandoned Lakhouat mine in Siliana, Tunisia threaten nearby areas through erosion of contaminated material. Synthetic Aperture Radar (SAR) enables monitoring topographic change over time. This study used Sentinel-1 C-band SAR data from 2013 to 2021 to generate annual Digital Surface Models (DSMs) of the mine tailings. DSMs were (1) produced, (2) co-registered for alignment, and (3) had elevation values extracted via interferometry. Pixels with decreasing/increasing values indicated erosion/accumulation. Results showed declines over 420 m exceeded those at 400–410 m. Tailings were classified as: boundary zones declined up to 4.8 m indicating concentrated erosion; middle zones remained steady implying less erosion; accumulation zones rose up to 1 m likely due to sedimentation, despite erosion dominating as area/elevation decreased. SAR effectively detected erosion-related elevation changes, aiding hazard assessment from windborne/waterborne toxic dusts and calling for remediation.

Keywords

Remote sensing · Synthetic aperture radar (SAR) · Elevation monitoring · Mine tailings · Environmental impact · Tunisia

J. Nouairi (✉)
The Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy
e-mail: jnouairi@ictp.it

J. Nouairi · M. Ghribi
National Institute of Oceanography and Applied Geophysics (OGS), Sgonico, Trieste, Italy

A. Azedou
National School of Applied Sciences, Ibn Tofail University, Kenitra, Morocco

1 Introduction

The abandoned Pb-Zn Lakhouat mine in northwest Tunisia left extensive mine wastes (MW) highly susceptible to erosion. Old extraction techniques failed to recover all metals, leaving PTE-rich wastes that pollute surrounding areas by contaminating topsoils and vegetation.

Remote sensing (RS) enables non-destructive mapping and monitoring of land surfaces over time (Henry et al. 2018). Digital Surface Models (DSMs) generated from Synthetic Aperture Radar (SAR) data provide high-resolution topographic information unaffected by clouds or darkness. Comparing DSMs at different times enables identification of elevation changes indicating erosion or sedimentation (Khosravi et al. 2021).

This study aims to detect elevation differences between 2013 and 2021 DSMs of the Lakhouat mine area produced from Sentinel-1 SAR data. Three steps were followed: (1) DSM generation for each year, (2) co-registration to ensure geographic alignment, and (3) elevation change analysis to find erosion areas and waste accumulation. Identifying zones of decreasing or increasing elevation can help evaluate priority remediation areas.

While RS allows extensive observations, this study focuses narrowly on quantifying elevation differences using DSM analysis. Addressing environmental impacts requires continued monitoring and sustainable remediation efforts.

Methodology

Digital Surface Model (DSM) generation and comparison were used to identify elevation changes at the Lakhouat mine tailings between 2013 and 2021. Synthetic Aperture Radar (SAR), an active remote sensing technique, provided the high-resolution elevation data.

Sentinel-1 C-band SAR imagery acquired by the Copernicus program in 2013, 2015, 2017, 2019, and 2021 was

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Table 1 Acquisition dates for the SAR imagery

Year	Acquisition date	Data used	Platform
2013	01/04/2013–01/09/2013	Copernicus global DEM-	Google earth engine
2015	16/01/2015 and 21/01/2015	Sentinel-1-VV-band	Copernicus data space ecosystem
2017	22/07/2017 and 28/07/2017	Sentinel-1-VV-band	Copernicus data space ecosystem
2019	31/05/2019 and 06/06/2019	Sentinel-1-VV-band	Copernicus data space ecosystem
2021	19/06/2021 and 25/06/2021	Sentinel-1-VV-band	Copernicus data space ecosystem

downloaded. Two scenes per year captured the study area under optimal conditions to minimize humidity and rainfall effects (Table 1). SNAP open-source software implemented the standard SAR processing chain including radiometric calibration, geometric correction and filtering to obtain preprocessed imagery.

Interferometric SAR techniques were then applied to extract elevation information from the phase difference between slightly offset SAR acquisition geometries (Liu et al. 2019). This phase difference correlates precisely to ground elevation (Simonetto et al. 2005). The resulting Digital Surface Models were generated through interferometry for each year (Fig. 1).

Lastly, the co-registered annual DSMs were compared pixel-by-pixel to quantify elevation differences between 2021 and the baseline 2013 DEM. Changes indicated by decreasing or increasing elevation values revealed zones of erosion and sedimentation. Figure 2 specifically maps the elevation difference across the Lakhouat mine tailings over this eight-year period, providing the key results on temporal topographic evolution.

Kriging interpolation enhanced the resolution of DSM products for clear change detection and interpretation. This focused methodology addressed the objectives of identifying spatial patterns and magnitudes of elevation change.

Results

All extracted DSMs for the period 2013–2021 were exported to a GIS environment for comparison. The latter were classified into five elevation classes to better show the topographical change for each class. As shown in Fig. 1, the extent of the mine has two main fill structures with an elevation of 428 m for the largest and an elevation of 416 m for the second. In a general view, the surface of the mine is gradually decreasing over time all over its extent. The class of pixels with an elevation of greater than 420 m shows a marked decrease over time compared to the class of pixels with an elevation between 400 and 410 m. To show the change in elevation over this period in a clearer way, the difference in elevation between the DSMs of the years 2021

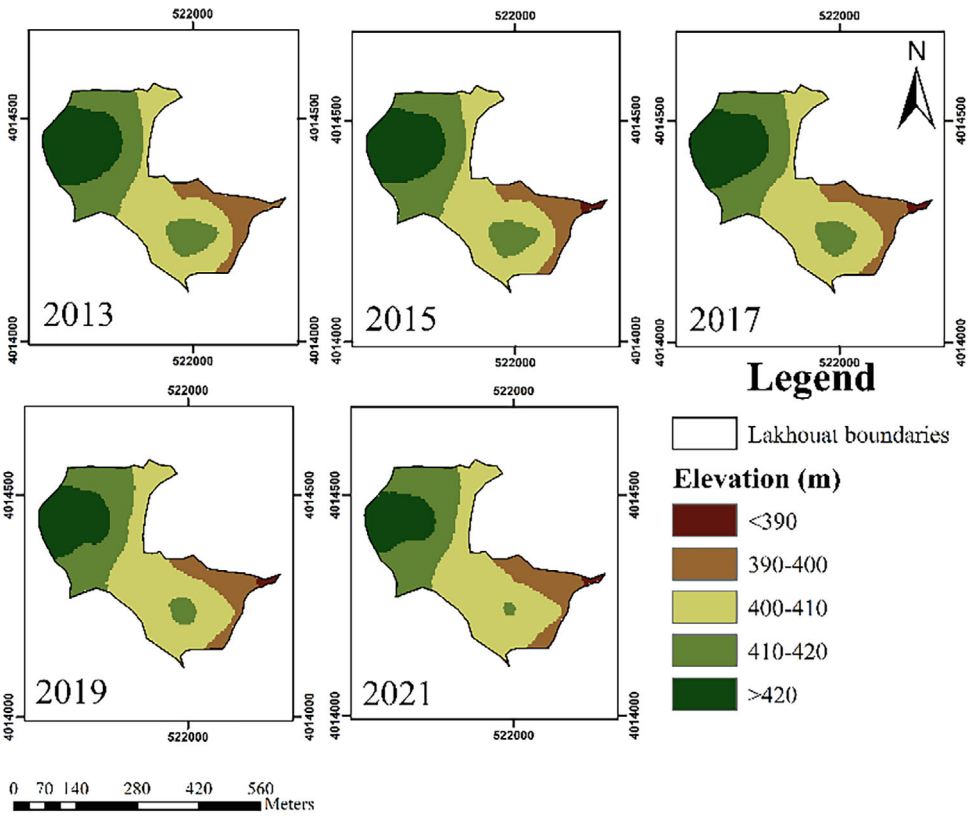


Fig. 1 Dynamic change of Lakhouat mine over the 2013–2021 period

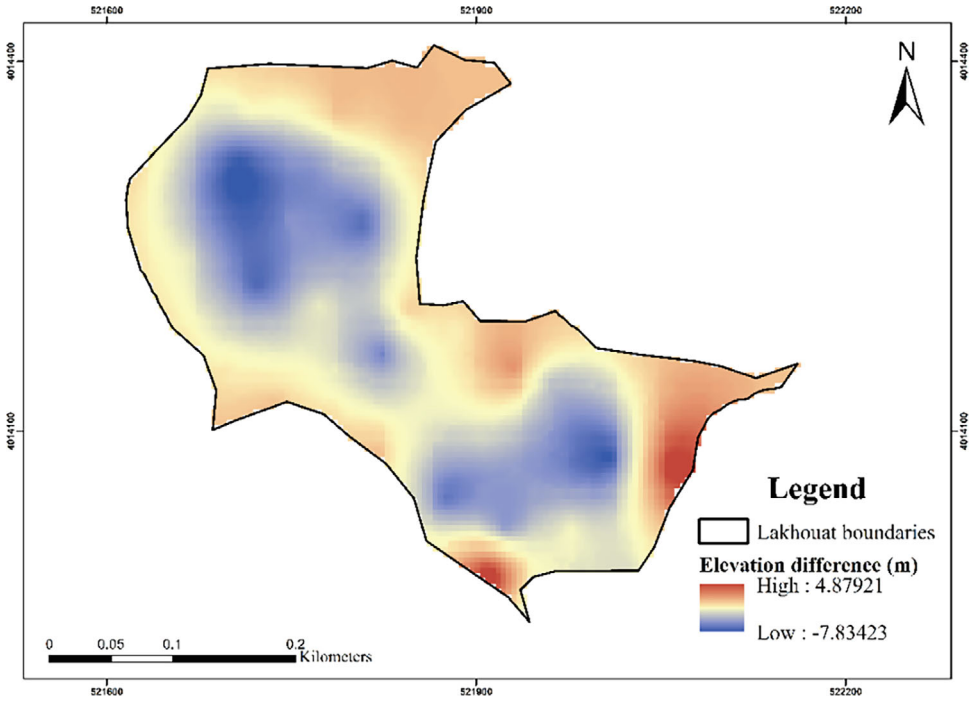


Fig. 2 Lakhouat mine elevation difference between 2021 and 2013

and 2013 was calculated (Fig. 2). This enabled us to show the areas that have experienced greater change more clearly.

The difference in elevation between the DSMs of the years 2021 and 2013 was calculated. The observed elevation difference can be categorized into three zones (Fig. 2):

1. Boundary zones: These areas had the most substantial decreases in elevation, up to 4.8 m. This erosion is likely a result of concentrated erosion at the edges of the tailings, contributing to an overall reduction in surface area.
2. Intermediate zones: In contrast to the boundary zones, these areas showed relatively stable elevations, indicating less erosion activity.
3. Accumulation zones: Within the tailings, some areas had small increases in elevation, up to 1 m. These increases are likely due to sedimentation processes. However, erosion still dominates in these zones, as evidenced by the net decrease in both surface area and elevation over time.

To provide a detailed understanding of the spatiotemporal change in the elevation of the Lakhouat mine, a topographic profile of 517 m was established using GIS tools (Fig. 3). This provided a representation of the terrain relief for each year of the study period.

2 Discussion

The results of this study reveal distinct patterns in the erosion of mine tailings based on the variation of their elevation. Specifically, it was observed that tailings above 420 m underwent more significant decreases in elevation compared to those ranging from 400 to 410 m. These findings suggest varying erosion processes within the tailings.

The study's use of Kriging interpolation to enhance DSM resolution is limited by its assumption of stationarity, which may not apply in complex terrains. Kriging is also sensitive to outliers, potentially introducing bias and impacting precision/reliability of final DSMs. Acknowledging such methodological constraints, considering alternative approaches, or explicitly discussing Kriging uncertainties is important to comprehensively assess limitations and qualify conclusions, thereby supporting the results.

The results of this study align with existing research using remote sensing to monitor mine waste degradation. Similar to Trabucchi et al. (2012), higher erosion rates were observed at the boundaries of the opencast mines in Spain's Martin River basin, supporting Kenner's model of waste concentration in the upper Flüelapass talus (Kenner 2020). The methodology, generating co-registered DSMs from multi-

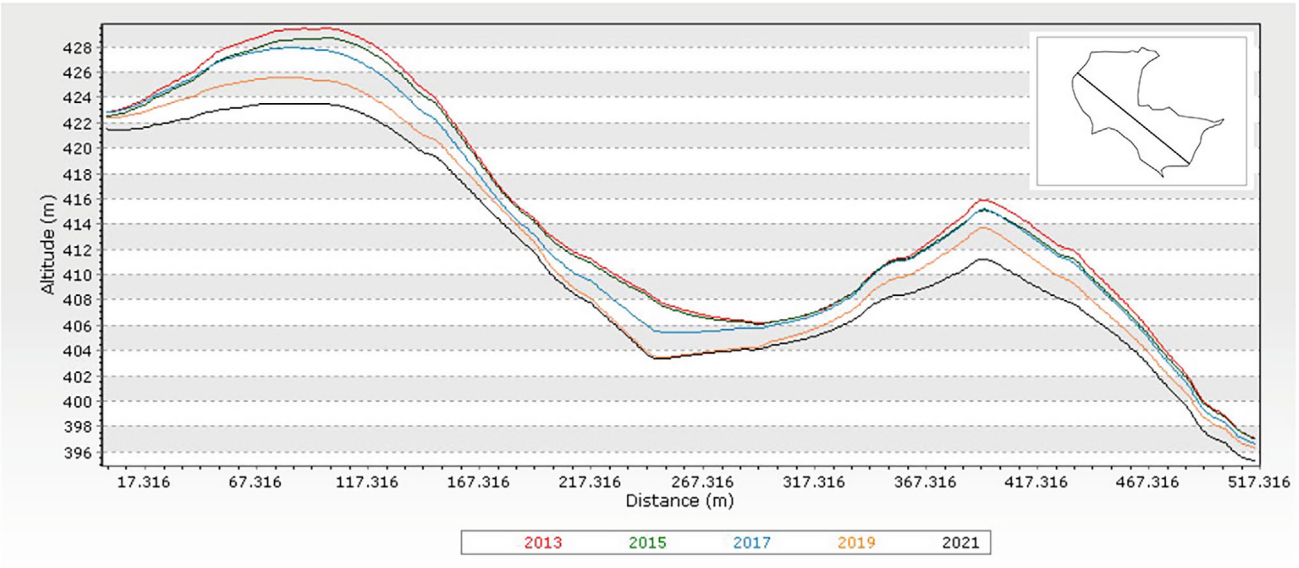


Fig. 3 Topographical profile of changes in the Lakhouat mine over the period 2013–2021

temporal SAR imagery and analyzing elevation changes, mirrors the approaches used by Zhang et al. (2021) and Escayo et al. (2022) in their studies of mine sites in China, Portugal, and Spain. However, this study advances these applications by focusing on an abandoned mine site where ongoing erosion presents significant environmental risks. By applying Sentinel-1 to monitor the Lakhouat mine in Tunisia over eight years, this work contributes new insights into long-term degradation processes at legacy sites.

This study had some limitations. While SAR imagery provided effective multi-temporal coverage, the coarser spatial resolution of Sentinel-1 data compared to airborne SAR systems might have obscured finer-scale erosion patterns. Additionally, Kriging interpolation to generate DSMs from InSAR phase measurements introduced uncertainties due to the stationarity assumptions in complex mining terrain. Future research could improve understanding by using higher-resolution data, alternative interpolation methods, and integrated field measurements.

3 Conclusions

Sentinel-1 SAR data from 2013 to 2021 revealed zones of erosion and sedimentation at the abandoned Lakhouat mine tailings in Tunisia through Digital Surface Model analysis. Patterns indicated overall declines, with erosion dominating. Continued monitoring and cross-disciplinary collaboration are needed to track instability, evaluate pollution hazards to nearby communities, and guide remediation addressing long-term impacts. SAR demonstrates utility for aiding such efforts at legacy mine sites through repeat topographic mapping. Importantly, the erosion of mine tailings, which contain PTEs, poses risks to nearby communities through the dispersal of dust, soil contamination, and potential water pollution. This underscores the urgent need for timely remediation efforts and ongoing monitoring to mitigate these environmental and health risks.

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Evaluating Green Infrastructures Using Socio-Economic Indicators and Geographical Information System (GIS) in the Context of Public Management: An Application to Andalusia Region

José Luis Caparrós-Martínez, Juan Milán-García, Nuria Rueda-López, and Jaime de Pablo-Valenciano

Abstract

Context/Purpose European initiatives, such as the European Commission's Green Deal, indicate that green infrastructure (GI) could play a crucial strategic role for cities and municipalities throughout Europe. This research outlines a methodology for identifying and evaluating GI at the municipal level. What sets this approach apart is the inclusion of socio-economic indicators from the municipalities where the GI is located, with Andalusia (Spain) serving as the example region. *Methods* To identify and describe the components of green infrastructure (GI) at the municipal level, Geographic Information System (GIS) techniques are utilized, and a cluster analysis is conducted to validate the findings. *Results* In the region, rural municipalities contain most of the GI. However, these municipalities are characterized by low socio-economic levels and high unemployment rates. In contrast, coastal and metropolitan areas are home to municipalities with larger populations and higher socio-economic levels. Furthermore, a negative correlation has been identified between municipal public debt and the presence of GI. *Interpretation* It is essential that the different regions of Europe perform a proper diagnosis and assessment of their respective GI. *Conclusion* The results suggest that municipalities in rural areas are "green financing" the population of Andalusia as a whole. Promoting measures that restore and conserve green infrastructure should be a priority for policymakers.

Keywords

Green infrastructure · Geographic information systems · Cluster analysis · Ecosystem services · Socio-economic indicators · Municipalities · Municipal debt

1 Introduction

The European Commission (European Commission: The Economic Benefits of the Natura 2000) defines green infrastructure (GI) as a deliberately planned network of natural and semi-natural spaces, along with other environmental features, designed and managed to offer a variety of ecosystem services. There is broad consensus that this concept is multifunctional, providing both ecological and social benefits (Jones and Somper 2014). Meerow (2020) considers increasing access to green space and improving air quality as benefits of GI, among others. O'Brien et al. (2017) identify the cultural ecosystem benefits gained from GI. Following Kumar et al. (2019), GI can improve human health and deliver various socio-economic and environmental benefits.

The present work offers a methodology that analyzes GI at the municipal level by employing Geographic Information Systems (GIS). Its uniqueness lies in the integration of socio-economic indicators from the municipalities in which GIs are found, with Andalusia (Spain) serving as the reference region. GI can act as a catalyst to economic growth by attracting inward investments and generating employment (European Commission: The Economic Benefits of the Natura 2000). Caparrós-Martínez et al. (2020) highlight the significant contribution of rural municipalities in Andalusia to the provision of ecosystem services, despite their low socio-economic indicators. Furthermore, among these indicators, it is interesting to consider one related to public finances, since the cost savings generated by GI (Law et al. 2017) could help to reduce the pressure on municipal debt. Due to this, three hypotheses are put forward in this paper:

J. L. Caparrós-Martínez · J. Milán-García · N. Rueda-López (✉) · J. de Pablo-Valenciano
University of Almeria, Almeria, Spain
e-mail: nrueda@ual.es

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H1: Municipalities with a higher proportion of GI are those with a higher socio-economic level (i.e., higher per capita income and lower unemployment rate).

H2: Municipalities with a higher proportion of GI are population attraction focal points (i.e., they present positive rates of population evolution and with higher population density).

H3: Municipalities with higher GI ratio are those that register more sustainable public finances (i.e., lower public debt).

2 Methods

Firstly, the indicators related to GI and the socio-economic sustainability of municipalities in Andalusia were selected (see Table 1). Statistical and cartographic information has been selected from Environmental Information Network of Andalusia (REDIAM), the Andalusian Multiterritorial Statistical Information System (SIMA), Atlas of Andalusia, National Statistics Institute (INE), and Spatial Data Infrastructure of Spain (IDEE). On the one hand, the representative indicators of the socio-economic environment of the municipality were selected following the classification criteria proposed by Da Cruz and Marques (2014). On the other hand, the selection of representative indicators of GI was made on the basis of those proposed in the specialized literature (Aguilera et al. 2018; Eurostat. Urban Europe 2016; Pakzad and Osmond 2016; Ruckelshaus et al. 2016). Afterward, this was contrasted with the opinion of a panel of experts: managers of the Junta de Andalucía, local development agents of rural municipalities and rural development groups.

After compiling municipal data on the distribution of GI and municipal socio-economic variables, ArcGIS 10.4.1 was employed to process data. Spatial intersection was applied to combine the layers of GI and socio-economic data, generating a new integrated layer. Ultimately, the attributes of this layer were analyzed to identify patterns and associations between GI and socio-economic characteristics, assessing their impacts and benefits.

Table 1 GI and socio-economic indicators

Identification indicators	Characterization indicators	Socio-economic indicators
Core area (protected natural area and habitats) Buffer zones/ ecological corridors	Areas of rich biodiversity Fragmentation (artificial surface) Chemical and quantitative valuation aquifers)	Evolution in population (1996–2019) Municipalities with small populations Population density Annual declared income Municipal rate of unemployment Municipal debt

3 Results

After using the selected indicators, the results obtained are shown in Fig. 1.

The indicators related to the state of GI indicate that the core areas of these infrastructures almost entirely coincide with the network of protected natural spaces and habitats of community interest.

In the interior areas of the region, the core areas of GI align with forest and high mountain ecosystems where there is a traditional ecologically based human management. In contrast, the central areas of coastal and semiarid green infrastructure (GI) in the region have significantly diminished over the past few decades due to population growth, urbanization, and the expansion of intensive agriculture.

Demographic indicators show that, since the mid-twentieth century, rural municipalities in Andalusia, including those within core GI areas, have experienced ongoing population declines.

Socio-economic indicators reveal that higher-than-average regional unemployment rates and per capita income indicator are concentrated in coastal areas and urban agglomerations. Region's largest companies are situated in these places, so their economic dynamism is higher. Thus, H1 and H2 were not confirmed. However, a positive impact on employment and income was observed in some rural municipalities within protected natural areas.

On the other hand, a negative correlation is observed between the variables of municipal public debt and the presence of GI. This confirms H3, demonstrating that investing in GI can generate long-term economic savings. For example, GI can improve water supply and have a positive impact on public health, reducing healthcare costs.

4 Discussion

As the results indicate, GI in Andalusia is primarily concentrated in rural areas, which are less socio-economically developed compared to urban and coastal regions. Proper management and conservation of GI can lead to significant cost savings, reducing public expenditure and debt (Zoppi 2020), as our findings suggest. However, the benefits of GI are harder to quantify in market terms compared to the costs of implementation. This difficulty arises because the positive outcomes of GI take longer to materialize and there is a lack of tools for the economic valuation of environmental services (Palmer et al. 2015). Consequently, there is a discrep-

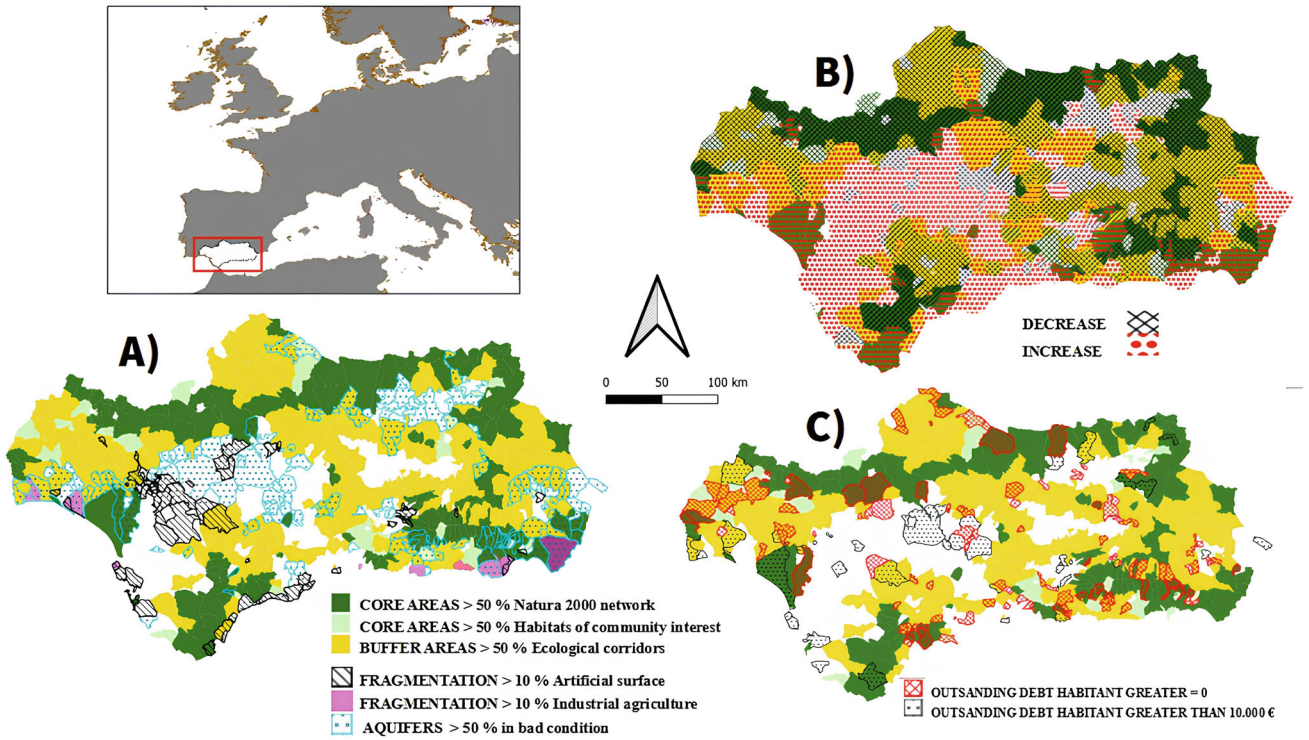


Fig. 1 **a** GI and fragmentation. **b** GI and evolution of the population between 1996 and 2019. **c** GI and municipal debt

ancy between the economic, social, and environmental value of GI and their financial analysis (Liberalesso et al. 2020). Despite this, existing studies show that the profitability of GI alternatives surpasses that of traditional gray infrastructure (Parker and Zingoni de Baro 2019). Therefore, Filazzola et al. (2019) recommend that policymakers and practitioners enhance GI design to support urban ecosystems due to its potential benefits for both human and global biodiversity.

5 Conclusions

The findings highlight the need for a more sustainable approach in the coastal and metropolitan regions of Andalusia.

Rural municipalities are effectively providing ecological support for the entire Andalusian population. Public officials should prioritize actions that restore and conserve green infrastructure (GI) while also addressing the region's demographic and socio-economic disparities. As a result, public funding strategies should account for these demographic differences. This study demonstrates that investing in the conservation and management of GI can be a cost-effective approach for Andalusian municipalities. Nevertheless, additional research is necessary to clearly establish the causal relationships between the variables examined.

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Riding Forestry Progress: The Italian Forest Map Prototype (CFI2020)

Giovanni D'Amico, Walter Mattioli, Diego Giuliarelli, Lorenzo Cesaretti, Gioele Tiberi, Gherardo Chirici, Raoul Romano, and Piermaria Corona

Abstract

Forests and forestry sector need up-to-date, consistent, robust information for management, monitoring and planning, especially in Mediterranean environment where extreme events driven by climate change are increasing every year. In Italy, several Regions and Autonomous Provinces created local forest maps based on specific needs and regulations; however, a National Forest Map is still missing. The FORMIPAAF project aims, among different objectives, to develop the first Italian Forest Map Prototype (CFI2020), at a national scale of 1:10.000. Main objective of the project is to foster data advancement and updating in the forestry sector, by simplifying access to detailed information and to large-scale forest data, such as CFI2020. In order to realize CFI2020, available local maps, properly analyzed and harmonized, have been merged to achieve a first large-scale information layer that can be easily updated with existing information in the forestry sector. Following a modular and multiscale approach, the project establishes: 1. forest definitions, mapping three different definitions of forested areas: FAO-FRA 2000 (international standard), TUFF 2018 (national standard) and local/administrative definitions; 2. a homogenous and unique nomenclatural system for forest classification integrating local nomenclature with the most widely used systems at national and international scale (e.g.: European Forest Types, INFC category, national forest category sensu Del Favero). CFI2020 will also provide information about canopy cover, silvicultural system and disturbance type, if any. Finally, CFI2020 will be implemented in the upcoming National Forestry Information System, where all the information about forestry sector will be soon available.

Keywords

Forest mapping · Italian forest map · National forestry information system · Forest definition · Nomenclature system

1 Introduction

Forests and the forestry sector play a paramount role in current global challenges related to the climate crisis, biodiversity decline and loss, the need for recovery of degraded ecosystems and the decarbonization of the economy. Thus, Italy, due to international agreements (FAO-FRA 2020; Eggleston et al. 2006; Forest Europe 2020), periodically provides data on specific indicators related to the state of forests and the forestry sector. Meeting the agreement standards requires effective sector policies and balancing environmental protection and socioeconomic development policies. In order to support policymakers in appropriate forest planning actions, as well as to be able to ensure national forest management and planning, up-to-date and reliable information and data are needed.

In order to support these needs, the Ministry of Agriculture funded the FORMIPAAF project. The project involves the development of the first 'National Forest Information System' (SINFor) that will make forestry information available online, both in the form of aggregate statistics and maps. The statistical information database, consistent with monitoring standards defined by pan-European agreements

G. D'Amico · P. Corona
CREA—Research Centre for Forestry and Wood, Arezzo, Italy

G. D'Amico (✉) · G. Chirici
DAGRI—University of Florence, Florence, Italy
e-mail: giovanni.damico@crea.gov.it

W. Mattioli · D. Giuliarelli · L. Cesaretti · G. Tiberi
CREA—Research Centre for Forestry and Wood, Rome, Italy

R. Romano
CREA—Research Centre for Agricultural Policies and Bioeconomy, Rome, Italy

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(Forest Europe, the European Union and United Nations organizations), would allow periodic monitoring of the state of the forestry sector and the release of statistics and reports. The mapping database will provide the prototype National Forest Map (CFI2020), which is a viewable and queryable information layer made by considering different forest definitions.

In fact, based on the research carried out at the national scale, it is shown that: 1. the last forest map prepared at the national level with a scale that is sustainable for forest management dates back to 1936 (Ferretti et al. 2018); the only national forest map made more recently is the one derived from the fourth thematic level of the Corine Land Cover, but with a minimum mapping unit of 25 hectares; 2. in Italy, three definitions of forest are used for local and national management or international statistics purposes (D'Amico et al. 2023). However, individual regions and autonomous provinces, for their own management needs, created forest maps independently, following their own needs and specific local regulations. The pivotal principle for the implementation of the CFI2020 map is the use of all pre-existing material, in terms of both nomenclatural systems and the design of forest cartographies. Therefore, a large-scale information layer product, derived from mosaicking the local maps properly analysed and harmonized, is used as the starting information layer for the photointerpretation phase where it will be corrected and updated based on the coverage of the latest available aerial orthophotos. Preliminary results from two regions distributed in northern and southern Italy are examined after the initial months of the project. The results in terms of forest area for each Italian region are compared with official INFC2015 statistics.

2 Materials and Method

The initial forest map of Italy was created by mosaicking maps of different types downloaded from local online geoportals (D'Amico et al. 2021a) and then updated, following the steps summarized in Fig. 1, based on the methodology used in Corona et al. (2020) and D'Amico et al. (2021b) (Fig. 1).

The photointerpretation is still in progress. Indeed, it requires extensive effort, since for each polygon, the belonging to the different forest definitions is reported. In particular, excluding some local definitions for which we refer to D'Amico et al. (2023), the forest definitions of national interest both used in the forest regulation Legislative Decree No. 34/2018 ('Testo unico in materia di foreste e filiere forestali'—TUFF) are: 1. TUFF 2018 National standard definition (area $\geq$ 2000 m^2; crown cover density $\geq$ 20%; width $\geq$ 20 m); 2. FAO-FRA 2000 international standard definition (area $\geq$ 5000 m^2; crown cover density $\geq$ 10%; width $\geq$ 20 m). The prototype of the national forest map (CFI 2020) aims to provide Italy with a forest-non-forest mask that will be enriched with detailed information on forest categories and types in the coming years. However, also in this initial prototype, a homogenous and unique nomenclatural system for forest classification integrating local nomenclature with the most widely used systems at national and international scale (e.g.: European Forest Types, national forest inventory (INFC) category, national forest category sensu Del Favero) was developed (Table 1).

The forest area data from South Tyrol and Trentino Autounomus Provinces, Aosta Valley, Basilicata, Abruzzo, Sicily here presented represent the first outputs produced. The preliminary data presented, not yet conclusively tested

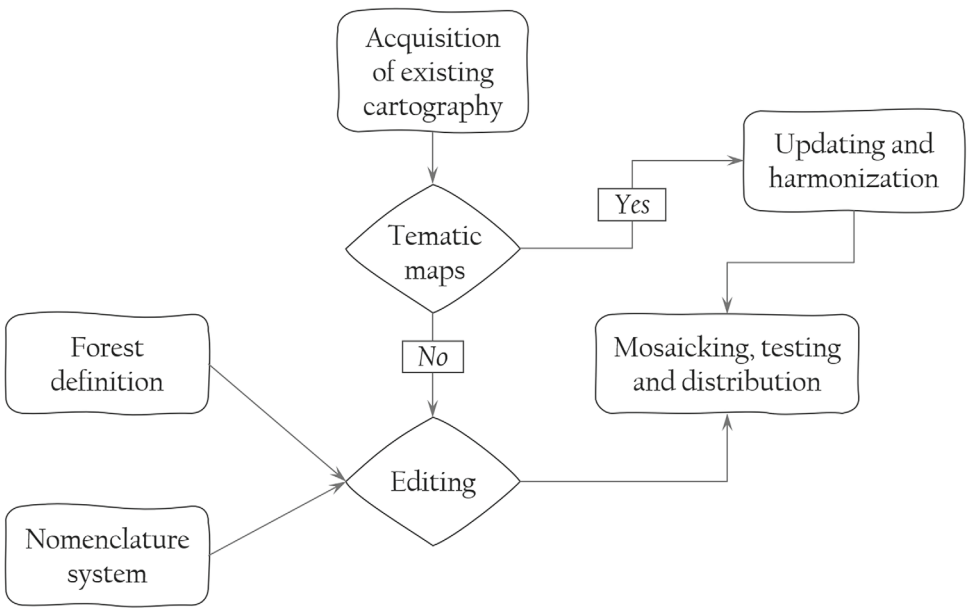


Fig. 1 Workflow of forest map development

Table 1 CFI2020 database records

Record of geodatabase		
ID		Unique code
Definition of forest	TUFF	Yes/no
	FAO	Yes/no
	Local	Yes/no
Canopy cover (%)		10–20%; 20–50%; 50–75%; ≥75%
Structural type		(a) OM high forest; (b) OM coppice; (c) not OM forest
Disturbances		Forest fires, landslides and avalanches
Administrative unit		ISTAT classification code
Local type		Unique code: Highest level of local nomenclature system
EEA type		European environmental agency types
INFC type		INFC category

OM stands for ordinary managed

as the project is still ongoing and will finish in June 2024, are provided aggregated at the regional scale. To validate the results, we compared aggregated regional forest area from CFI2020 with the reference official estimates from the Italian NFI (INFC 2015) (Gasparini et al. 2022). The accuracy of our results was compared in terms of RMSE%, calculated as the percentage of RMSE relative to the average official values.

3 Results

The forest area aggregated for region was compared with official estimates of Italian NFI taking as reference the forest estimates for all regions. To note that for Toscany and Sardinia, where the last version of the local forest map are not available yet, other wooded lands are also considered (Gasparini et al. 2022). The overall RMSE%, calculated as the percentage of the RMSE to the mean NFI values, was 12% while the r_2 of 97%, had an increasing trend over time (Fig. 2).

The RMSE was calculated as:

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{i=1}^{n} \left(y_{\mathrm{NFI}i} - \hat{y}_i\right)^2}{n_p}}$$

where n_p is the number of Italian regions, $y_{\mathrm{NFI}i}$ is the official NFI value (of forest area) for the ith region and $\hat{y}_i$ is the aggregated estimation (of forest area) from CFI2020 for the ith region.

The preliminary results obtained are consistent with those estimated by INFC2015. Overall, the national forest area appears to be growing by about 3%. In particular, regions with a pronounced increasing trend are Sicily, Campania, Lazio, Liguria and Basilicata. While in some regions, with data that are not yet complete, the forest area is less than the NFI estimates.

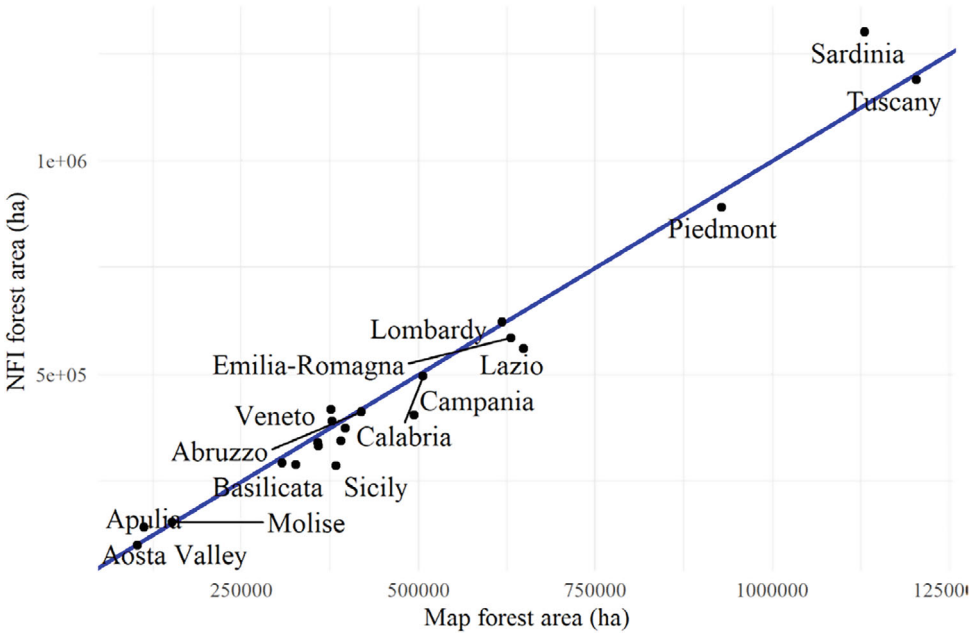


Fig. 2 INFC 2015 forest area against CFI2020 forest area

4 Discussion

The preliminary data presented provide a comprehensive overview of the Italian forests. However, careful analysis is required to assess borderline conditions in the forest definition. As shown in Fig. 2, the forest area is increasing compared to NFI estimates. However, in southern regions, the large presence of Mediterranean scrub and formations bordering the definition of forest will have to be carefully analyzed. While in the Alpine regions of northern Italy, the increase in forested areas, mainly concentrated in areas at the altitudinal limits of vegetation, appears smaller. On the other hand, in some regions where final update of the local forest map is not yet available, the mapped forest area is less than inventory estimates. Specifically, excluding Sardinia, where the local forest definition may have played a relevant role (D'Amico et al. 2023), the currently available forest maps of Apulia, Veneto, Umbria and Molise reflect this condition.

To compare CFI2020 and NFI data, the forest map conforming to the FAO definition was examined in this study. In fact, the final version of CFI2020 will allow the forest mask to be selected according to international (FAO) and national (TUFF) standard forest definitions.

5 Conclusion

The CFI2020 national forest map prototype is an essential component for the modernization of the Italian forestry sector. Together with the statistical data from national forest inventories, Italy finally will have tools for forest management and monitoring. In addition, with the implementation of the SINfor, the dissemination of increasingly reliable forestry data will facilitate the provision of indicators required in international consortia for monitoring environmental protection and climate change mitigation.

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Multispectral Vegetation Indexes and 3D Image Analysis for Aboveground Biomass Estimation in Meadows: A Comparison between Models

Daniele Pinna, Elena Basso, Cristina Pornaro, Francesco Marinello, and Stefano Macolino

Abstract

The implementation of remote sensing technologies for agricultural applications has undergone continuous growth in the last couple of decades. Aboveground biomass (AGB) estimation for grasslands and pastures using remote sensing technologies and machine learning is gaining significant interest throughout the scientific community. In this study, we investigated and compared the use of vegetation indices (NDVI, GNDVI, SR, NDRE) calculated from multispectral images and volumetric roughness values derived from a Digital Elevation Model (DEM) obtained with the Structure from Motion (SfM) photogrammetric technique estimating AGB. We carried out this study in two adjacent permanent meadows located in Schio (VI, northeastern Italy) whose total surface was 3.29 ha. We trained two models using the Random Forest (RF) machine learning algorithm to estimate AGB over the study area, the vegetation indices-based model performed better (R^2 = 0.84) but the results obtained by the model based on DEM roughness were very close (R^2 = 0.82). The results obtained show an excellent potential of new analysis techniques based on Structure from Motion models, which are cheap, widely known, and do not need multispectral cameras. However, many characteristics of the vegetation, such as the botanical composition of the meadow, reflecting in its density, strongly influence the biomass content, and the use of parameters based on volume and external texture may limit the accuracy of this model.

Keywords

Multispectral images · Normalized difference vegetation index · Green normalized vegetation index · Digital elevation model · Photogrammetry · Grasslands · Dry matter yield

1 Introduction

Accurate monitoring and characterization of grassland biophysical and biochemical parameters such as aboveground biomass (AGB) evaluation and estimation are gaining more and more importance in grassland studies (Sun et al. 2022). Traditional measurement methods rely on plot-based surveys, which involve huge amounts of ground measurements, mainly based on the cut-and-dry method (Bazzo et al. 2023). Even though these methods can provide accurate results, they are subjective, time-consuming, and laborious, and can only be applied to small areas, so they are not suitable for regional and global scale studies (Sun et al. 2022). The complexity in predicting AGB of grasslands is related to the variability in vegetation composition, spatial variation of large-scale topography, seasonal phenological cycles and stress of the plants. Remote sensing-based approaches provide the potential for measuring structural and biochemical aspects of plants at high spatial and temporal resolution at a variety of spatial scales. The methods utilized can vary depending on data acquisition and analysis, they include digital imaging (RGB, multispectral, hyperspectral, radar), photogrammetry, laser scanning and combinations of them with various platforms and sensors (Atzberger 2013). Recently, Unmanned Aerial Vehicles (UAVs) have shown to be a significant and practical tool for measuring and calculating biophysical characteristics at grassland distribution scales (Atzberger 2013). With respect to satellites, UAVs performances have shown to be significantly better when surveying objects at small to medium-spatial scale (less than 50 ha) guaranteeing higher temporal

D. Pinna · E. Basso · C. Pornaro (✉) · F. Marinello · S. Macolino
University of Padova, Legnaro, PD, Italy
e-mail: cristina.pornaro@unipd.it

D. Pinna
e-mail: daniele.pinna@phd.unipd.it

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and spatial resolution as well as greater versatility at lower cost (Bazzo et al. 2023). The interest in applying UAV remote sensing techniques to grassland AGB estimation has increased recently, and different structural and optical features have been used for AGB characterization and estimation (Xu et al. 2020). Nonetheless, image-based techniques for estimating AGB using UAVs are still in their infancy (Bazzo et al. 2023).

The aim of this study was to compare and evaluate two different techniques based on multispectral vegetation indices and on Structure from Motion (SfM) Digital Elevation Model (DEM) on their ability to estimate AGB in the study area.

2 Materials and Methods

The study was carried out in two adjacent permanent meadows with a total surface area of 3.29 ha, located in Schio (VI, northeastern Italy; 45.6889 N, 11.3607 E), one mainly composed of *Lolium multiflorum* (fertilized with slurry) and the other of *Lolium arundinaceum* (=*Festuca arundinacea)*, *Lolium perenne*, and several other species typical of lowland meadows (fertilized with manure). The mean annual temperature of the study area is 13.8 °C, and the annual rainfalls are 1307 mm (Malo station; 1994–2022).

The study area was overlapped with a grid of points 20 m spaced, for a total of 75 points where 1 m^2 plots were located. On 24th to 25th of May 2023, at each position, the AGB was collected and over-dried at 105 °C for 48 h to determine dry matter yield (g/m^2).

On the 24th of May 2023, a flight with a DJI Matrice 600 Pro drone equipped with X5S RGB camera and Micasense RedEdge MX multispectral camera was performed over the area taking 458 pictures with a ground resolution of 4 cm.

Both multispectral and RGB images were elaborated using Agisoft Metashape software (v.1.7). From the multispectral images, five raster images with 4 cm/pixel resolution, one for each spectral band (Blue, Red, Green, NIR and RedEdge) were obtained. The RGB images were then elaborated using the Structure from Motion (SfM) photogrammetry technique to obtain a high-resolution (4 cm) Digital Elevation Model. The DM (g/m^2) values collected at the 75 sampling points were interpolated to obtain a raster image of estimated biomass values over the study area using the Ordinary Kriging technique, the map of interpolated DM (g/m^2) values is shown in Fig. 1. The seven raster images obtained (5 bands, DEM and interpolated biomass) were then imported into a GIS environment (QGIS 3.28 Firenze Edition). A 2x2 m grid was created over the study area and for each cell the following fields were calculated: DM (g/m^2), Normalized Difference Vegetation Index (NDVI), Green Normalized Difference Vegetation Index (GNDVI), Normalized Difference Red Edge Index (NDRE) Simple Ratio (SR), Mean Height (DEM) and Sq (root mean square height). As an example, the map of the NDVI values is shown in Fig. 2. The Sq value for each cell was calculated as the square root of the mean of the square differences between the DEM value at each 4 cm pixel and the DEM mean at the 2 m cell level. This parameter gives an estimation of the roughness of a surface, and it is considered as the variation of the volume inside a given cell. Once the fields were collected in a single shapefile, the data table collecting the field values for the 8700 2 × 2 m cells covering the study area was imported into the statistical software JMP Pro 17 to undergo statistical analysis.

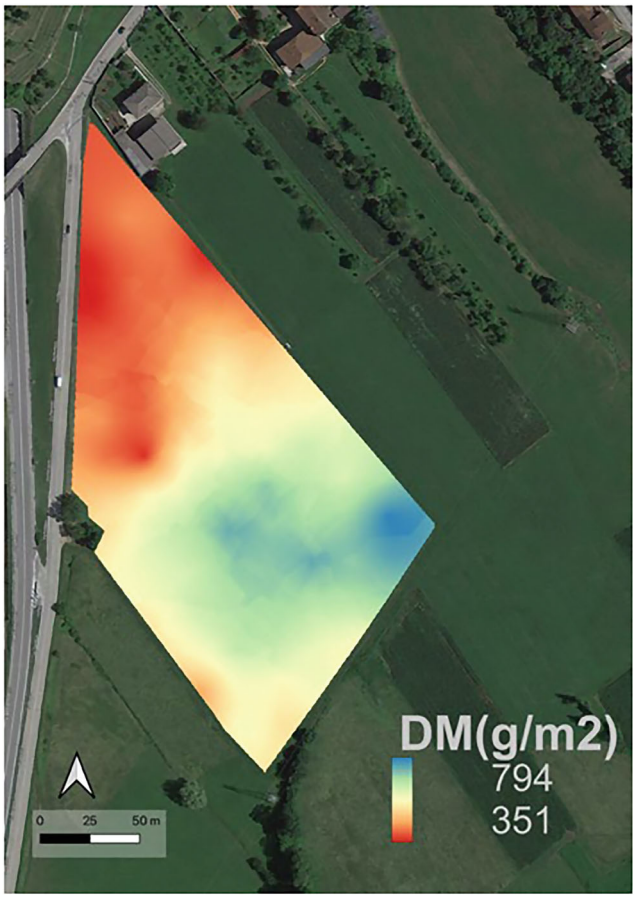


Fig. 1 Dry matter (g/m^2) map

3 Results

The aim of the study was to investigate and compare the performances of vegetation indices (VIs) calculated from multispectral images with volume and roughness parameters obtained from Structure from Motion-derived DEM estimating DM values (g/m^2). In the first phase we performed a linear regression between each vegetation index and RMSH with DM obtaining poor results; NDVI was the best parameter in predicting DM yield with a determination coefficient

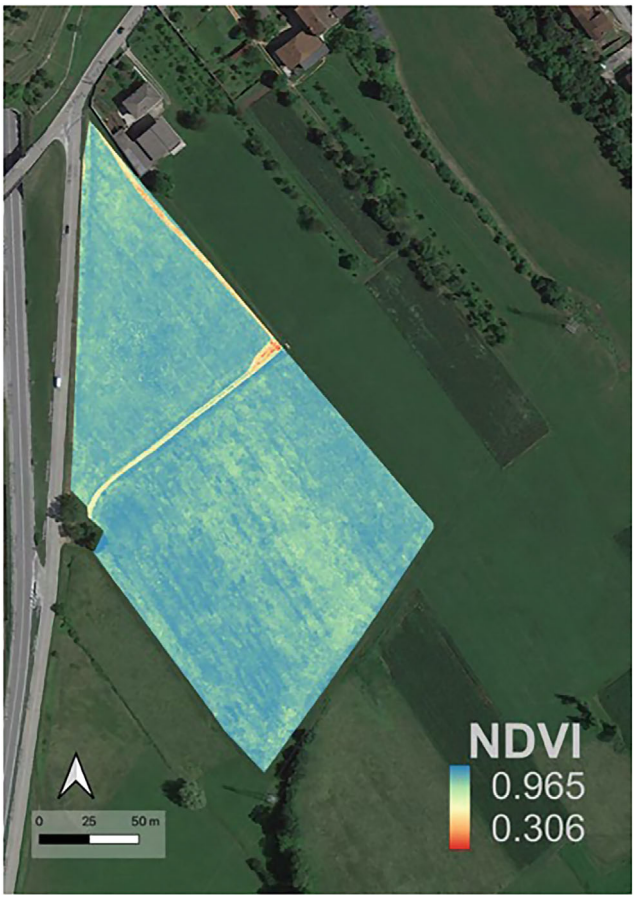


Fig. 2 NDVI map

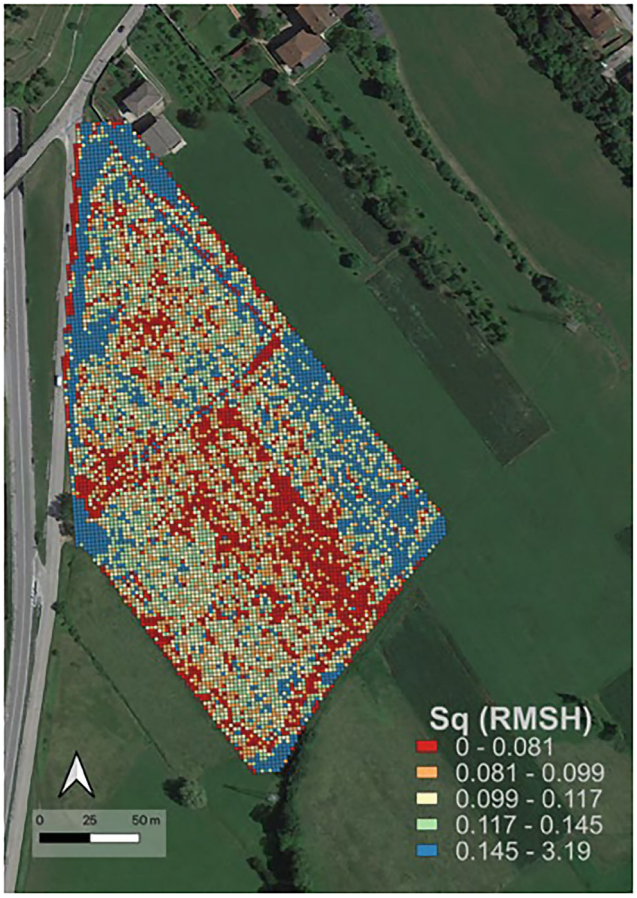


Fig. 3 Sq (RMSH) map at cell level

as low as $R^2 = 0.39$. The Table 1 reports the metrics related to the trained linear regression models.

In the second phase, we trained two different models based on the Random Forest algorithm (RF). The first model used the VIs (NDVI, GNDVI, SR, NDRE) while the second used Sq (RMSH) and the Mean Height value of each cell to estimate DM yield.

Both models performed very well over the 8700 cells covering the study area (Figs. 3 and 4). The model based on VIs obtained the best results ($R^2 = 0.845$, RMSE = 44.24 g/m^2), but also the model based on the DEM was very good ($R^2 = 0.824$, RMSE = 47.13 g/m^2).

4 Discussion

Vegetation indices derived from multispectral images, especially NDVI, can be representative of vegetation cover, status, and quantity, but their accuracy is limited, especially with high vegetation cover, and when the indexes tend to be saturated. Based on the findings of this study, the utilization of parameters related to three-dimensional features of vegetation, such as Sq (root mean square height), may help in overcoming this saturation effect, which would be an important step in building reliable models that can estimate AGB of permanent meadows with accuracy and precision.

Table 1 Coefficients and metrics of linear regression models predicting DM values

Predictor	Slope	Intercept	R^2	RMSH (g/m^2)
NDVI	3477.9	− 2106.9	0.393	92.038
GNDVI	2987.6	− 1783.6	0.246	102.52
SR	6.124	463.41	0.145	107.71
NDRE	3028.2	− 1994.7	0.275	99.261
DEM	− 48.09	8990.37	0.288	97.373
RMSH	− 60.61	560.86	0.012	114.72

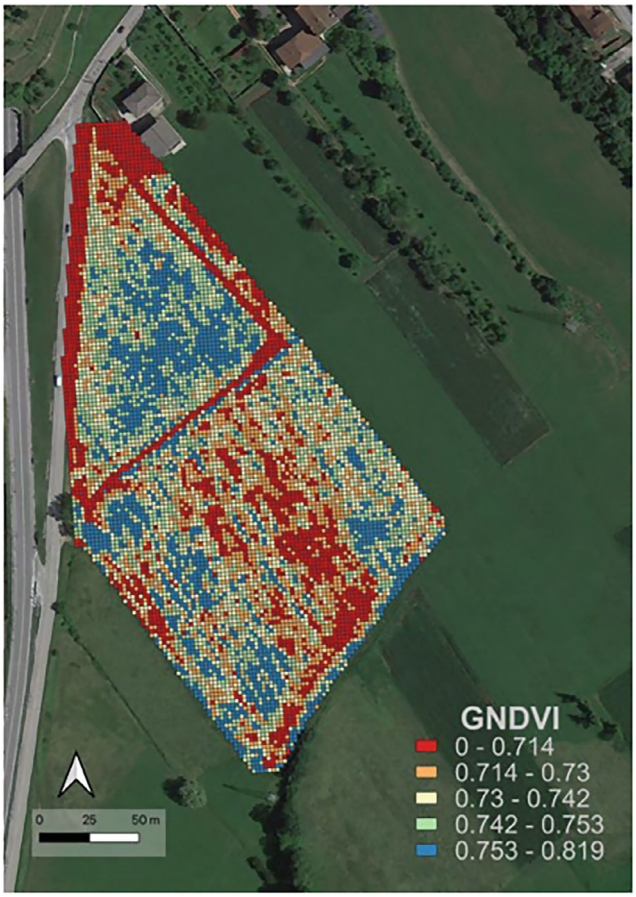


Fig. 4 GNDVI map at cell level

The introduction and use of advanced statistical techniques, such as machine learning algorithms, to analyze remote sensing data have gained significant importance in recent years and led to the development of AGB estimation models able to deal with more complex and variable scenarios (Stumpe et al. 2023; Guevara-Escobar et al. 2023). In recent years, algorithms based on decision trees, such as Random Forest, have been widely used to estimate AGB in grassland environments (Xu et al. 2020; Stumpe et al. 2023; Guevara-Escobar et al. 2023). Even though some authors developed a data collection protocol for measuring AGB with drone photogrammetry (Cunliffe et al. 2019), the multitude of techniques, approaches, and environments makes it so that there is still no standard process for collecting and analyzing this data to extract AGB information.

5 Conclusions

Even though the estimation of aboveground biomass in grass-dominated environments has been effectively carried out with a mixed approach involving remotely sensed data and machine learning algorithms at the regional level (Liu et al. 2017; Meng et al. 2020), the accuracy and reliability of biomass estimation tools at the field level are still low to be effectively utilized in field management.

Developing complex tools based on machine learning algorithms using big amounts of data from vegetation indexes and three-dimensional parameters may help us understand the huge amount of variability present in grassland environments and develop more sophisticated models able to estimate AGB with more accuracy and precision. Therefore, the availability of effective and accurate biomass estimation tools at the field level would help improve the decision making process related to pasture management.

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Evaluation of Machine Learning Models for Predicting the Daily Maximum Air Temperature: A Case Study Laâyoune in Morocco

Marwa Licer, Khalid Minaoui, and Hanae Belmajdoub

Abstract

In recent years, the world has witnessed a concerning increase in air temperature attributed to climate change, with significant repercussions in areas such as energy consumption, human health, food security, and the economy. However, it is possible to mitigate these effects by accurately forecasting air temperature, which plays a crucial role in weather forecasting. In this article, we propose an analysis to evaluate the performance of three machine learning models: Multiple Linear Regression (MLR), Support Vector Machine (SVM), and Random Forest (RF). Our objective is to identify the most appropriate model for predicting air temperature in the city of Laâyoune, located on the Atlantic coast approximately 500 km south of Agadir. Laâyoune is the largest city in the Moroccan Sahara, characterized by high daytime temperatures and low nighttime temperatures. To forecast air temperature from 2009 to 2022, we will use six weather and climate variables: wind speed, humidity, heat index, dew point, and pressure.

Keywords

Machine learning · Maximum air temperature · predicting · SVM · MLR

1 Introduction

The accurate prediction of air temperature is pivotal in climate-related decision-making processes, influencing sectors like agriculture, energy, and public health (Bochenek and Ustrnul 2022). With the growing implications of climate change, as evidenced by the progressive rise in global air temperatures, there is an urgent need for robust predictive methodologies. This paper introduces an analytical comparison of four machine learning models: Multiple Linear Regression (MLR), Support Vector Machine (SVM), and Random Forest (RF). Our intent is to discern the most effective model for projecting daily maximum air temperatures, particularly focusing on Laâyoune, a city located on Morocco's Atlantic coast known for its extreme thermal fluctuations. The primary aim of this study is to address the exigency for accurate temperature forecasts by leveraging advanced machine learning techniques. These forecasts are crucial not only for routine weather prediction but also for preparing and mitigating the risks associated with climate variability. By selecting Laâyoune as our case study, we spotlight the peculiarities of temperature variations in arid regions and contribute to a deeper understanding of weather patterns in such climates. Consequently, the objectives of our research are to evaluate the precision and reliability of these models and to enhance predictive performance, thereby providing a valuable resource for climate scientists and policy-makers engaged in climate adaptation strategies.

2 Methodology

2.1 The Study Area and Data

The study focuses on the region of Laâyoune, the largest city in the Moroccan Sahara, with geographic coordinates of 27° 7′ 31.032″ N and 13° 9′ 45.002″ W. The climate in this city is generally characterized by high daytime temperatures and a noticeable decrease during the night, particularly in the hot and dry summer months. Table 1 displays the meteorological data used in this evaluation, extracted from the Global Historical Climatology website. The data was collected daily from seven weather stations covering the period between 2009 and 2022.

M. Licer (✉) · K. Minaoui · H. Belmajdoub
LRIT, Faculty of Sciences in Rabat, Mohammed V University, Rabat, Morocco
e-mail: licer.marwa@gmail.com

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Table 1 Features and parameters used in this study

	Features list	
Data	ISO role	Temporal scale and unit
Max temperature	Target	Daily °C
Heatindex	Feature	Daily °C
Humidity	Feature	Daily °%
Dewpoint	Feature	Daily °C
Pressure	Feature	Daily MB
Windspeed	Feature	Daily km/h

2.2 Machine Learning Methods

The SVM (Sapankevych and Sankar 2009) is a resilient learning algorithm often harnessed for classification and regression. In temperature forecasting, SVM regression, or SVR, works by mapping input features into high-dimensional space and finding a hyperplane that best fits the data. This can be mathematically articulated as:

$$f(x) = \sum_{i=1}^{n} (\alpha_i - \alpha_i^*) \langle x, x_i \rangle + b$$

α_i and $\alpha_i{}^*$ are Lagrange multipliers. These coefficients derive from the solution of a dual optimization problem that SVR solves, where they represent the weight of the support vectors in the final model. They are nonzero only for the support vectors.

$<x, x_i>$ denotes the inner product between the input feature vectors. It essentially measures the similarity of the input vector x to the training examples x_i. In nonlinear SVR, this inner product is replaced by a kernel function that computes the inner product in a transformed feature space.

b: is the bias term, which adjusts the threshold of the model. It's equivalent to the intercept term in linear regression, shifting the decision boundary to better fit the data.

The role of the kernel function is critical. It allows the SVR to handle nonlinear relationships by transforming the input space into a higher-dimensional feature space where a linear separation is possible. In temperature prediction, the SVM model is advantageous because it can handle the complex relationships that exist between various atmospheric parameters and temperature. By adjusting the kernel function, SVR can be finely tuned to capture the subtleties of climate data, leading to accurate and reliable temperature forecasts.

MLR (Tranmer and Elliot 2008; Maulud and Abdulazeez 2020) aims to establish a linear correlation between multiple independent variables and a single outcome variable. The relationship in an MLR model is depicted by the equation:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \varepsilon$$

where Y is the predicted temperature, X_n represents independent variables, β_n are the coefficients, and ε is the error term. MLR is favored in meteorological studies for its simplicity and the direct way it quantifies the impact of each climate variable on temperature predictions.

RF (Segal 2004) leverages the power of ensemble learning by constructing a "forest" of decision trees. Each tree in the RF model votes on the outcome, and the average of these votes predicts the final temperature. The RF formula can be expressed as:

$$\hat{Y} = \frac{1}{B} \sum_{b=1}^{B} T_b(x)$$

In this, B is the number of trees, T_b denotes the bth decision tree, and x is the vector of input features. RF's advantage in temperature prediction comes from its collective approach, significantly reducing the risk of overfitting, a common challenge in predictive modeling of environmental data, thereby ensuring reliable forecasts.

2.3 Performance Measure

The performance metrics used to evaluate machine learning models are:

The mean absolute error (MAE) (Chai and Draxler 2014) is calculated by adding all absolute errors and dividing by the number of errors it indicates perfect fit when close to 0.

$$\text{MAE} = \frac{1}{n} \sum_{i=1}^{n} |y_i - y_p| \quad (8)$$

n is the number of observations.
y_i is the actual value.
y_p is the predicted value.

The residual sum of squares (Morgan and Tatar 1972) is a statistical technique used to measure the amount of variance in a data set that is not explained by a regression model itself:

$$\text{RSS} = \sum_{i=1}^{n} (y_i - y_p)^2 \quad (9)$$

The R-squared (Miles 2005) is a statistical measure of how close the data is to the fitted regression line.

$$R^2 = 1 - \frac{\sum_{i=1}^{n} (y_i - y_p)^2}{\sum_{i=1}^{n} (y_i - ym)^2}$$

ym: is the mean of the actual values y_i.

Table 2 Performance of ML models in predicting air temperature

ML model	MAE	RSS	R^2
MLR	0.77	1.03	0.94
SVM	0.49	0.68	0.69
RF	0.54	0.57	0.97

3 Results and Discussion

In our investigation, we meticulously analyzed a dataset comprising 3897 instances of daily maximum temperature recordings, segmented into an 80% portion for model training and a 20% portion for validation. Our exploration involved assessing the capabilities of three sophisticated machine learning models: Multiple Linear Regression (MLR), Support Vector Machine (SVM), and Random Forest (RF). As depicted in Table 2, the models were evaluated against three primary indicators of performance: mean absolute error (MAE), residual sum of squares (RSS), and the coefficient of determination (R^2). The findings revealed MAE values spanning from 0.49 to 0.77, RSS scores ranging between 0.57 and 1.03, and R^2 metrics from 0.94 up to 0.97. These metrics collectively indicate a strong ability of the models to account for the variability in temperature observations. Further examination of Table 2 indicates that the MLR model registered the highest MAE value, suggesting a lower level of precision relative to its counterparts. In stark contrast, the RF model was characterized by a notably smaller MAE, thereby signifying its heightened accuracy and positioning it as a superior predictive tool for maximum air temperature in the scope of this study. This model's performance notably surpasses that of the lowest MAE reported in the prior study (Adnan et al. 2021), marking a considerable advance in machine learning-driven temperature prediction.

Delving into Table 3, we present a detailed juxtaposition of actual recorded temperatures against the values predicted by each model, highlighting the variances between them. This detailed account provides transparency into the performance of each model on given dates, shedding light on the precision of daily predictions and the consistency of each approach. Particularly impressive is the SVM model, which delivered an MAE score of a mere 0.49, setting a new precedent in accuracy over prior tested methodologies.

4 Conclusions

The core goal of this study is to evaluate a range of machine learning algorithms, including Multiple Linear Regression (MLR), Support Vector Machine (SVM), and Random Forest (RF), in their capability to forecast the peak daily air temperatures in Laâyoune, Morocco. We have compiled and analyzed a comprehensive dataset spanning from January 1, 2009, to August 31, 2022. From our rigorous analysis, it emerged that the SVM model outshone its counterparts by registering the lowest mean absolute error (MAE) of 0.49 and a residual sum of squares (RSS) of 0.68, thus showcasing its robustness in modeling temperature data. Meanwhile, the RF model exhibited commendable efficacy as well, particularly evident from its coefficient of determination (R^2) of 0.97, signifying its predictive strength. Conversely, the MLR model lagged in performance relative to the SVM and RF models. Looking ahead, we foresee the implementation of hybrid models as a promising avenue for further enhancing predictive accuracy. By integrating the strengths of various individual models, hybrid approaches may capture complex patterns in data more effectively. Such models could potentially leverage the solid foundation provided by SVM's lower MAE and RF's high R^2, leading to even more precise temperature forecasts.

Table 3 Comparison of actual temperatures versus predictions from MLR, SVM, and RF models

Date	Actual	Prediction	MLR	SVM	RF
2017–04–12	27	26.19	0.81	0	0.44
2018–01–06	20	19.05	0.95	0	0.00
2014–08–05	28	28.74	− 0.74	− 1	− 1.18
…	…	…	…	…	…
2022–01–30	24	23.21	0.79	2	1.47
2016–06–06	27	25.80	1.20	1	0.79
2012–10–07	31	30.59	0.41	− 1	− 0.73

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Land Cover Classification Based on a Later Fusion of Multi-input Convolutional Neural Networks Applied to the Oasis of Gabes

Yassine Ben Salem, Radhia Chairet, Mohamed Aoun, and Nihel Chekir

Abstract

The field of Geographic Information Systems (GIS) is becoming essential for solving environmental problems, especially land cover information. Then, the availability of satellite imagery and advances in machine learning facilitates the production of such information and minimize human intervention. In the classification phase, deep learning algorithms are used to produce land cover maps. In our paper, we succeed to solve the problem of the urban escape of Gabès oasis by studying the land cover of this oasis. In order to study this land cover, we first classify complex areas acquired by the GeoEye sensors by exploiting the power of the CNN while integrating the OBIA. Since our land cover classes are heterogeneous (trees, grass, buildings, roads, bare ground, and shadows) and have different observation scales, the specificity of each class should be well identified to make the classification more accurate. For this purpose, textural and spectral data are used as input to a multiscale CNN model. We investigate the impact of integrating the structural feature set SFS and NDVI index into a deep learning architecture. We propose a new algorithm that improves classification accuracy and provides a compact land cover map within three strategies including multiscale CNN, object-based post-classification refinement and decision-level fusion method. The new fusion method makes good use of the additional information provided by NDVI and SFS bands and has shown promising results (overall accuracy = 93.7%).

Keywords

Object detection, land cover map · Convolutional neural network · Feature level fusion · Decision level fusion · Object-based image analysis · Structural feature

1 Introduction

In environmental projects and ecosystem management, land cover information is becoming increasingly important. These data allow us to approach the ground truth and understand development problems. The availability of satellite imagery and advances in machine learning make producing such information easier while minimizing human intervention. Land cover maps are produced using a classification technique. For VHRS, due to the high variability of the intra-class spectral attributes, per-pixel classification has been found to be ineffective (Juniati 2017). Rather than focusing on the spectral values of each pixel, it is better to focus on the spatial and contextual information expressed by the neighborhood of the pixel. Therefore, an object-based approach can be used for efficient delineation and classification of high-resolution images (Blaschke and Holbling 2014). OBIA involves segmenting the image into homogeneous areas. This segmentation helps to extract spatial, textural, and contextual features. Numerous studies have demonstrated that object-based spatial and textural features can significantly enhance classification accuracy (Blaschke and Holbling 2014; Cleve et al. 2008). In reference (Wang et al. 2017) Wang produced a global map of built-up areas using hierarchical object-based GLCM method based on textures derived from Landsat imagery and achieving a 2.8% improvement in overall accuracy compared to classifications based solely on spectral bands. In our research (Chairet et al. 2019), we have confirmed that GLCM features improve the classification results of Sentinel 2A images composed of four bands at 10 m resolution. Despite these hand-crafted

Y. B. Salem (✉) · R. Chairet · M. Aoun · N. Chekir
University of Gabes, Gabes, Tunisia
e-mail: yassinebensalem@ieee.org

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features have proven effective in enhancing classification performance, they typically require extensive experience and expert knowledge to determine. Additionally, even after the intricate design process of various features, it remains challenging to identify the most effective ones for recognizing different objects.

In recent years, machine/deep learning algorithms have been increasingly adopted for various image analysis applications. Among these, Convolutional Neural Networks (CNNs) are the most renowned deep learning models, having achieved remarkable success in computer vision and pattern recognition (Girshick et al. 2014; He et al. 2016). This success has encouraged the GRSS community to apply CNNs to image analysis tasks (Zhu et al. 2017). CNNs have been employed in various remote sensing tasks, including pixel-based classification (Scott et al. 2017), target recognition (Vakalopoulou et al. 2015), semantic segmentation (Marmanis et al. 2018), and scene classification (Castelluccio et al. 2015).

CNNs utilize a series of layers (convolutional, pooling, and activation functions) to automatically extract spatial, textural, and contextual information from images. Originally designed for image recognition, CNNs require input images to be rectilinear. Currently, there are two primary approaches to classifying land cover using CNNs (Zhu et al. 2017).

2 Study Area and Data

The study area covered in this paper spans approximately 25 km^2 in the center of Gabes, Tunisia, located in the southern Mediterranean region. A very high spatial resolution (VHSR) GeoEye satellite image was acquired on July 20, 2020. This image comprises four multispectral bands with a spatial resolution of 2 m and one panchromatic band with a spatial resolution of 0.7 m. A pan-sharpening process was conducted to create a 0.7-m color image by merging the panchromatic band with the multispectral image. In this study, the four bands (red, green, blue, and near-infrared) were processed to produce the land cover map. For training, 400 polygons divided into six classes of interest (trees, grass, buildings, roads, bare ground, and shadow) were used, while 270 polygons were used to test the model.

3 Proposed Method

The diversity of land cover classes within the study area makes distinguishing between them challenging. To enhance the CNN's ability to accurately learn and predict each class, additional information is integrated with the multispectral input bands. Besides the multispectral image (four-band), three other inputs are prepared: the multispectral image combined separately with the NDVI band and two variants of the SFS bands.

Selecting the appropriate input patch size is vital in patch-based CNNs. To determine the optimal size, the effect of different input sizes on classification results is analyzed. Various patches are extracted from the image to represent the training data (Fig. 1).

CNN Deep Learning Algorithm

In a CNN, the input image or our patch is processed through three successive layers: a convolutional layer, an activation function layer, and a pooling layer. These layers extract both low-level and high-level features, forming the feature extraction stage. This stage is followed by a set number of feature extraction stages, culminating in one or more fully connected layers and a classifier layer.

4 Experimental Results and Discussion

Figure 1 illustrates our main concept of a multi-input CNN based on late fusion and presents the resulting outputs. Table 1 provides a summary of the classification accuracies achieved by our proposed CNN models, comparing the F1 scores (harmonic mean) for six classes: trees, grass, buildings, roads, bare soil, and shadow. The models tested include CNN4, CNN16, MSCNN-multispectral, OBMSCNN-multispectral, MSCNN-fus_input, OBMSCNN-fus_input, and OBMSCNN-fus_decision.

The findings revealed that the grass class achieved the highest F1 score, followed by the road class. The OBMSCNN-fus_decision method achieved the highest accuracy for the bare soil class, with an accuracy rate of 97.5%.

5 Conclusion

We addressed the challenge of classifying a complex area captured by GeoEye sensors. We leveraged the performance of CNNs while integrating object-based image analysis (OBIA). Given the heterogeneity of our land cover classes—trees, grass, buildings, roads, bare soil, and shadow—and their varying observation scales, it is crucial to accurately identify the specific characteristics of each class to achieve successful classification. We propose a new, simple, and efficient fusion method at the decision level of multiscale CNNs to effectively utilize the additional information provided by the three bands. We also investigate the impact of incorporating two SFS feature bands and the NDVI band into the multispectral image for CNN classification.

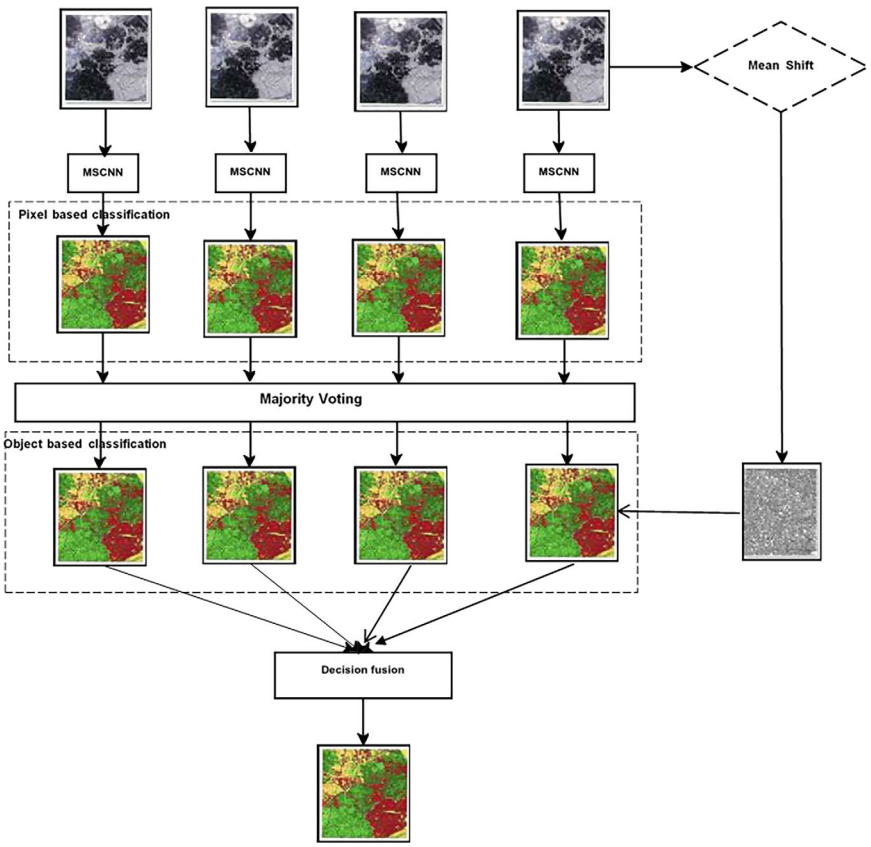


Fig. 1 Multi-input CNN based on later fusion

Table 1 Classification accuracies of CNN models

	OA%	KI%	F1 score					
			Trees	Grass	Building	Road	Bare soil	Shadow
CNN 4 multispectral	74.1	66.78	76.95	83.84	57.52	85.36	75.74	43.95
CNN 16 multispectral	72.2	64.73	85.56	89.86	53.36	84.47	68.82	41.53
MSCNN-multispectral	85.2	80.05	87.17	90.15	75.35	84.51	91.85	42.45
OBMSCNN multispectral	89.9	86.84	88.63	91.15	84.87	90.76	95.00	46.65
MSCNNfus_input	87.1	83.18	89.55	90.74	78.60	89.86	90.41	54.54
OBMSCNNfus_input	87.98	84.24	91.75	93.57	78.33	90.38	90.53	58.37
OBMSCNNfus_decision	93.69	91.69	89.32	90.09	92.53	95.29	97.46	62.79

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Modeling of Water Erosion in the Ahmer Watershed by EPM Method Using GIS, Remote Sensing and Artificial Intelligence

Naïma Elassaoui, Ahlam Sirine, Omar Kadiri, and Abdelaziz Sadok

Abstract

Water erosion in Morocco is altering fertile soils and threatening agriculture and ecosystems. Assessing these risks is crucial to safeguarding agricultural land and water, and guaranteeing the country's ecological and food sustainability. The objective of this study is to map the areas susceptible to hydraulic erosion within the Ahmer watershed situated on the Ben Ahmed plateau in western Morocco. Numerous studies in a similar context have been conducted in this region, such as El Assaoui and al. 2023, titled "Assessment of Water Erosion by Integrating RUSLE Model, GIS, and remote sensing—Case of Tamdrost Watershed (Morocco)," and El Assaoui 2019, titled 'Risk assessment of water erosion by RUSLE Lahmer watershed in The Settat plateau in Morocco." The methodology is based on the use of GIS, remote sensing, and artificial intelligence to map the various factors involved in the erosive process, such as rainfall, temperature, vegetation cover, soil erodibility, and topography, and integrate them into the EPM equation. The results outcome are: the average value of the specific degradation is about 66.55 (T/ha/year), reaching a maximum value of 2562.02 T/ha/year and a minimum value of 0 T/ha/year. By analyzing the soil loss map, we observed that areas vulnerable to erosion are located in the downstream part of the El Himer watershed. This region is characterized by loose soil, which is easily eroded, and a steep slope that accelerates water runoff. In conclusion, this study underscores the urgency of addressing erosion-related challenges to ensure the long-term sustainability of Morocco's environment, agriculture, and food production.

Keywords

Water erosion · EPM · GIS · Remote sensing · Artificial intelligence

1 Introduction

Water erosion is a major environmental threat for semi-arid regions such as Morocco, caused by climatic factors such as rainfall, topography, and soil type, as well as human activities such as agriculture, deforestation, and unplanned urbanization (El Assaoui et al. 2023). This soil degradation affects over 40% of fertile agricultural land, impacting more than 12.5 million hectares of cultivated land (Lahlou 1996).

This study aims to quantify and map water erosion in the El Himmer basin; is part of the Ben Ahmed plateau in northern Morocco, covering an area of 190 km^2 with a perimeter of 89.93 km. It contributes to the Berrechid aquifer, one of the largest groundwater reservoirs in the region (El Assaoui 2017). The methodological approach is based on the use of the Erosion Potential Model (EPM), geomatics, and Google Earth Engine, to identify the areas most vulnerable to erosion and provide relevant information for decision-makers.

2 Materials and Methods

The EPM model, developed by Gavrilovic in the 1950s, utilizes cartography and integrates various parameters

N. Elassaoui (✉) · A. Sirine
Water and Environmental Laboratory, Earth Sciences, Faculty of Sciences, Mohammed V University in Rabat, Rabat, Morocco
e-mail: nelassaoui@gmail.com

O. Kadiri
Geological Mapping Department, Ministry of Energy Transition and Sustainable Development, Rue Abou Marouane Essaadi BP: Rabat Institutes, Rabat, Morocco

A. Sadok
Department of Civil Engineering, Mohammedia School of Engineers Mohamed V University in Rabat, Rabat, Morocco

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within a geographic information system to estimate water erosion. To achieve this, diverse data types were collected. Lithological information from a 1/200,000-scale geological map was used to assess soil erodibility. Topographical data was obtained from a 15-m resolution digital terrain model to derive slope information. Satellite images provided vegetation index data and erosion type and extent details. Rainfall data was gathered through an AI-driven approach on the Google Earth Engine platform, enabling the acquisition of monthly average rainfall data from 2000 to 2021. Through a synergistic use of these data sources, the EPM model's factors were evaluated, facilitating water erosion estimation in the studied catchment. This integrated approach, coupled with advanced technologies, yielded more accurate water erosion estimates, enhancing comprehension of erosion processes within the study area. The EPM model integrates six factors—mean annual precipitation (H), temperature (T), soil erodibility (Y), soil protection coefficient (Xa), type and extent of erosion (φ), and slope (Ja). Using this combination of factors, the EPM model calculates water erosion (W) according to the following equation:

$$W = H^{*}T^{*}\pi^{*}\sqrt{Z^{3}}$$

With: W: Estimated average annual soil loss (m^3/km^2/year); H: Average annual precipitation in (mm); T: Temperature factor; Z: Potential erosion.

And: $Z = Y^{*}\mathrm{Xa}^{*}\left(\varphi + \sqrt{\mathrm{Ja}}\right)$ where Y: Soil erodibility factor; Xa: Soil protection coefficient; φ: Coefficient of type and extent of erosion; Ja: Watershed slope in (%).

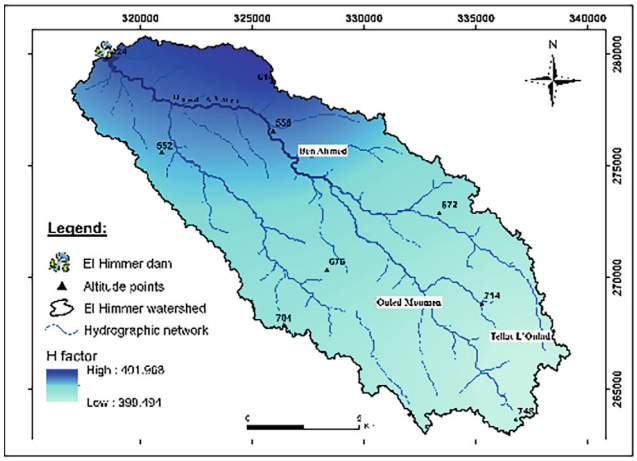


Fig. 1 Map of average annual precipitation factor H

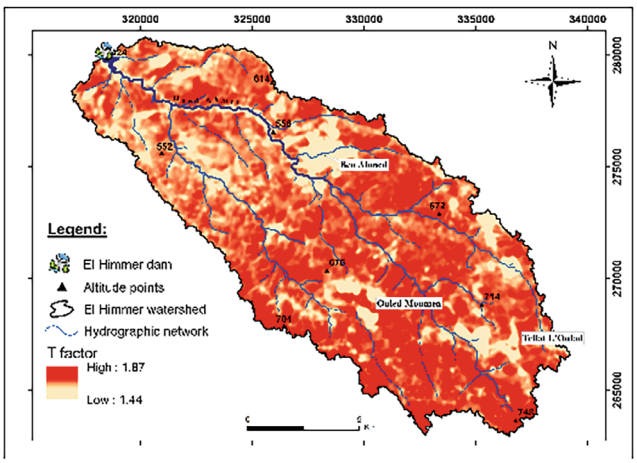


Fig. 2 Map of temperature factor T

3 Results

3.1 Average Annual Precipitation Coefficient *H*

Precipitation significantly impacts soil erosion, as its intensity, volume, and duration influence runoff and soil displacement. Raindrops also contribute by loosening soil particles (Fig. 1).

3.2 Temperature Factor *T*

According to (Gavrilovic 1970), the temperature coefficient is determined by the following formula:

$$T = \sqrt{\frac{t_0}{10} + 0.1}$$

where: t_0 mean annual temperature in C°.

$$t_0 = \frac{K_2}{\ln\left(\frac{K_1}{\varphi\lambda\prime}\right) + 1}$$

where: K_1 and K_2 are thermal conversion constants generated from the MTL file metadata of the satellite images. λ' the spectral radiance (Fig. 2).

3.3 Potential Erosion *Z*

The "Z" potential erosion factor is an essential indicator for assessing the probability of erosion occurring in the watershed. The values of this factor are determined according to the different erosion classes established by Gavrilovic (El Assaoui et al. 2023; Chaaouan et al. 2013) (Fig. 3; Table 1).

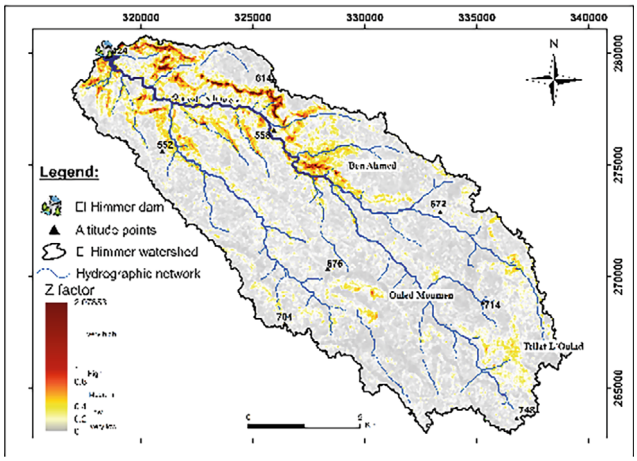


Fig. 3 Map of potential erosion *Z*

Table 1 Degree of erosion according to the *Z* factor (Gavrilovic 1970)

Erosion degree	*Z* factor	Area percentage (%)
Very low	< 0.2	76.41
Low	0.2–0.4	17.86
Medium	0.4–0.8	4.80
High	0.8–1	0.44
Very high	> 1	0.49

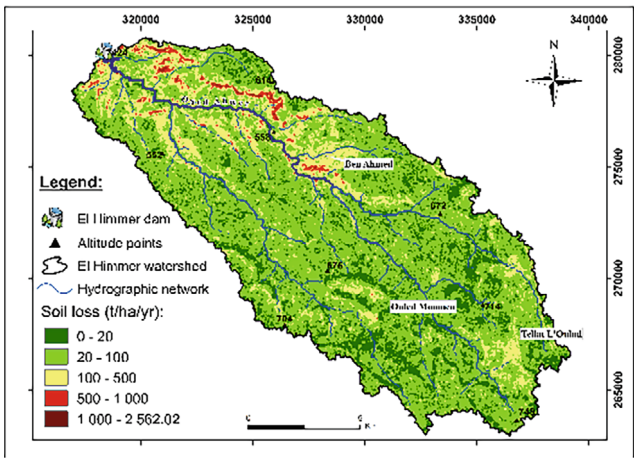


Fig. 4 EPM soil loss map (t/ha/year)

3.4 Estimated Soil Loss *W*

The EPM model generates a soil loss map expressed in m^3/km^2/year. However, to make soil losses easier to understand, it is common practice to convert them into units of tons per hectare per year (t/ha/year). This conversion involves dividing the result by the average density of the soil (Efthimiou 2016) (Fig. 4).

4 Discussion

The cartographic study reveals key trends in the watershed analyzed. Precipitation shows an east–west growth pattern, correlating with the proximity of the oceans, which influences precipitation patterns. Temperature coefficients range from 1.44 to 1.87, corresponding to areas with high temperatures, mainly in the southeast due to the distance from the Atlantic.

In terms of erosion potential, a significant proportion of the basin (76.41%) has low erosion (below 0.2), while 17.86% has moderate erosion (between 0.2 and 0.4). Areas of high erosion are infrequent and cover less than 1% of the basin, located mainly downstream along the banks of the Oued. The soil loss map shows a variability ranging from 0 to 2562.02 t/ha/year, with an average of 66.95 t/ha/year. The most common soil losses are between 20 and 100 t/ha/year, but areas of high erosion (> 500 t/ha/year) coincide with sectors where less resistant soils and steeper slopes accelerate runoff and lead to substantial erosion.

5 Conclusions

The results show that the areas most vulnerable to erosion are mainly downstream of the El Himer basin. This region is characterized by the prevalence of fragile soils from the Quaternary period, combined with steep slopes that accelerate runoff. This combination of factors favors more pronounced erosion, underlining the imperative importance of implementing specific measures to minimize soil losses and preserve the balance of the local ecosystem.

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Interoperability Between BIM and GIS for Assessing the Market Value of Public Real Estate Assets

Daniela Tavano and Francesca Salvo

Abstract

In Italy, there is a growing emphasis on the appraisal, management, and allocation of public real estate assets, underscoring the heightened need for discerning valuation methodologies that account for their distinctive attributes. Public authorities have the option to create a "Plan of Disposals and Valorization (PDV)" in order to reposition their assets from a liability to a financial asset. The PDV includes properties for better economic utilization, allowing local authorities to sell or lease them to private entities. Property sale requires a market value appraisal. The appraisal of public real estate assets is not simple because there is often a lack of local market comparables for these property types, and they do not produce any income. These circumstances make the Cost Approach the only possible method to appraise the market value of public assets. The practicality and effectiveness of the Cost Approach method provide reassurance in this complex task. Utilizing new technology tools can simplify the application of the Cost Approach for appraising public assets. It is important to note that this work is of significant importance in the context of a recent development process related to the digitization of real estate assets. Many public administrations are adopting this process to make the management and maintenance of their assets easier. Building Information Modeling (BIM) technology is used in this context. BIM skills include management, data organization, computation of modeled quantities, and cost estimation. The Geographic Information System (GIS) is a computer technology dedicated to collecting valuable data for appraisal. In its most recent evolution, GIS allows the integration of a BIM model into a geolocated information system. The connection between BIM and GIS is currently a widely discussed issue in the construction industry. The purpose of this work is to digitally facilitate the assessment of the market value of public real estate assets, a task of significant importance in the field of real estate appraisal. This involves utilizing both BIM and GIS technologies to execute the Cost Approach method.

Keywords

Building Information Modeling · Geographic Information System · Cost Approach · Real estate valuation · Public real estate assets

1 Introduction

Over the past 20 years, the use, enhancement, and management, or alternatively, the disposal and sale of public real estate, has become a particularly significant issue in Europe (Acampa 2019). The appraisal of public real estate assets, when the practical reason behind it is the sale and market value is the criterion for reference, is a far-from-simple operation. His difficulty can be attributed to the nature of the assets being evaluated, which, in most cases, lack comparable elements in the local market and do not generate income (Artemenkov et al. 2008; Fattinnanzi et al. 2020; Simonotti 2006; Salvo et al. 2020). The International Valuation Standards (IVS) outline three main valuation methods that are widely accepted to appraise the market value of a property: (a) the Market Approach, (b) the Income Approach, and (c) the Cost Approach (International Valuation Standards Council 2023; European Valuation Standards 2023; Royal Institution of Chartered Surveyors 2017). In most cases, the Cost Approach emerges as the only viable approach to estimate the market value.

D. Tavano (✉) · F. Salvo
Department of Environmental Engineering, University of Calabria, Rende, Italy
e-mail: daniela.tavano@unical.it

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Nowadays, the diffusion of new Information and Communication Technology (ICT) tools can facilitate and optimize the application of the Cost Approach for the public assets' appraisal. This observation is part of a larger context concerning the digitization of real estate assets, which numerous public administrations have initiated to streamline the management and maintenance of their properties. This development process has prompted public administrations to adopt new computer technologies to preserve property data over time. In this framework, the technology of Building Information Modeling (BIM) comes into play. BIM technology is widely regarded as the most effective methodological system to manage, share, and preserve information about the built environment. The BIM capabilities also include the computation of modeled quantities and the corresponding cost estimation. These skills can initiate the implementation of new automatic or semi-automatic procedures to estimate the market value of public real estate assets based on the Cost Approach. Recently, some scholars have focused on the applications and potentials of BIM for real estate valuation (Arcuri et al. 2020; Manganelli et al. 2019; Manganelli and Tataranna 2020; Salvo et al. 2022; Celik Simsek and Uzun 2021; Jafary et al. 2022).

Collaboration among related computer technologies can have interesting implications. Among these technologies, the Geographic Information System (GIS) stands out. The appraisal literature encompasses GIS applications aimed at the implementation of automated valuation procedures (Ciuna et al. 2017). Today, the interoperability between BIM and GIS is a hot topic in the international discourse regarding the construction industry. Implementing a valuation procedure based on the Cost Approach, there are two essential property elements to analyze, namely the land and the building and the strategic advantage lies in the synergistic utilization of BIM and GIS technologies. In a historical moment where the entire real estate world is undergoing significant transformation and the theme of digital innovation is highly debated, the research intends to develop a procedure to estimate real estate public assets based on the Cost Approach, aided by BIM and GIS technologies.

2 Methods

The Cost Approach allows the appraisal of the property market value (MV) by combining the market value of the land with the reconstruction cost of the building, minus any possible loss of value. The following formula (1) can illustrate the process.

$$\mathrm{MV} = \mathrm{MV}_L + \mathrm{RC}_{\mathrm{DEP}} \tag{1}$$

where MV_L is the land market value, and $\mathrm{RC}_{\mathrm{DEP}}$ is the reconstruction cost (possibly depreciated).

Generally speaking, the crucial steps that characterize the appraisal activity employing Cost Approach are three: (1) appraisal of the land market value; (2) calculation of the reconstruction cost; and (3) calculation of the depreciation. Based on this insight, the proposed procedure in this paper is arranged into three distinct stages: Stage 1—Using BIM to calculate the building reconstruction cost; Stage 2—Using GIS to appraise the land market value; and Stage 3—Migration of the results obtained in the first two stages into an Excel spreadsheet to calculate the deprecation and carry out the property market value according to the depreciated reproduction cost criterion.

Stage 1—The application of BIM aims to quantify the building reconstruction cost through the preparation of a BIM-*based* bill of quantities (BoQ). This is made possible by the 5D dimension of BIM, which, on the one hand, allows accurate and detailed computation of all modeled elements (quantity take off function) and, on the other hand, enables the association of cost parameters with the modeled elements, allowing the creation of a bill of quantities.

Stage 2—The appraisal of the land market value within the GIS environment is carried out by developing an Automated Valuation Model (AVM) using the *Model Builder* tool. The developed AVM estimates the land market value using a direct valuation approach, incorporating algorithms corresponding to the mono-parameter appraisal method.

The functioning of the GIS-*based* AVM involves creating thematic *layers* that contain data pertaining to the land, such as selling prices, dimensions, and area incidence coefficients. The initialization input for the AVM is provided by the georeferenced positioning of the BIM model on the map, which initiates the search for real estate data to which the mono-parameter appraisal method will be applied.

Stage 3—In this final phase of the procedure, the quantification of the remaining cost items comprising the reproduction cost of a property is conducted. In order to estimate the depreciation incurred by each of these cost items, the impacts of the functional components, *structures*, *finishes*, and *systems*, on the construction cost are initially analyzed. For this purpose, three impact coefficients are introduced (σ_{st}, σ_{fi}, σ_{sy}) and applied to the other cost items to allocate them into three categories (st, fi, sy) one for each considered functional component. This division is necessary to consider the specific depreciation that each functional component undergoes, based on its economic lifespan. Depreciation is calculated for its three types: physical deterioration, functional obsolescence, and economic obsolescence. By adding the depreciated reproduction cost items to the land market value obtained in Stage 2, the property market value is derived.

3 Results

The described methodology has been applied to a public property known as "Ostello della Gioventù," located in the municipality of Joppolo (VV) in the south of Italy. On the BIM side, the implementation of the procedure in the case study demonstrated how the advantages of BIM in calculating construction costs conflict with the substantial computational burden of digital modeling *ex novo*, which needs sourcing, studying, and subsequently digitizing of the paper documentation obtained from technical offices. However, the increased investment of time and resources during this initial phase is offset by the efficiency gained in the phase related to quantity take-off and subsequent preparation of the bill of quantities. On the GIS side, the construction of the *layers* necessary for the development of the GIS-*based* AVM has been possible through data collected from the *Observatory of the Real Estate Market* (OREM), based at the University of Calabria. The application demonstrated that the structured model is versatile and capable of adapting to various market contexts. This ensures the model's applicability to contexts different from the pilot one, provided that the structure of the computerized database remains unchanged. On the interoperability BIM-GIS side, it can be argued that the placement of the BIM model on the map resulted in a significant loss of information, as the 3D model retained its physical appearance, but lost its rich data content. This circumstance required the use of an Excel spreadsheet to merge the data from the two environments and then finalize the valuation process (Stage 3).

4 Discussion

The discussion of the proposed procedure is structured into three main threads: Side BIM, Side GIS, and Side Interoperability BIM-GIS.

Side BIM: The difficulty encountered during the application of the procedure Stage 1 could find a solution through the anticipated digitization of the built heritage. On one hand, this would allow the professional to avoid the burden of creating a 3D model ex novo, and on the other hand, to have access to a unified database that preserves comprehensive and concise information about the architecture, materials, structures, and systems of a building asset.

Side GIS: Establishing publicly accessible real estate databases, necessary to build the layers of the GIS-*based* AVM, can make a valuable contribution to enhancing the feasibility of the proposed procedure. Certainly, the developed AVM is subject to several potential enhancements. Additional extrinsic features could be measured and analyzed within the model, and multiparametric appraisal approaches could be implemented.

Side Interoperability BIM-GIS: As the case study has highlighted, at the moment, the interoperability between BIM and GIS is not optimal. Despite this, the focus on the potential of their combined use is significant, fueling numerous research and experimentation efforts.

5 Conclusions

The digitization of various processes in the real estate sector is undergoing rapid transformation, owing to the capabilities provided by advanced computer technologies in acquiring, managing, and analyzing a vast quantity of data and information pertaining to real estate properties. In this context, the appraisal sector is challenged to develop new methodologies based on what digital means offer, while simultaneously observing IVS and the dictates of appraisal tradition. At the same time, effort is required from industry stakeholders to promote the digital transition of the entire construction sector and to encourage the establishment of publicly accessible real estate databases.

If real estate evaluation bases its validity on the availability and quality of information as well as how sharable it is, information technologies are the most concrete and fruitful perspective in appraisal research, even where a systematic, rational, objective, and automatic valuation approach seems difficult to apply (Arcuri et al. 2020).

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Mapping of Prone Subsidence Areas in the Douala Sub-Basin: Preliminary Results Using Remote Sensing Data

Louise Nsangou, Jorelle Larissa Meli'i, Nicola Perilli, Salomon Cesar Nguemhe Fils, and Philippe Njandjock Nouck

Abstract

The Littoral Region which extends from Kribi to Limbé is the most strategic economic area of Cameroon. In this area that includes the Douala sub-basin, national and international companies and entrepreneurs are investing huge economic resources in the construction of buildings and infrastructures. Some of them are strategic for the future of Cameroon and the neighboring landlocked countries. In recent decades, the rapid population growth of Douala and its surroundings has prompted the construction of imposing buildings and infrastructures and has induced dramatic groundwater exploitation for domestic and agricultural needs. This ever-growing urbanization and consequent groundwater over-pumping is promoting land subsidence of the study area. The aim of this work is to identify the most prone areas to land deformation in the Douala sub-basin, using remote sensing data and GIS techniques. Thus, SRTM_DEM and Landsat 8 images have been processed in the ArcGIS environment to generate nine thematic layers, used as criteria in the Analytical Hierarchy Process-based Multi-criteria decision analysis. According to the elaborated land subsidence prone areas (LSPA) map, we can distinguish two main areas where buildings and infrastructures can suffer damage related to the compaction of the soil. We have the urban area, around industrial sectors and popular neighborhoods, where the groundwater pumping can amplify the subsidence rate, and the southern suburban part of the study area, where the spreading of high-water demanding crops has been causing an excessive exploitation of aquifers in the last decade. Although the developed LSPA is a preliminary map, it could be a useful tool for decision makers to identify, ratify, and disseminate recommendations and guidelines aimed at improving land use management and mitigating impacts related to land subsidence.

Keywords

Subsidence mapping · Remote sensing · GIS · MCDA · Douala sub-basin · Cameroon

1 Introduction

The lowering of the topographic surface due to soil compaction can induce land subsidence. This geohazard is characterized by a very slow rate/year, so when the first damages to buildings or infrastructures are detected, it is often too late for repairs, and reconstructions are generally expensive and challenging. The coarse- to fine-grained clastic wedges of alluvial and coastal areas can be affected by soil compaction, which can be enhanced by overloading of the soil and overexploitation of groundwater. Both are related to urban and suburban expansion, induced by rapid population growth and the consequent strong increase of anthropogenic activities including agriculture. That in turn can trigger land deformation and contribute to increased rates of subsidence (Tosi et al. 2013; Sidiq et al. 2019), causing damages to buildings and infrastructures, and result into loss of life. These causes are currently active in the

L. Nsangou (✉) · J. L. Meli'i · P. Njandjock Nouck
University of Yaoundé I, Yaoundé, Cameroon
e-mail: louisensangou@icloud.com

J. L. Meli'i
e-mail: julangephil@gmail.com

P. Njandjock Nouck
e-mail: pnnouck@yahoo.com

N. Perilli
University of Pisa, Pisa, Italy
e-mail: nicola.perilli@unipi.it

S. C. Nguemhe Fils
Institute of Geological and Mining Research, Yaoundé, Cameroon
e-mail: cefils1@yahoo.fr

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coastal area of Douala, characterized by a dramatic spread of buildings and infrastructures, and huge groundwater pumping for agriculture, mainly horticultures and industrial plantations, in suburban and rural areas. In recent decades, the coastal areas of African countries such as Nigeria, Kenya, and Egypt have been subject to this destructive phenomenon, but published works on this geohazard are still few (Cian et al. 2019). Furthermore, few are articles published on floods and sea level rise threaten the Douala area (Yengoh et al. 2017; Niba and Gideon 2021), whilst studies on land subsidence are missing. According to the literature, InSAR data and/or geodetic measurements are necessary to build a reliable subsidence inventory needed to apply quantitative approaches, such as Random Forest, Frequency Ratio, Fuzzy logic, or Machine Learning, to map the Land Subsidence Index (Hirales-Rochin 2020; Jelgersma 1996). Considering the absence of the subsidence inventory for the Douala area and the importance of investigating this threat, for the first time, our work aims to generate a qualitative map of the areas prone to subside in the urban, suburban, and rural territories of the coastal area of Douala, using remote sensing data and Analytical Hierarchy Process (AHP).

2 Settings, Materials, and Methods

The study area, located on the Gulf of Guinea (Fig. 1), includes the urban area and surroundings of Douala, expanding over approximately 210 km^2 between latitudes 04°01'–04°06' North and longitudes 09°40'–09°45' East. Douala is the largest city of Cameroon and its economic capital. It is also one of the major industrial and economic centers of Central Africa due to the port activities, and it is experiencing an enormous population growth. This exponential socio-economic growth, also thanks to port activities, is favoring a rapid spread of the urban and extra-urban fabric toward the surrounding rural areas. As a result, the construction of multi-storey buildings, the casual development of semi-industrial and industrial activities is shaping the urban and suburban fabric while the destruction of forests or the replacement of traditional crops with water-intensive crops are shaping the rural areas. The sedimentary record includes Paleo-Oligocene marly-dominated succession, overlaid by Mio-Pliocene alluvial to deltaic sediments, which partly represent the hilly areas of the Douala and the Pleistocene coastal deposits (Wouri Fm). These units are draped by ferrallytic and hydromorphous soils, characterized by a large proportion of coarse to fine-grained fractions.

As stated above, the absence of a subsidence inventory prevents the use of quantitative approaches to map the subsidence index. Therefore, among the qualitative approaches used in the literature to evaluate this geographical risk, we have chosen the most used and reliable one, namely Analytical Hierarchy Process (Hirales-Rochin 2020). It allows 1—to select the main conditioning factors (CFs) which for our objective are those that contribute to triggering and amplifying land subsidence, and 2—to attribute to each CF a weight to each of their distinct classes, based on the skills and expertise of the involved team. In this study, the selected

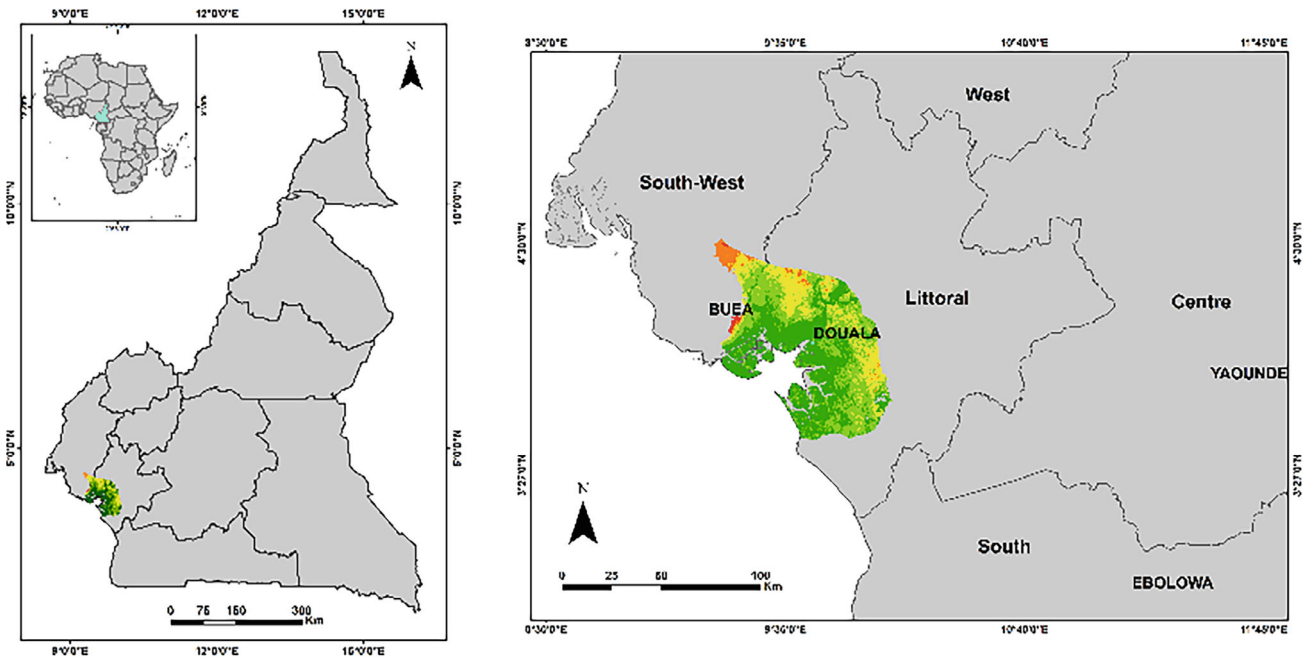


Fig. 1 Location of the study area

CFs are: elevation (E), slope (S), drainage density (Dd), land cover (LC), lithology (Lt), topographic wetness index (TWI), normalized difference of vegetation index (NDVI), distance to roads (DtRo), and distance to rivers (DtRi). Different data sources were used to generate these thematic layers.

The Digital Elevation Model—SRTM 1 Arc-Second 30m, from USGS Earth Explorer, permitted to obtain E, S, Dd, TWI, and DtRi. The LC map was derived from the 2022 ESRI land cover map, the lithology was taken from the Cameroon Geological map, and the NDVI and the DtRo were calculated using, respectively, Landsat 8 images and Open Street Map data. All these layers were synthetized in the ArcGIS 10.8 software. The AHP is a powerful mathematical tool that allows to evaluate the importance of different CFs affecting a phenomenon and to identify the most relevant ones, based on their pairwise comparison (Saaty 1980). These 9 CFs represent the used criteria arranged in a matrix and classified according to the Saaty scale (from 1 to 9) before proceeding to the pairwise comparison for the calculation of the weights (w) of each criterion, and then to the obtention of the eigenvalue vector (λ_{max}), the consistency index (CI) and finally the consistency ratio (CR) using the formulae given below:

$$\lambda_{max} = \frac{1}{n}\left[\sum_{I}^{n}(Aw_i)/w_i\right]$$

$$CI = (\lambda_{max} - n).(n-1)$$

$$CR = CI/RI$$

where n is the number of criteria being compared and RI the random consistency index. In this study, RI = 1.45 because there are nine factors. The ranking is considered acceptable when the CR is less than or equal 0.1 (Saaty 1980). If the CR is greater than 0.1, that means the rankings assigned to each criterion need to be revised.

3 Results

Conditioning factors. For each thematic layer, five classes were distinguished with the exception of the NDVI which includes only 3 classes. Below, some remarks on the 9 CFs used for generating the land subsidence prone areas (LSPA) map. For **elevation** the lowest and the highest value are assigned to the hilly areas from where the sediments are uptake, and to the lowlands where sediment are prone to be compacted, respectively. For **slope,** the highest and the lowest value are assigned, respectively, to the flat areas where the sediments are deposited and the lowest value to their source areas. Regarding **land cover,** the highest rate was given to built-up areas and the lowest one to rangelands/bare lands. We here assume that high **drainage density** corresponds to less permeable and more compactable clayey sediments, while low drainage density to more permeable and less compactable sandy deposits. For **lithology,** the highest and the lowest values were given respectively to the very fine grained estuarine and stratified marly successions. The highest values of **TWI** have been assigned to the areas characterized by high-water accumulation being most likely to be subject to soil compaction and the highest values of **NDVI** correspond to areas characterized by crops with high water consumption, which are the most sensitive areas to subside. For **distance to river**, assuming that the least compacted sediments are those close to the rivers, the highest value is therefore assigned to these areas and for **distance to roads,** the highest value is given to the areas close to the roads where soil compaction is promoted by the vibration induced by traffic.

Land subsidence prone areas (LSPA). The LSPA map was generated using the weighted overlay option of the Spatial Analyst tool in ArcGIS 10.8. To each layer derived from the CFs, after being reclassified into five classes with different degrees of proneness to subsidence (very low, low, moderate, high, and very high), they were given the weights calculated through the AHP process. The areas with moderate, high and very high proneness represent 57.43, 20.99, and 0.25% of total area, respectively. And the areas with very low and low proneness to subsidence are each represented by 0.47 and 20.86% of the total area. Reducing the classes from five to three, approximately 57.43% of the study area shows a moderate proneness and those with a low and high value correspond to 21.33 and 21.24% of the total study area, respectively (Fig. 2). The latter includes the plains bordered by the Wouri estuary, characterized by alluvial, deltaic, and estuarine deposits. In particular, the map shows that moving away from the estuary the susceptibility to subsidence decreases, and the most sensitive areas to soil deformation roughly coincide with the urban area of Douala.

4 Discussion

The absence of INSAR-based subsidence inventory for the study area due to the persistent cloud cover, prevents the use of a quantitative approach for subsidence mapping. To weigh the selected 9 CFs and rank their classes, we used the qualitative AHP-based Multicriteria Decision Analysis method. Soil thickness and depth of water table are not used because their data are missing or not reliable, while CF climate was ignored because it is the same for the entire investigated area. After assigning the weight to the CFs and making up the pairwise comparison matrix, we obtained a

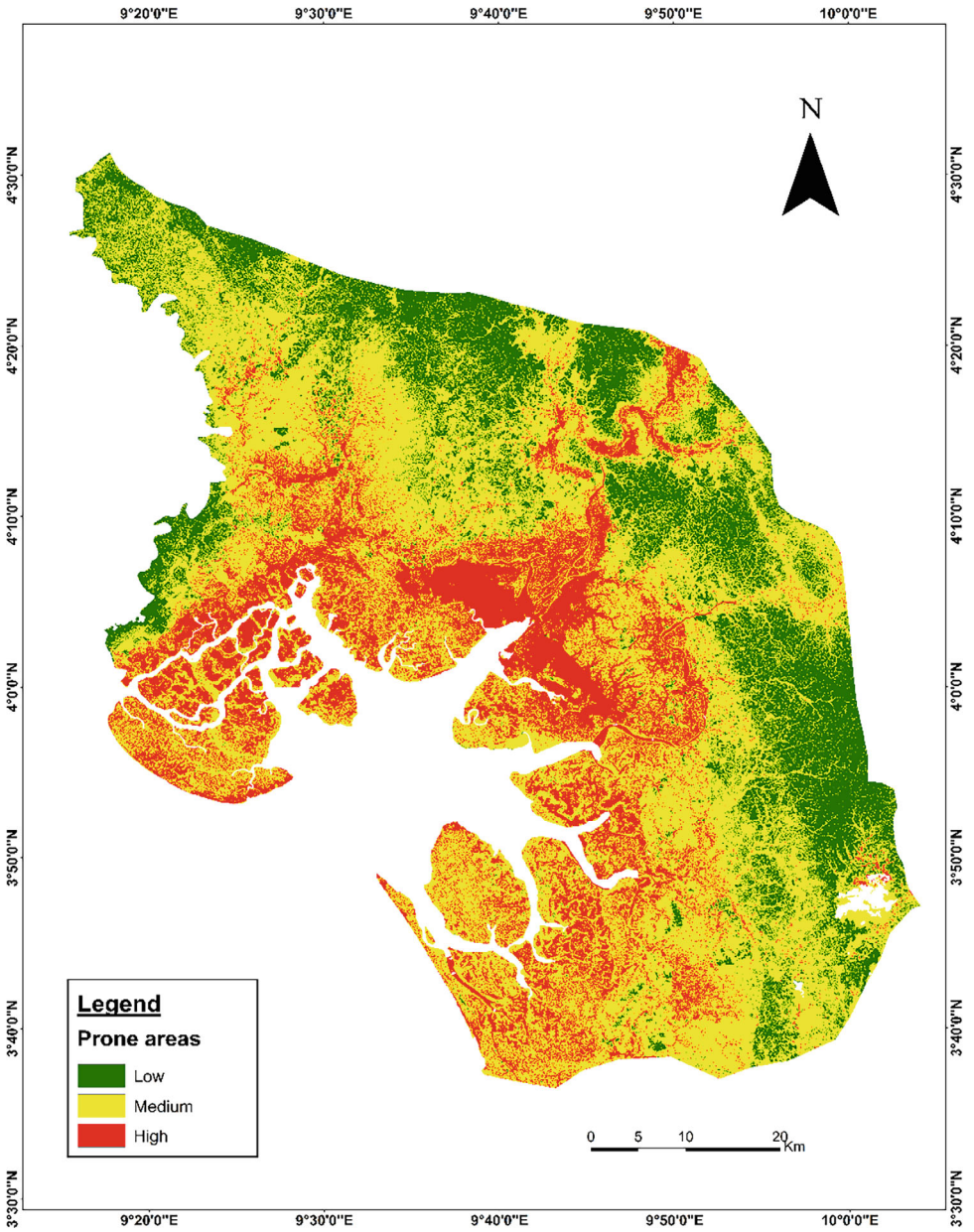


Fig. 2 Land subsidence proneness areas of the study area and distribution of the three distinguished classes with different degrees of proneness to subsidence

CR value of 0.08. As stated by Saaty (1980), when CR is smaller than 0.1, the consistency, namely the judgement is acceptable. Although the reliability of the results obtained in this study needs to be validated with subsidence inventory and ground-truth data, the LSPA map obtained shows that 21.24% of the study area has high risks to be subject to land subsidence. Subsidence-prone areas are found primarily within the belt bordering the Wouri Estuary, which is characterized by alluvial to deltaic and estuarine clastic wedges, where shallow groundwater is stored. This sector includes the areas where classes that scored high on the four main criteria mentioned above overlap. They are low altitude (< 25 m), low slope (0–2°), built-up areas (LC), and Pleistocene fine-grained sediments (Lt). Concerning the important CFs, the AHP-based achieved results show that over 9, there are 4 CFs that stand out with high values. They are land cover (weight = 0.25), elevation (weight = 0.24), slope (weight = 0.18), and lithology (weight = 0.14). Certainly, all these data must be implemented, however they 1—allow us to know which areas are likely to be most vulnerable to this geohazard and, 2—are useful and necessary to design and enable a network for monitoring and measuring ground deformations of the study area. Concerning this last point, the reconstruction of the geometry of the main aquifers, and of the fine-grained and organic rich clayey intervals, is a mandatory task for identifying the areas where geoelectric and penetrometric investigations must be carried out to

improve the reconstruction of the subsoil lithostratigraphy and, mapping the most risk areas to soil deformation.

5 Conclusion

The main purpose of this work was to map the land subsidence prone areas (LSPAs) using remote sensing data of the Douala sub-basin. The lack of a land subsidence inventory for the study area made it impossible to use quantitative methods. Therefore, the application of AHP-based MCDA allowed for the first time to obtain an LSPA map of the Douala area and its surroundings. Considering that the study area is prone to soil deformation, the following remarks can be highlighted. 1—The deployment of a monitoring system to build a subsidence inventory of this phenomenon characterized by a very slow soil deformation, is necessary. 2—It is also essential to carefully investigate the groundwater withdrawal, seawater intrusion and land use, starting from human-induced overload. Although our findings need to be supported by a reliable subsidence inventory, they can be used as a baseline study of the subsidence and for prioritizing the above reported two commitments. They are also useful for spatial planning decision-makers and stakeholders involved in urban and suburban development, starting from the identification of the initial recommendations and rules aimed at mitigating or implementing these geographical risks.

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Morphotectonic Evidences Along the Sanaga Fault Between Betare-Oya and Edea: Preliminary Results Using Remote Sensing and GIS Techniques

Carolle Fomekong Lambou, Jorelle Larissa Meli'i, Nicola Perilli, Salomon Cesar Nguemhe Fils, and Philippe Njandjock Nouck

Abstract

The Sanaga Fault (SF) or the Sanaga Shear Zone (SSZ) is one of the major regional tectonic structures of Cameroon. First mapped from Betare-Oya to Edea areas as single tectonic element, it has been subsequently mentioned and represented in many papers as a composite and segmented tectonic structure. However, works focusing on the entire SF/SSZ are still very few. Consequently, the strike, length, and position of the SF/SSZ are not yet constrained and it is still a matter of debate whether the SF/SSZ is single continuous or is a composite segmented structure. This work aims to map the morphotectonic structures and the lineaments identified along a NE–SW rectangular band of land including a large portion of the Sanaga River valley, from Betare-Oya to Edea area and, therefore is addressed to improve the knowledge on the SF/SSZ. Morphotectonic structures and lineaments were generated after processing SRTM_DEM, satellite images. Based on 1—the main morphotectonic structures identified and 2—the lineaments pattern, the NE–SW oriented rectangular study area, can be divided in three key sectors located 1—west of the Ndikinimeki-Edea alignment, 2—between Edea/Makondo and Nanga Eboko area, and 3—NE of Nanga Eboko area. The NNE–SSW morphotectonic structures mapped west of the Ndikinimeki-Massok-Edea alignment, are not referable to the SF/SSZ and the presence of structures that could be assigned to the SF/SSZ between Edea/Makondo and Obala/Ntui areas is questionable. Are instead referable to the SF/SSZ, part of the NE–SW oriented morphostructures mapped N and S of the Sanaga River between, Ntui and Nanga Eboko and, part of the NE–SW oriented morphostructures recognize in the Bibey and Betare-Oya subsectors. In summary, our data support that the SF/SSZ is a composited and segmented regional structure, recognizable from Betare-Oya to Bibey and from Nanga Eboko to Ntui areas. However, according to the achieved preliminary results, further work is still necessary including the collection of field data.

Keywords

Sanaga Fault · Morphotectonic structures · Lineaments · Remote sensing · GIS · Cameroon

C. F. Lambou (✉) · J. L. Meli'i · P. Njandjock Nouck
University of Yaoundé I, Yaoundé, Cameroon
e-mail: michellelambou@gmail.com

J. L. Meli'i
e-mail: julangephil@gmail.com

P. Njandjock Nouck
e-mail: pnnouck@yahoo.com

N. Perilli
University of Pisa, Pisa, Italy
e-mail: nicola.perilli@unipi.it

Present Address:
S. C. Nguemhe Fils
Institute of Geological and Mining Research, Yaoundé, Cameroon
e-mail: cefils1@yahoo.fr

1 Introduction

First recognized by Dumont (1986), the SF/SSZ NE–SW oriented structure, extending between Betare-Oya to Edea areas or from Betare-Oya to Edea area, cross-cuts the Nyong Complex, the Yaoundé Group and the Lom Group (Dumont 1986; Moussango Ibohn et al. 2022). Furthermore, although this structure is mentioned and represented in may papers, specific works focusing on SF/SSZ or part of it are still very few, and in the published tectonic sketches, is represented as a single continuous strait or a composite and/or segmented structure (Toteu et al. 2001, 2004; Ngako et al. 2003; Kankeu et al. 2009). Therefore, the strike, the

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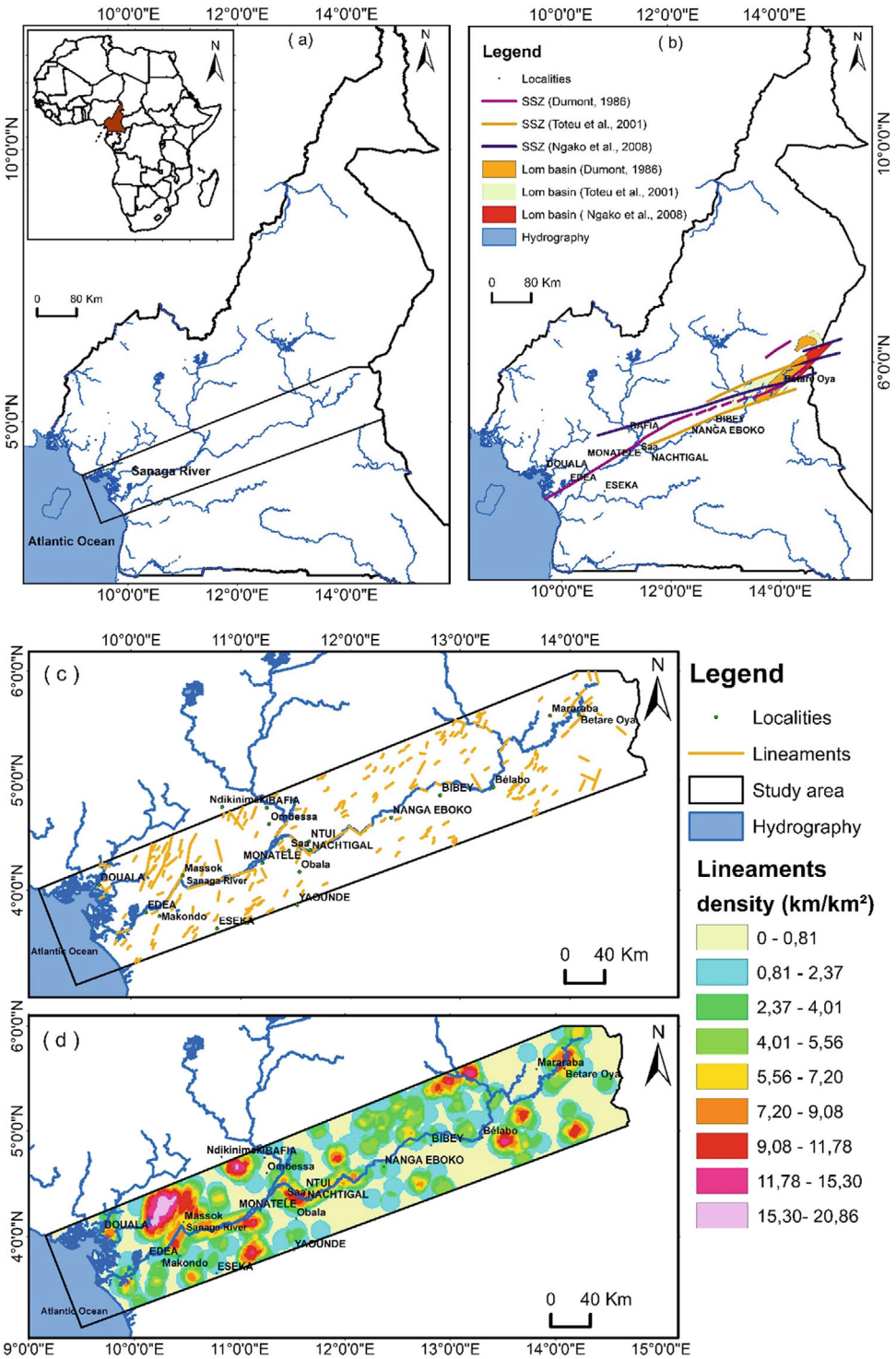


Fig. 1 Localization of the study area (**a**) and previous mapping of the SF/SSZ (**b**). Lineaments map (**c**) and lineaments density map (**d**) of the study area

length and the position of this regional tectonic structure are not yet constrained (Fig. 1) and, a map of the main morphotectonic structures and lineaments of the selected study area, extracted from satellite images, are not yet available. Furthermore, the relationship between the SF/SSZ and the other close regional shear zones, e.g. Central African SZ or Betare-Oya SZ are still not investigated. This work is a preliminary contribute to improve the mapping of the SF/SSZ, based on the analysis of the main morphostructures and of lineaments extracted from SRTM_DEM images.

2 Settings, Materials, and Methods

The study area extends between LAT 3° 00′ 00″ N to 6° 00′ 00″ N and LONG 9° 00′ 00″ E to 15° 00′ 00″ E. This 150 km wide and 500 km long NE–SW oriented band, running from the Betaré Oya to the Edea areas, is here be divided in three sectors. **1**—West of Ndikinimeki-Edéa alignment mainly outcrop the metamorphic rocks of the Nyong-Bayomen domain and of the Ndikinimeki Group. In the W sector the main tectonic structures show an NNE–SSW regional strike. **2**—In the central sector, from Bafia-Monatélé to Nanga Eboko, outcrops the i—the metamorphosed volcano-sedimentary series of the Yaoundé Group along with Central Cameroon Suite and the Ngambe Suite, and ii—the crystalline rocks of the Central Cameroon calc-alkaline Suite along with the Linté-Godé alkaline. **3**—Compared to the previous ones, in the E sector between Nanga Eboko and Bétaré-Oya, also outcrops the crystalline rocks belonging to the Central Cameroon Suite and the volcano-sedimentary series of the Lom Group. All the tectonic structures belonging to this sector, show predominantly regional NE–SW strike, and part of them are belong to the Betare-Oya Shear Zone (Toteu et al. 2001; Kankeu et al. 2009). Using SRTM_DEM with a resolution of three arc seconds (90 m), the hillshade, slope, drainage and elevation investigated to identify both morphostructures and the lineaments. The main morphostructures have been identified where a topographic ridges and offset were recognizable (mainly) in the hillshade and slope maps. The lineaments were manually and automatically extracted from the different hillshade with four solar illumination angles 0°, 45°, 90°, 135°. The manual extraction of the lineaments has been realized by superimposing to the hillshade the slope and/or the drainage and/or the elevation maps (Lambou et al. 2025). The automatic extraction of the lineaments has been carried out using the "line" extraction module of the PCI Geomatica software, where the extraction algorithm is based on edge detection, thresholding and lineament extraction (Soliman and Han 2019). For both morphostructures and the lineaments, the Rose diagrams have been elaborate for the different sectors.

3 Results

Based on the directions and density of the morphostructures and lineaments and the Rose Diagrams of the structures mapped, the preliminary noteworthy results for the three distinguished sectors and the five subsectors are below reported.

Western Sector. This sector is an NNE–SSW oriented area located west of the Ndikinimeki-Makondo-Edea alignment. It is characterized by the presence of sigmoidal morphostructures oriented from NNE–SSW to NE–SW, which from Edea to Elogbatindi areas they show NNE–SSW to NS directions. All these structures are cross-cutted by ENE–WSW to ESE–WNW oriented structures, some of which also show sigmoidal shape. Between Massok (NE of Edea) and Makondo (E of Edea), one of these major structures runs parallel to the Sanaga River, showing a NNE–SSW direction. The lineaments mapped for this sector show NNE–SSW to NE–SW directions that are consistent with the direction of the morphostructures.

Central Sector. This sector can be divided into a western, northern and southern subsectors. The western subsector includes the Bafia and Monatélé areas, which are characterized by poly-deformed curved morphostructures, showing an NNE–SSW to NE–SW direction. The east front of these structures runs from Ombessa to Obala areas. W of Monatélé, namely between Monatele and Makondo the mapped morphostructures show continuity from the northern to southern side of the Sanaga river. Furthermore, N of Dibang have been mapped some parallel morphostructures that show a NE–SW direction, which towards NE and SW are bounded by morphostructures showing NNE–SSW and NNE–SSE direction, respectively. In the northern subsector, namely the area east of the Ombessa-Obala alignment and northern of the Ntui-Nanga-Eboko alignment, have been recognized two sets of morphostructures, mainly show an NNE–SSW to NE–SW direction. The few scattered structures mapped in the southern subsector, located westwards of the Ntui-Yaoundé alignment and south of the Sanaga Rivers, show a NNW–SSE to NNE–SSW direction. It is very important to point out that the clusters of lineaments mapped along both sides of the Sanaga Rivers, and in particular those N of the Ntui-Nanga-Eboko alignment, show a clear NE–SW direction.

Eastern Sector. This sector extends between the Nanga Eboko and Betare-Oya areas. It is mainly characterized by subparallel NE–SW-oriented structures. These morphostructures are better recognizable in the Betare-Oya subsector than in the Bibey subsector. However, NW and E of Bibey, i.e. N and S of the Sanaga River, although the morphostructures are sparse and difficult to map they show an orientation comparable to those recognized in the Betare-Oya subsector. The direction of the lineaments of both subsectors are consistent with each other and with the direction of the morphostructures.

In summary, the SF/SSZ is a composite and segmented structures easily recognizable in the Betare-Oya area and in part in the Bibey area. Furthermore, structures referable to the SF/SSZ are also recognizable to the north and south of the Ntui-Nanga Eboko alignment, namely on both sides of the Sanaga River. Evidence of this regional tectonic structure are certainly absent westwards of the Ndikinimeki-

Edea alignment, and they seem to be absent also between Makondo and Ntui areas, located E of Edea and W of Monatele, respectively.

4 Discussion

The SF/SSZ is one of the main tectonic structures of Cameroon, represented as a single continuous strait (Dumont 1986; Mvondo et al. 2007) or composite (Toteu et al. 2001, 2004; Ngako et al. 2003; Kankeu et al. 2009) structure or is traced as a segmented structure (Dumont 1986; Moussango Ibohn et al. 2022; Cheunteu Fantah et al. 2022). Concerning the extension, the SF/SSZ runs from Betare-Oya to Edea areas (Toteu et al. 2001; Ngako et al. 2008) or from the Betare-Oya to Monatele-Saa area (Toteu et al. 2001; Kankeu et al. 2009). However, the supporting data and/or a discussion for all these options are weak or missing and, very few are the papers that specifically focus on the SF/SSZ (Ngako et al. 2003, 2008). Furthermore, all the authors agree that the only geological evidence of this tectonic structure is the Lom mylonites (Soba 1989). The main noteworthy points and their comparison with the literature are reported below.

Eastern Sector. According to the literature (Toteu et al. 2001, 2004; Ngako et al. 2003, 2008; Kankeu et al. 2009; Nguemhe Fils et al. 2020), in the north eastern sector of the investigated area, located E of the Nanga Eboko, which includes the Bibey and Betare-Oya areas, the SF/SSZ is a composite and segmented tectonic structure showing a NE–SW to NNE–SSW directions.

Western Sector. The NNE–SSW-oriented sigmoidal morphostructures and lineaments which characterized the western most part of the study area, belongs to the Kribi Campo Shear Zone (Cheunteu Fantah et al. 2022; Nzeuga et al. 2022) and/or the Rocher du Loup Shear Zone (Ngako et al. 2008) and/or the Southern Cameroon Shear Zone (Toteu et al. 2004).

Central Sector. The NNE–SSW to NE–SW oriented poly-deformed structures and the lineaments of the Bafia and Monatele areas along both side of the Sanaga river and the NNE–SSW structures westwards of the Ntui-Obala alignments seems to exclude the presence of the tectonic structures referable to the SF/SSZ, even if ENE–WSW oriented structures are present westwards of the Ntui-Obala alignments. On the contrary, the morphostructures and lineaments mapped southwards and northward of the Ntui-Nanga Eboko alignment showing a NE–SW direction, are probably the main morphotectonic evidences, belonging to the SF/SSZ.

Considering the above results and remarks, the SF/SSZ is neither a single continuous strait nor a composite or segmented structure running from Betare-Oya areas to Edea. It is probably a complex segmented shear zone, perhaps even partly buried (e.g. in the Bafia Monatele area), whose morphological evidence has been partly masked by subsequent geological (e.g. Bibey) or erased by morphogenetic (Ntui-Nanga) processes—(Eboko area). Consequently, the Bafia and Monatele areas from Noun to Nyong rivers is one of the priority areas that should be investigated for better map the limit between the NE–SSW sigmoidal morphostructures referable to the Kribi Campo/Rocher du Loup and/or the Southern Cameroon Shear Zone and the structures referable to the SF/SSZ. The area located E of the Nanga Eboko also need to be carefully studied to reconstruct and constrains the relationship between the Betare-Oya Shear Zone and the SF/SSZ. The area between the Nanga Eboko and Ntui should be the subject of a study aimed at better reconstructing the clusters of tectonic segments identified along both sides of the Sanaga river, as well as in the Yaoundé region, to highlight their relationships with the structures referable to the Congo Craton.

5 Conclusions

Using RS and GIS techniques, a preliminary map of the main morphostructures and lineaments recognized within a NE–SW oriented band enclosing a large part of the Sanaga River valley, is here provided for the first time. The NNE–SSW oriented morphostructures recognized in the western sector, probably belonging to the Kribi Campo/Rocher du Loup and/or Southern Cameroon Shear Zone and, exclude the presence of tectonic structure referable to the SF/SSZ, westwards of the Ndikinimeki-Makondo-Edea alignment. Segments referable to the SF/SSZ are recognized 1—in the east sector, NE of the Nanga Eboko, namely in the Betare-Oya and Bibey area and 2—in the central sector along both side of the Sanaga River, between Ntui-Nanga-Eboko. The subsector including the Bafia and Monatele areas is characterized by NNE–SSW to NE–SW-oriented, poly-deformed structures, which are neither referable to the structures located west of the Ndikinimeki-Massok-Edea alignment nor to those (probably) referable to the SF/SSZ. Consequently, the cluster of the tectonic structures referable to the SF/SSZ need to be further investigated, between Makondo and Ntui and between Ntui and Nanga Eboko. And 1—the Bafia and Monatele areas, 2—the areas NE of the Nanga Eboko and 3—the area south of the Yaoundé, need to be further investigation for unlock the relationship between the SF/SSZ with the other close regional tectonic structures.

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Impact of Land Use Changes on Sediment Yield Using the SWAT Model: Case of Wadi Rmel Watershed, Northeast of Tunisia

Fathia Jarray, Taoufik Hermassi, and Mohamed Mechergui

Abstract

Tunisia, a Mediterranean country, is severely affected by water scarcity and water erosion. Soil erosion loss values are often variable from basin to basin and from period to period. This study aims to assess the impact of land use changes on soil erosion using the Soil and Water Assessment Tools (SWAT) model in the Wadi Rmel watershed. In fact, the model was used to simulate various land use change scenarios between 2000 and 2020 and to assess their impacts on sediment yields. Based on soil loss rates, the watershed was classified in 2000 as having a low soil loss category, which corresponded to an annual sediment yield less than 5 t/ha/year. However, in 2020, 82.5% of the total area had a low soil loss category and 17.5% was affected by a tolerable erosion risk. SWAT model was also used to identify and characterized the situation of the 27 sub-basins. Analysis of the spatial erosion patterns across various sub-basins in 2020 revealed that sub-basin 26 had the highest sediment yield at 8.5 t/ha/year, while sub-basins 6 and 20 showed minimal sediment transport. The most affected sub-catchments are 17 and 26, located in South-Western zones. These two sub-catchments are mainly characterized by major land use changes in urban and rangeland zones. The most important factors affecting the erosion rate were deforestation, increasing urbanization and uncovered sites. Finally, this research furnishes a valuable instrument for forecasting soil erosion risk and devising long-term management strategies aimed at mitigating runoff and sediment erosion.

Keywords

SWAT · Land use · Sediment yield

1 Introduction

Soil erosion represents a significant worldwide environmental and economic challenge, particularly in the Mediterranean region (Terranova et al. 2009). In Tunisia, the soils face a substantial threat owing to prolonged periods of aridity, which are succeeded by intense rainfall episodes. These rainfalls occur on steep slopes characterized by fragile soils and sparse vegetation cover. Additionally, the northeastern regions of Tunisia have undergone rapid land use and land cover (LULC) transformations in recent decades. Changes in land use and land cover (LULC) (Ahady et al. 2022,Guha and Govil 2021) within a watershed is one of the ways that have affected the hydrological cycle and soil resources. Measuring soil erosion accurately remains one of the most significant challenges in the fields of natural resource management and environmental planning (Arekhi et al. 2010). Nowadays, Computer simulation models are gaining popularity for forecasting soil erosion across different land use scenarios, and a multitude of such models have been developed to address this need. SWAT, the Soil and Water Assessment Tool, was selected for this particular case study due to its incorporation of numerous valuable components and functionalities for simulating sediment loss. The main objective of this research is to assess the influence of LULC changes occurring between 2000 and 2020 on soil erosion within the Wadi Rmel watershed. Additionally, it aims to analyze the connection between sediment yield and the patterns of LULC changes, particularly in the context of pasture and rangeland transformations.

F. Jarray (✉) · M. Mechergui
National Agronomic Institute of Tunisia, Tunis, Tunisia
e-mail: fathiajarray1993@gmail.com

F. Jarray · T. Hermassi
LRGR/National Research Institute for Rural Engineering, Water and Forestry, Ariana, Tunisia

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2 Materials and Methods

2.1 Study Area

The Wadi Rmel watershed is located in northeastern of Tunisia, in the Governorate of Zaghouan (Fig. 1). The watershed covers an area of 670 km^2 and drains into the Rmel dam.

2.2 Data Collection

The modeling process utilizes the following dataset:

- Topographic data: Digital Elevation Model (DEM) (30-m resolution).
- Land use data of 2000 and 2020: Unsupervised classification of Landsat-8 satellite imagery with 30-m spatial resolution, validation by field visits.
- Soil data: Digitized Tunisian soil map (scale: 1/50,000).
- Climatic data (precipitation, temperature, relative humidity, solar energy, and wind speed): The rain gauge station of Zaghouan.

2.3 SWAT Model

SWAT is a semi-distributed hydrologic model. The calibration, validation, and sensitivity analysis for the SWAT model were conducted using the SWAT-Calibration Uncertainty Program (SWAT-CUP) in conjunction with the (Sequential Uncertainty Fitting 2) SUFI-2 algorithm (Abbaspour 2015). The impact of LULC was determined as the quantified change. Indeed, the study was executed by running the model with two distinct sets of land use data. Finally, it was assumed that all alterations in soil loss rates could be attributed to modifications in the land use inputs.

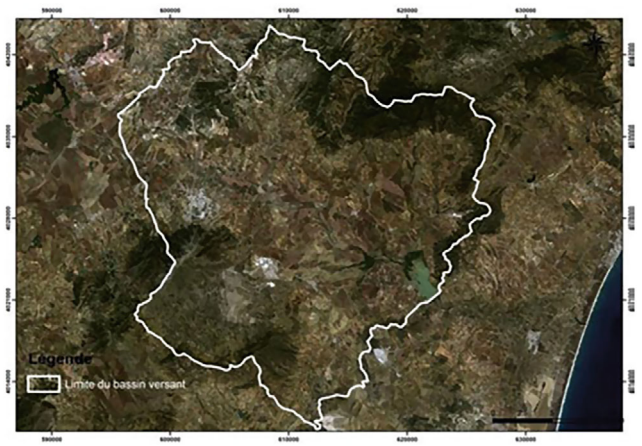


Fig. 1 Study area location

3 Results

3.1 LULC Change Over 20 Years

The Wadi Rmel watershed has occurred an important LULC changes between 2000 and 2020. The area of wheat, forest and pasture have been an important reduction. Indeed, the area of rangeland was decreased from 79 to 36 km^2 and with an area of change around 43 km^2 between 2000 and 2020. In contrast, the urban area was increased from 7 to 14 km^2 during the last two decades. On the other hand, the olive class underwent the most significant transformation, marked by an increase of approximately 43 km^2 by 2020, from 95 km^2 in 2000 to 138 km^2 in 2020.

3.2 Spatial Distribution of Soil Loss

In this work, the SWAT model was used to evaluate erosion state of the studied watershed in two different periods, 2000 and 2020. In fact, and based on soil loss rates the Wadi Rmel catchment was classified in 2000 as a low soil loss category, which corresponded to an annual sediment yield less than 5 t/ha/year. However, in 2020, 82.5% of the total area was classified as a low soil loss category and 17.5% was affected by a tolerable erosion risk, with an annual sediment yield of 5–10 t/ha/year. Once the SWAT model results were utilized to classify erosion severity at the catchment level, the model was further employed to identify and rank critical sub-catchments based on their erosion risk. The watershed was divided into 27 sub-basins based on topography. In 2020, two sub-basins number 17 and 26 were, respectively, in tolerable soil loss category where the simulated average of soil loss was higher than 8.5 t/ha/year. In fact, by examining the arrangement of erosion patterns across studied area for the year of 2020, it was averred that the most affected sub-basins were located in South-West zones. On the other hand, the sub-catchments 11, 16, 20, and 24 representing the most negligible sediment transport were located in the plain zone and forested area in the North-East of the catchment (Fig. 2).

4 Discussion

The objective of this research is to investigate the impact of changes in land use on soil erosion during the period from 2000 to 2020. Based on the results obtained from the

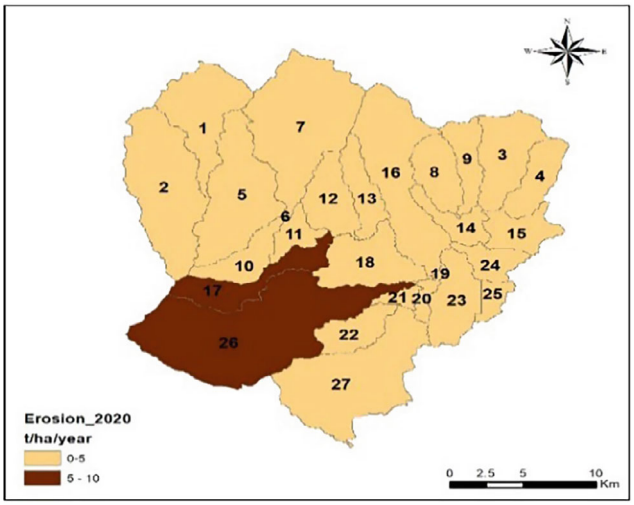


Fig. 2 Spatial pattern of annual losses in the Wadi Rmel watershed (2020)

SWAT model, research related to erosion simulation has shown that the areas most heavily impacted within the catchment are primarily characterized by cultivated land and steep slopes. These findings highlight that land use and slope gradient are the primary factors influencing the extent of soil loss in the catchment. Comparing the map of LULC change and the map of spatial distribution of soil loss, the sub-basin level analysis revealed that the erosion rate increases were observed in South–West parts where forested area was changed to agricultural zones. These results are consistent with other findings (Gachene et al. 2020; Novara et al. 2021). Table 1 displays the distribution of land cover in the previously identified highly affected sub-catchments, namely number 26 and 17. It is observed that the two sub-catchments were highly covered with wheat with 51% in sub-catchment 26 and 65% in sub-catchment 17. Moreover, these sub-basins were characterized with an important presence of bare soil, pasture and urban zones (Table 1). The arrangement of land use in this area leads to reduced residence time for rainwater to infiltrate the soil, consequently causing elevated erosion rates. This result confirmed that the land use changes has a pronounced effect on sediment yield.

5 Conclusions

The objective of this study was to evaluate soil erosion rates within a substantial semi-arid catchment, such as the Wadi Rmel catchment located in Northeastern Tunisia, using the SWAT model. The findings indicate that the integration of the SWAT model with satellite remote sensing and geographic information systems (GIS) offers valuable tools for estimating soil erosion. Based on soil loss rates, the watershed was classified in 2000 as having a low soil loss category. However, in 2020, 82.5% of the total area had a low soil loss category and 17.5% was affected by a tolerable erosion risk. In fact, the assessment of soil loss rates revealed that not all sub-catchments within a larger catchment make an equal contribution to sediment yield. In this study, SWAT model showed that the sub-basin 17 and 26 are the most affected by soil erosion and land use changes. In conclusion, the most important factors affecting the erosion rate were deforestation, increasing urbanization and uncovered sites.

Table 1 Land cover characteristics within the most vulnerable sub-catchments

Land cover	Area under sub-catchment 26 (%)	Area under sub-catchment 17 (%)
Bare soil	10	11
Forest	2	0
Olive	17	6
Pasture	16	14
Urban zone	4	4
Wheat	51	65

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A GIS-Based Frequency Ratio Model for Mapping Groundwater Vulnerability in the Bekalta Aquifer, Tunisia

Imen Hentati, Nadia Trabelsi, Ibtissem Triki, and Moncef Zairi

Abstract

An important tool for establishing groundwater quality monitoring networks and putting preventive measures into place, particularly in arid and semi-arid regions, is the assessment of groundwater vulnerability to pollution. This study's primary objective is to evaluate the use of the frequency ratio (FR) model in groundwater vulnerability assessment and mapping. Through the calibration of Susceptibility Index (SI) parameter rates, the frequency ratio approach, a bivariate statistical analysis, offers a new paradigm for evaluating groundwater vulnerability. This research examines the spatial relationships between the nitrate samples and hydrogeological factors such as depth to water, topography, recharge, aquifer media, and Land use/Land cover. The Bekalta area's groundwater vulnerability was assessed using the SI standard and the FR-SI models. According to the SI standard model, the groundwater vulnerability zone has been divided into three categories which are high (60%), moderate (37%) and low (3%). The vulnerability models were validated by applying the relative operating characteristic (ROC) curve method. The FR-SI model shows better performance compared to the SI standard model, with the area under the ROC curve (AUC) value of 0.822 and 0.645, respectively. The optimized map using the FR-SI model showed three classes: low (50%), moderate (47%), and high (3%) vulnerability. These findings can be applied for accurate decision-making in the area's groundwater management.

Keywords

Groundwater vulnerability · Frequency ratio · Accuracy model · FR-SI

1 Introduction

Groundwater vulnerability mapping becomes a crucial tool for quantifying the sensitivity of groundwater resources (Rahman 2008). Vulnerability assessments must be accurate, scientific, and based on reliable data (Mohammadi et al. 2009). Several methods have been developed to assess groundwater vulnerability.

The overlay index approaches use a system of arbitrary ratings and a weighting formula (Aller et al. 1987). Some authors have criticized the choice of the number of factors, the ratings, and the weights used to compute the vulnerability index (Secunda et al. 1998; Antonakos and Lambrakis 2007). For example, DRASTIC index might be obtained using fewer parameters, with several advantages in accuracy and costs (Napolitano and Fabbri 1996). Two sensitivity analysis tests frequently were applied; the map removal sensitivity analyses introduced by Lodwick et al. (1990) and the single-parameter sensitivity analysis introduced by Napolitano and Fabbri (1996). The former identifies the sensitivity of the vulnerability map towards removing one or more maps from the suitability analysis while the latter uses an effective weight to assess the impact of each DRASTIC parameter on the vulnerability index (Afshar et al. 2007). A GIS-based combination of analytical hierarchy process (AHP) has largely been explored in a number of scientific applications including groundwater vulnerability mapping to estimate a ranking or weighting of each of the criteria that describes the importance of each of these criteria

I. Hentati (✉)
Faculty of Sciences of Sfax, Sfax, Tunisia
e-mail: imenhentati@yahoo.fr; imen.hentati@fss.usf.tn

I. Hentati · N. Trabelsi · I. Triki · M. Zairi
Laboratory 3E, National School of Engineers of Sfax—ENIS, Sfax, Tunisia

I. Triki
Faculty of Sciences of Gafsa, Gafsa, Tunisia

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in contributing to the overall objective (Ahmedou et al. 2007). According to Focazio et al. (2008), the process-based and statistical methods are favored over to index overlying approaches for water resource managers. The bivariate statistical methods as the frequency ratio (FR) approach is used in different field such groundwater potential zones mapping (Oh et al. 2011; Ozdemir 2011; Nampak et al. 2014; Trabelsi et al. 2018), groundwater pollution assessment (Shrestha and Luo 2018) and groundwater vulnerability mapping (Hamza and Umar 2020) however, Neshat and Pradhan (2015) used the frequency ratio (FR) as a pioneering approach to optimize the DRASTIC model rates and defined it as a hybrid method.

The Bekalta watershed, the focus of this study, experienced a progressive qualitative degradation of its water resources, primarily as a result of intensive agriculture's excessive use of fertilizers. The specific vulnerability assessment method, named Susceptibility Index (SI), was developed with the intention of evaluating aquifer vulnerability to diffuse agricultural pollution (Stigter et al. 2006).

This study aimed to analyze groundwater vulnerability using an integrated Susceptibility Index (SI) and FR-SI models, and to assess the efficiency of the FR model for groundwater vulnerability mapping.

2 Settings and Methods

2.1 Study Area

The watershed covers 45 km^2, and its highest point is 28 m above sea level and its lowest point is 7 m below sea level (Fig. 1). It is influenced by the Mediterranean humid and temperate climate. About 19 °C is the average annual temperature. Rainfall is the primary hydrological component in the area, with an annual average of 350 mm.

Old Quaternary sand–clayey strata with restricted vertical and horizontal extension make form the reservoir of the unconfined Bekalta superficial aquifer. The reservoir is 20 m thick on average. The Moknine Sebkha receives the majority of the groundwater flowing into the aquifer, which is refilled through direct infiltration (Hentati et al. 2016).

2.2 Methodology

The adopted methodology involves three steps: (1) datasets collection (toposheets, field data, hydrogeological data, and rainfall data), their processing and the preparation of thematic layers, (2) a frequency ratio model is used to revise the rates, (3) groundwater vulnerability mapping of

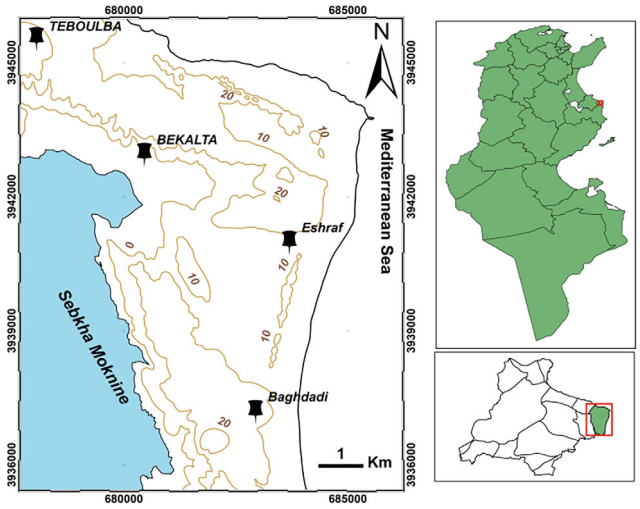


Fig. 1 Location of the study area

SI standard and FR-SI and their validation using ROC curve (Fig. 2).

The nitrate samples were used to compute FR values and validate the suitability and reliability of the two models. In fact, 12 (30%) nitrate samples were used for model validation whereas the remaining 28 (70%) were chosen for model training.

2.2.1 Susceptibility Index (SI) Model

The Susceptibility Index (SI) approach is a vulnerability assessment tool for determining a specific vertical vulnerability to pollution originated from agricultural activities mainly by nitrates (Stigter et al. 2006). The SI method considers different hydrogeological parameters: depth to water, net Recharge, aquifer media, topography, and Land use land cover (LU/LC). The SI is derived from ratings and weights assigned to the parameters by applying a linear combination of the five factors according to the following equation:

$$\mathrm{SI} = (D_\mathrm{w} * D_\mathrm{r}) + (R_\mathrm{w} * R_\mathrm{r}) + (A_\mathrm{w} * A_\mathrm{r}) + (T_\mathrm{w} * T_\mathrm{r}) + (\mathrm{LU/LC_w} * \mathrm{LU/LC_r}) \quad (1)$$

where D, R, A, T, and LU/LC are the five SI parameters. The relevance of weight and rate for each parameter is denoted by the subscripts w and r, respectively.

2.2.2 Frequency Ratio (FR) Model

The frequency ratio (FR) approach, which uses bivariate statistical analysis to calibrate the rates of Susceptibility Index (SI) parameters, offers a new framework for assessing groundwater vulnerability. Based on the observed correlations between the distribution of nitrate samples and each

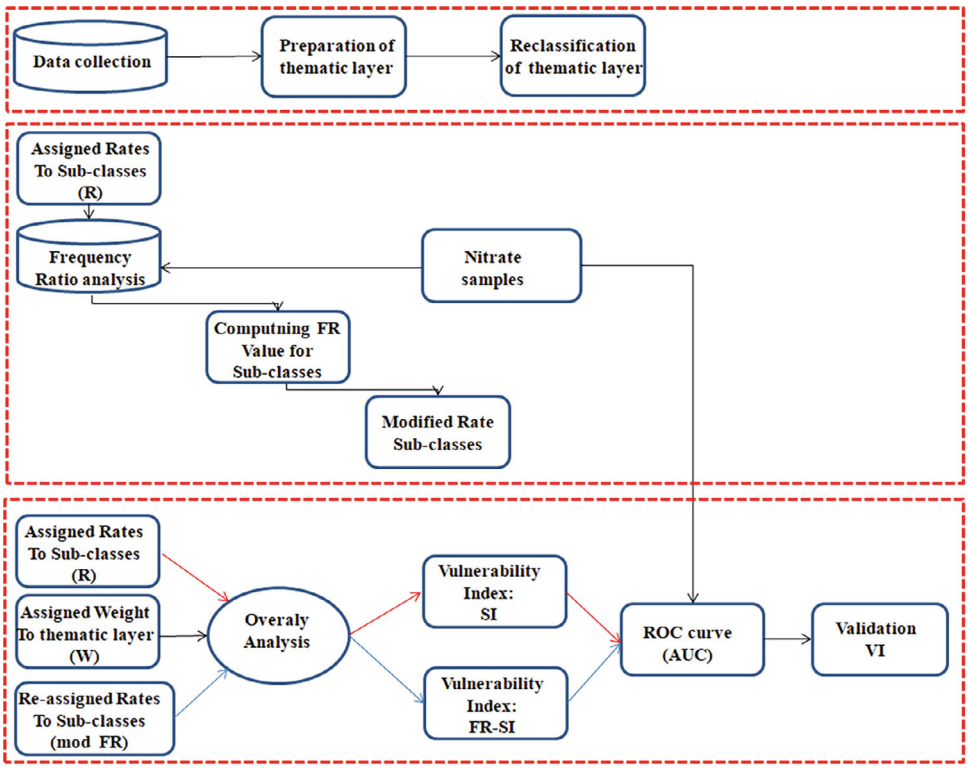


Fig. 2 Flow chart of methodology

of the five SI layers, the FR model is used to calculate the connection between nitrate samples and SI parameters. The relationship between each factor range with the nitrate samples allowed for the determination of its FR. The frequency ratio was computed as Eq. (2).

$$\mathrm{FR} = (A/B)/(C/D) = E/F, \tag{2}$$

where FR is the frequency ratio of the sub-classes, A is the number of pixels in each class for each SI parameters, B is the total number of pixels in the study region, C is the number of nitrate pixels in each class, and D is the total number of nitrate pixels in thematic layer, E is the percentage of nitrates in the class of each parameter; F is the percentage of area in the class for each parameter.

Rating values were modified for each class based on their FR values, the highest FR value was assigned the highest rating value, and the other rates for other classes were calculated through linear proportion (Arshad et al. 2020). The vulnerability index FR-SI was calculated according to Eq. (3).

$$\begin{aligned}\text{FR-SI} = {} & (D_{\mathrm{w}} * D_{\mathrm{modfr}}) + (R_{\mathrm{w}} * R_{\mathrm{modfr}}) + (A_{\mathrm{w}} * A_{\mathrm{modfr}}) \\ & + (T_{\mathrm{w}} * T_{\mathrm{modfr}}) + (\mathrm{LU/LC_w} * \mathrm{LU/LC_{modfr}})\end{aligned} \tag{3}$$

where D, R, A, T, and LU/LC are the five SI parameters. modfr expresses the modified rates derived via the FR method multiplied by the original SI weights.

3 Results

3.1 SI Vulnerability Index Map

The SI index values measuring the aquifer vulnerability fall into three classes corresponding to three vulnerability degree, ranging from low to high (Fig. 3). The spatial distribution of the vulnerability degree indicates that the aquifer of Bekalta is highly vulnerable.

3.2 FR-SI Vulnerability Index Map (Hybrid Method)

The FR-SI index was computed from the modified rates and original SI model weights. The range of the index score is categorized into three degrees, low, moderate, and high. Figure 4 illustrates the moderate zones found in the northern parts and the low-vulnerability zones in the southern part of the region.

3.3 Validation of SI and FR-SI Vulnerability Index Map

The area under the ROC curve (AUC) was used to validate the SI vulnerability index and FR-SI vulnerability index.

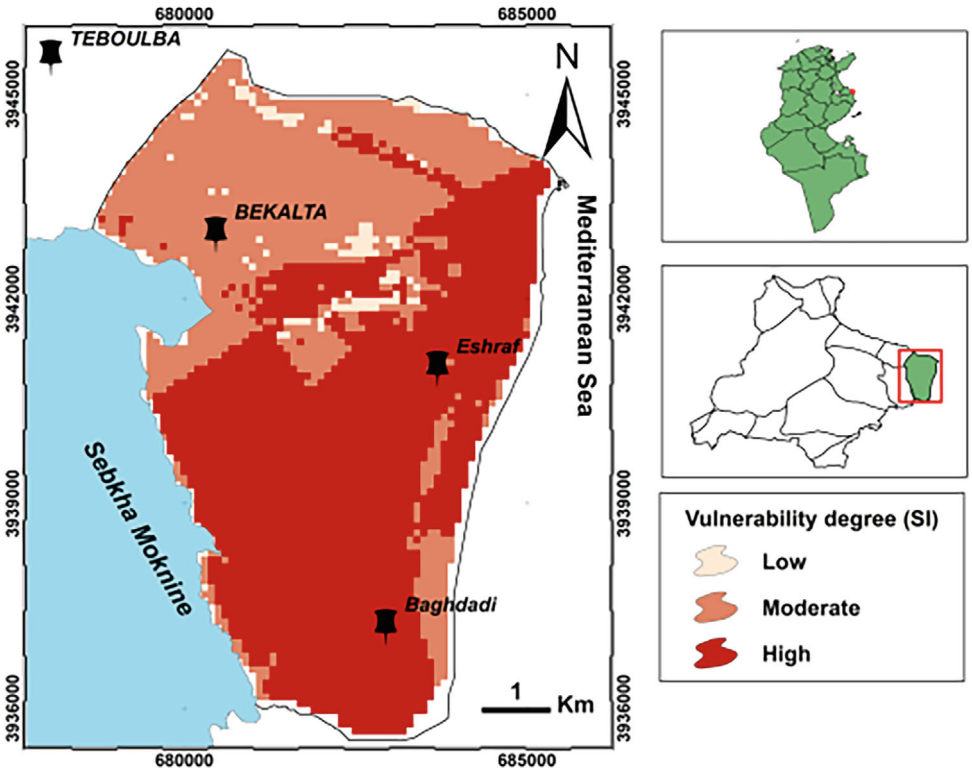


Fig. 3 A specific vulnerability map (SI)

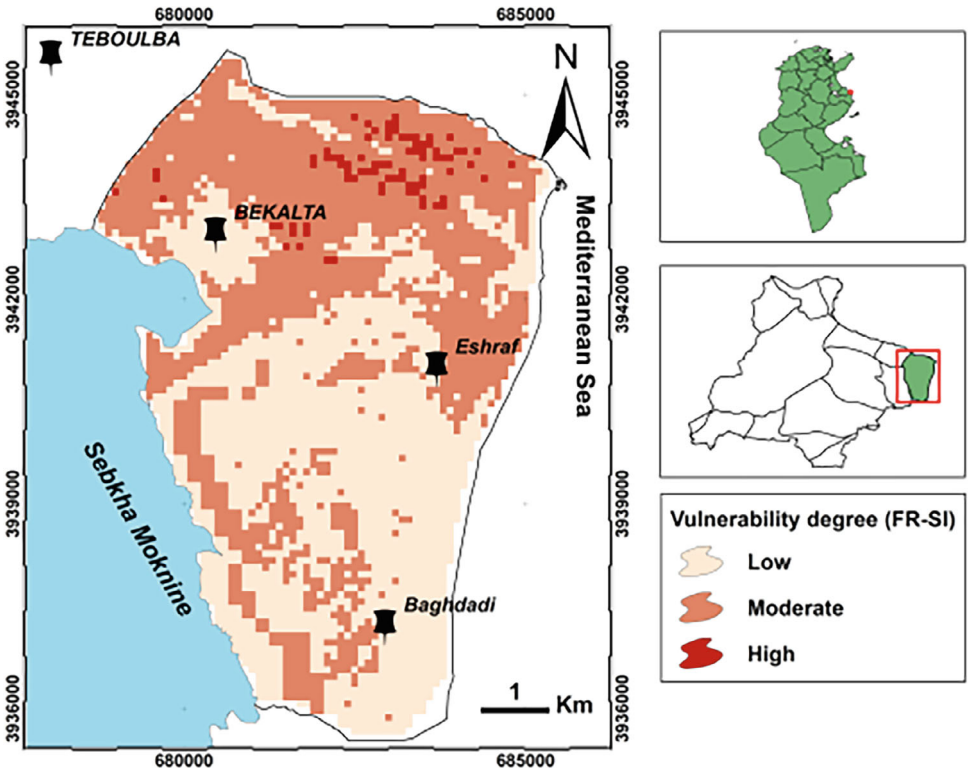


Fig. 4 A specific vulnerability map (FR-SI)

The AUC was plotted between the accumulated percentage of nitrate and the vulnerability index. For the SI and FR-SI vulnerability indices, the AUC values were 0.64 and 0.82, respectively.

4 Discussion and Conclusions

The specific vulnerability map of the Bekalta aquifer was produced by integrating the five layers of the SI method according to the weights and rates published by Stigter et al. (2006). According to the SI standard model, the groundwater vulnerability zone has been divided into three categories, high (60%), moderate (37%), and low (3%).

The SI layers including the statistically revised rates from the FR approach were integrated to generate the new hybrid FR-SI method. This latter showed three degree vulnerability but with a totally different configuration compared with the SI vulnerability index map. In fact, the moderate (47%) and high (3%) zones were found in the northern parts and the low-vulnerability zones (50%) in the southern part of the region.

The FR-SI model shows better performance compared to the SI standard model, with the area under the ROC curve (AUC) value of 0.822. The higher value of AUC indicates the efficiency of the frequency ratio model for groundwater pollution vulnerability level in the Bekalta aquifer. Indeed, the revision of the original SI parameters rating takes into account the spatial distribution of nitrate samples and that of the hydrogeological parameters.

These results will be helpful for better managing the territory and ensuring groundwater protection.

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Soil Loss Estimation in Abandoned Quarries: A RUSLE Model-Based Study in Settat, Morocco

Nabil Aouichaty, Yassine Bouslihim, Said Hilali, Abdeljalil Zouhri, and Yahya Koulali

Abstract

Open-pit quarrying may degrade the environment due to economic expansion and the demand for construction materials. Some quarries were abandoned after closing. Numerous studies have shown that abandoned quarries directly affect soil deterioration, prompting rehabilitation, or restoration. Settat provincial abandoned quarries were assessed for water erosion using the Revised Universal Soil Loss Equation (RUSLE). The equation requires data from several sources in various types and sizes. ArcGIS 10.5 helped the research process and manage data. It allowed spatial processing of numerous layers and the study of how input data affected the soil erosion map. Five erosion factors: rainfall erosivity (*R*), soil erodibility (*K*), slope steepness and slope length (LS), vegetation cover (*C*), and erosion control practices (*P*) were multiplied to calculate average annual soil loss. Most quarries have modest soil loss rates, ranging from 0 to 8100 kg/ha/yr. The results may help planners and decision-makers manage water resources and save soil.

Keywords

RUSLE · GIS · Abandoned quarry · Soil loss · Soil conservation

N. Aouichaty (✉) · S. Hilali · Y. Koulali
BNRNE Laboratory, FST, Hassan First University of Settat, Settat, Morocco
e-mail: aouichaty.nabil@gmail.com

N. Aouichaty · Y. Bouslihim
CRRA, National Institute for Agricultural Research, Rabat, Morocco

A. Zouhri
CAE Laboratory, FST, Hassan First University of Settat, Settat, Morocco

1 Introduction

Soil erosion, which is linked to land degradation, is a spatial and temporal phenomenon that is seeing a rise in several countries of the world (Pandey et al. 2009). Soil erosion is a natural occurrence that, when exacerbated by human activity, poses significant environmental and economic challenges (Lal 1998). Water erosion is identified as the primary factor contributing to soil deterioration in Morocco (Ouallali et al. 2016). The phenomenon results in yearly soil depletion, with rates varying between 5000 kg/ha/yr and exceeding 50,000 kg/ha/yr, contingent upon the unique circumstances prevalent in each respective location (Erosion in Morocco 2021). Hence, prior research has shown a clear correlation between abandoned quarries and the occurrence of mass movements and landslides. The potential consequences of this phenomenon include an increased susceptibility to erosion in regions that are particularly susceptible (Taoufik et al. 2020). The research aims to achieve is to assess and measure erosion rates in 22 disused quarries located in Settat province (central Morocco) (Ministry of Equipment, Transport, Logistics and Water, Directorate of Administrative and Legal Affairs 2018) by using the RUSLE model.

2 Materials and Methods

The methodology consists of evaluating the main factors in the RUSLE equation, which are involved in erosion processes (Jazouli et al. 2019). This method is the most widely used to quantify soil erosion worldwide, and it was selected based on the availability of the necessary data for its application in the province of Settat. Based on the given model (Eq. 1), the estimation of soil loss (*A*) is influenced by a multiplier function that incorporates five variables: *R*, *K*, LS, *C*, and *P* factor. The various elements were gener-

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ated using the ArcGIS program (version 10.5) (Renard et al. 1996).

$$A = R \cdot K \cdot \mathrm{LS} \cdot C \cdot P \tag{1}$$

The erosivity of rainfall is primarily influenced by climatic factors, with precipitation playing a pivotal role in the generation of erosion risks and forms. The precipitation data for a span of 20 years were collected from the database of NASA LaRC POWER Data Access Viewer. This data was retrieved for a total of 14 stations located within the designated research region. The production of the precipitation erosivity map included two main steps. Firstly, the *R*-factor (Eq. 2) (Rango and Arnoldus 1987) was calculated for each station. Subsequently, the *R*-factor map was generated using the Inverse Distance Weighting (IDW) method.

$$\log R = 1.74 \times \log \sum \left(\frac{P_i^2}{P} \right) + 1.29 \tag{2}$$

where R represents the erosive potential of precipitation, measured (MJ mm/ha h yr), P_i denotes the average monthly precipitation (mm), whereas P represents the average annual precipitation (mm).

The soil erodibility depends primarily on soil texture, organic matter, and permeability (Renard et al. 1996). The *K*-factor map within the research region was generated using ArcGIS software, using soil parameters obtained from the ISRIC-World Soil Information database. The equation provided was used to determine the erodibility of soil (Neitsch et al. 2000).

$$\begin{aligned} K = {} & 0.1317 \times (0.2 + 0.3 \times \exp[-0.0256 \times m_{\mathrm{san}} \\ & \times \left(1 - \frac{m_{\mathrm{sil}}}{100}\right)]) \times \left(\frac{m_{\mathrm{sil}}}{m_{\mathrm{cla}} + m_{\mathrm{sil}}}\right)^{0.3} \\ & \times \left(1 - \frac{0.25 \times m_{\mathrm{oc}}}{m_{\mathrm{oc}} + \exp[3.72 - (2.95 \times m_{\mathrm{oc}})]}\right) \\ & \times \left(1 - \frac{0.7 \times \left(1 - \frac{m_{\mathrm{san}}}{100}\right)}{\left(1 - \frac{m_{\mathrm{san}}}{100}\right) + \exp\left[-5.51 + 22.9 \times \left(1 - \frac{m_{\mathrm{san}}}{100}\right)\right]}\right) \end{aligned} \tag{3}$$

The variable K represents the soil erodibility index (t h/MJ mm). The variables m_{s}, m_{silt}, m_{C}, and orgC represent the percentages of sand, silt, clay, and organic carbon content, respectively, inside the layer.

The topographical factor is the combination of the length (*L*) and the steepness (*S*) slope. The application of Eq. 4, as proposed by Mitasova et al. (1996), was executed in this context using the raster calculator tool inside the ArcGIS program.

Table 1 Classification of vegetation cover

Classes	*C*-factor
Water body	0
Built-up land	0.003
Forest	0.004
Agriculture	0.4
Uncultivated land	0.75
Bare land	1

$$\begin{aligned} \mathrm{LS} = {} & \mathrm{Power}((\text{flow accumulation} \times \text{Cell resolution}) \\ & /22.1, 0.4) \times \mathrm{Power}(\mathrm{Sin}(\text{Slope of degree} \times 0.01745) \\ & /0.09, 1.4) \times 1.4 \end{aligned} \tag{4}$$

The factor of vegetation cover: The presence of plant cover plays a crucial role in safeguarding the soil and mitigating the process of soil erosion (Renard et al. 1996). This study assessed the *C*-factor, which was calculated using Landsat 8 images to create a *C*-factor map of the study location using supervised classification (Table 1) (Jazouli et al. 2019).

The erosion control practices factor includes level-curved crops, bank reforestation, butting, and reforesting (Roose 1996). Within the designated research region, the allocated *P*-factor value for the whole of the site was determined to be 1, due to the lack of implementation of soil conservation practices used within the province.

3 Results and Discussion

3.1 Assessment of Factors Contributing to Soil Erosion

For the *R*-factor, the findings indicate a significant erosive potential of precipitation in the majority of quarries in our study area, where values exceed 60 MJ mm/ha h yr. The results of the *K*-factor show that Settat Province is subject to a low rate of erodibility (0.053 t h/MJ mm). Also, the use of Eq. 4 within the province yields LS values that vary between 0 and 120,623. Lastly, the results of the *C*-factor show that all abandoned quarries are located in bare land.

3.2 The Assessment of Soil Erosion

Our soil loss assessment ranges from 0 to 282,770 kg/ha/yr. This assessment was derived by superimposing the five ArcGIS-evaluated variables.

According to the categorization put out by the author referenced inBeskow et al. (2009) (Table 2), the findings pertaining to erosion in abandoned quarries indicate that the mean soil loss values range from 0 to 8100 kg/ha/yr (Fig. 1). In contrast,

Table 2 Adjusted soil loss classifications from Beskow et al. (2009)

Rate of soil erosion (kg/ha/yr)	Classify qualitative soil erosion
0–5000	Slight
5000–15,000	Medium
15,000–25,000	High
25,000–100,000	Very high
> 100,000	Extremely high

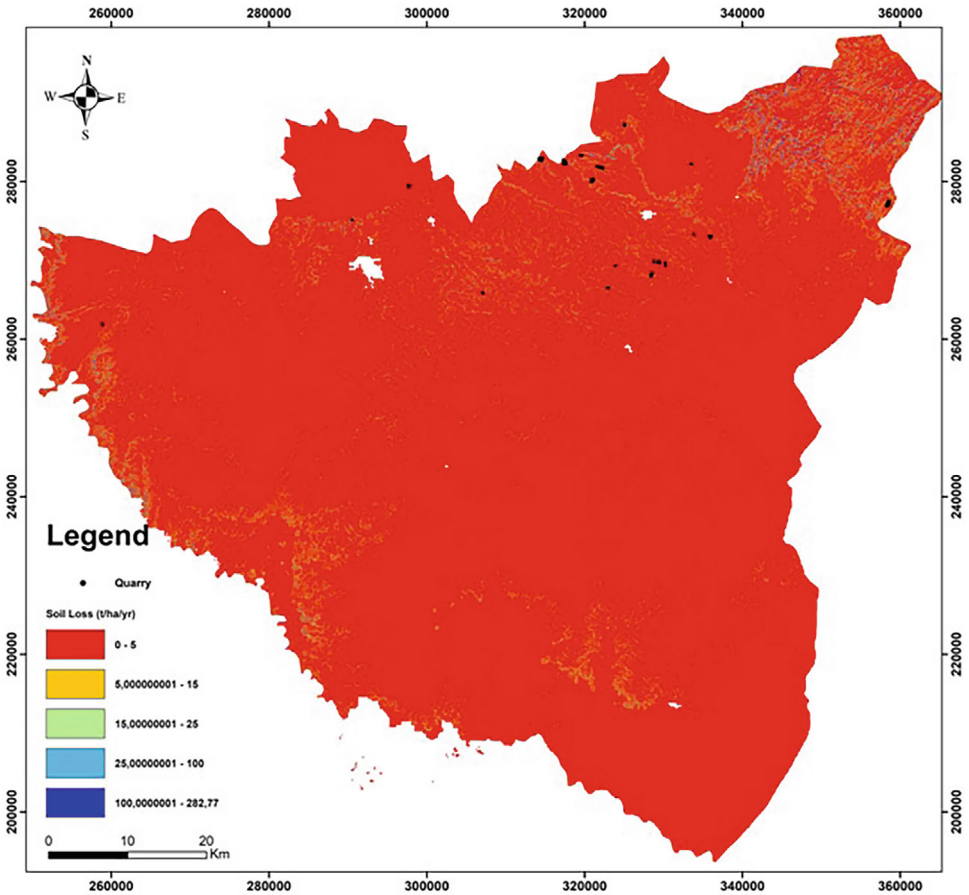


Fig. 1 Map of soil loss t/ha/yr

the authors of a study conducted in the Akreuch region (Taoufik et al. 2020) discovered a range of values between 9650 and 103,460 kg/ha/yr for various abandoned quarries. When comparing these findings to the results obtained in our own study, it is evident that these values are deemed significantly elevated due to the influence of soil properties, specifically the *K*-factor, while holding all other variables constant. In general, the Akreuch area has a significant degree of erodibility. A previous investigation (Bouslihim et al. 2020) was undertaken in the three watersheds located within the Settat-Ben Ahmed plateau using the SWAT model. The authors found a soil loss value that was comparable to the findings of our investigation, thereby affirming the reliability of the data obtained within the same geographical region.

4 Conclusions

The use of the RUSLE model demonstrates the gravity of soil erosion in abandoned quarries within the Settat province. As a result of variations in precipitation rates and topographical conditions, it was observed that 20 quarries exhibited a minor soil loss ranging from 0 to 5000 kg/ha/yr, while two quarries had a moderate soil loss ranging from 5000 to 15,000 kg/ha/yr. Hence, it is imperative to provide precedence to the rehabilitation or restoration of these quarries. This research also highlighted the advantages and simplicity associated with the use of GIS and remote sensing techniques in the context of soil loss modeling.

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Parallel Training of Hyperspectral Image Classification

Dorsaf Sellami, Amira Ayadi, Mongi Boulehmi, and Imed Riad Farah

Abstract

Hyperspectral remote sensing (HSRS) is widely used in various application areas. Hyperspectral images (HSI) are characterized by their large data volume and wide spectral dimension. These pose the main challenges in the analysis and classification of hyperspectral data which takes long training time. For time optimization and to facilitate the training of large volumes of data, new parallelism techniques based on deep learning have appeared named parallel and distributed training. Among the methods used in these techniques are data parallel (DP) and model parallel (MP). In our experimentation, we have taken the DP as the basic architecture to test their efficiency compared to the CPU and the GPU. Indian Pines (IP) is chosen as the hyperspectral dataset to test the efficiency of these strategies. We use 3D-CNN with principal component analysis (PCA) as the dimension reduction method. First, we process this dataset using CPU and GPU and then with data parallel. We obtain a proportional accuracy in the three tests. On the other hand, we observe a remarkable difference in the execution time. Using the GPU takes only 1 min and 20 s, whereas it takes about 30 min with the CPU. Then, with data parallelism, the execution takes 50 s. From these results, we notice that data parallelism gives the best result in terms of execution time.

Keywords

HSI · CPU · GPU · Data parallelism · Model parallelism

D. Sellami · A. Ayadi (✉) · I. R. Farah
RIADI Laboratory, National School of Computer Science, ENSI, Manouba, Tunisia
e-mail: amira.ayadi@fsjegj.rnu.tn

D. Sellami
e-mail: dorsaf.sellami@ensi-uma.tn

I. R. Farah
e-mail: imedriadh.farah@mse.uma.tn

M. Boulehmi
VPNC Laboratory, University of Legal Sciences, Economics and Management Sciences of Jendouba, University of Jendouba, Jendouba, Tunisia
e-mail: mongi.boulehmi@fsjegj.u-jendouba.tn

1 Introduction

HSI is one of the interesting images thanks to the development of remote sensing. HSI are used in the development of many applications in various domains. The HSI is generally represented by a data cube which presents the spatial and the spectral information (Ablin et al. 2020). HSI can be exploited in several ways, such as dimension reduction, unmixing and classification. HSI are characterized by their huge data volume and their high degree of band spectral redundancy. There are different ways used to reduce the spatial and spectral dimensions like PCA and ICA (Sellami and Farah 2018). The objective of HSI classification is to build a thematic map of hyperspectral data (Ayadi et al. 2021). The HSI classification has been studied by many researchers using supervised or unsupervised classification methods (Ablin et al. 2020; Golub and James 2014).

Conventional classification algorithms made more with multispectral images and do not adapt so to the analysis of HSI due to the huge volume of HSI (Li et al. 2019). There are two challenges handling HIS treatment: spectral dimensionality and spectral-spatial classification (Li et al. 2017). With the development of computer technologies, the HSI algorithms, previously running slowly, can now be very fast with a highly significant speedup achieved with a number of parallel and distributed implementations (Lv and Wang 2020) using multicore CPU (Slabaugh et al. 2010) or GPU (Yusuf and Alawneh 2018). The goal of this paper is to specify the performance of Multithreading data

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parallel compared to CPU and GPU in terms of accuracy and processing time. The remainder of this article is organized as follows. We discuss parallelism methods (data parallel (DP) and model parallel (MP)) and classification of hyperspectral data. Then we present our experimental results to improve the efficiency of the parallel data method. Finally, a conclusion and future works are given.

2 Parallelism Methods

Different tests performed show that traditional classification techniques and methods like Support Vector Machine (SVM), K-Nearest Neighbors (KNN), XGBoost are not very effective with this type of images, unlike deep learning (DL) models (Li et al. 2019). DL is a class of machine learning methods that excels in many tasks, especially in HSI classification.

However, current parallelized DL (Ben-Nun and Hoefler 2019) implementations can be poorly scalable due to the high parameter synchronization on the network. The use of the GPU allows more batches of data to be processed per unit time than CPUs, resulting in more frequent synchronization (Zhang et al. 2022). Modern parallelized DL models are running well NVIDIA GPUs.

Therefore, it is more efficient to parallelize these programs on different GPUs using the Parameter Server (PS) (Mayer and Jacobsen 2019) or Sufficient Factor Broadcast (SFB), moving the computation from the CPU to the GPU and performing memory copy operations (between Dynamic Random Access Memory (DRAM) and GPU) or communication operations (between GPUs) whenever necessary.

The methods when going to use to ensure parallelism are data parallelism and model parallelism. Results are compared with those of on a single CPU and GPU. The data parallelism consists of partitioning the data in the form of mini batches according to the existing GPUs or the multithreading where the model duplicates on all GPUs and each mini batch trains on a GPU in direct contact with the PS which calculates the backpropagation and aggregates the data.

Model parallelism consists in dividing the model on the GPUs and the data duplicate on the GPUs and train on a part of the model in direct contact with the PS which calculates the forward and backward propagation.

3 Experimentation Results

3.1 Hyperspectral Data Description and Methodology

The performance of the proposed method is verified using a conventional hyperspectral image dataset of IP. An IP was drawn by the Airborne Visible Infrared Imaging Spectrometer (AVIRIS) in 1992 and intercepted with a size of 145. The size of 145 is labeled for the hyperspectral image classification test. The spatial resolution of the image, which is generated by the spectral imager, is approximately 20 m. After removing the unnecessary bands, there are 200 bands left for experimental research. In the data set, there are 21,025 pixels, but, only 10,249 pixels are ground object pixels, and the remaining 10,776 pixels are background pixels. In the actual classification, these pixels must be eliminated. Since the intercepted area consists of crops, there are 16 classes in total (Fig. 1).

All experiments are conducted on an HP PALILION laptop equipped with a GTX 1650, AMD Ryzen 5 5600H CPU and 12 GB of RAM. After designing the network, we analyze various factors that affect the training process and model performance. These factors include input spatial window size, Dropout rate, learning rate, and the number of epochs. We work on a greedy search method to set the model optimal hyper-parameters. Following the different experiments, we set the learning rate to 0.01 (for a rate equal to 0.001, the accuracy equals 75% and for a value greater than 0.01 we fell in the case of overfitting) with a rate of decay of the weights of 1e−06 and a dropout rate of 40% which allows to reduce the overfitting when training the model. Then, the network weights are randomly initialized and trained using the SGD gradient

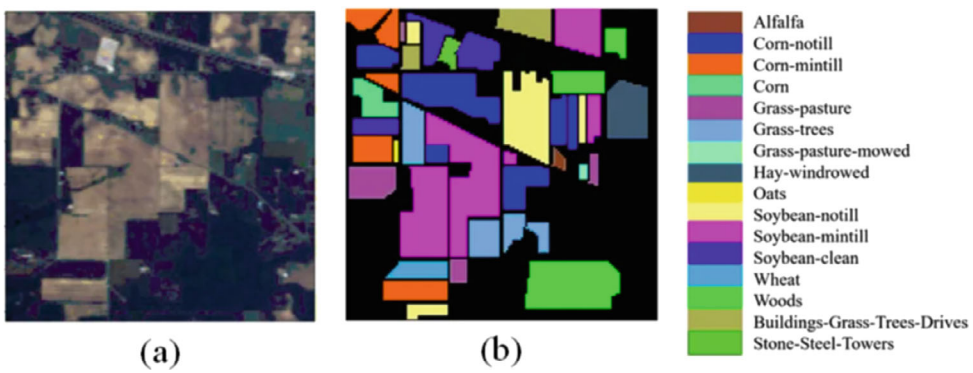


Fig. 1 Indian Pines scene. **a** Color composite image. **b** Ground truth classes. **c** Legend of crop types corresponding to the color codes in (b) (Yang et al. 2023)

descent optimization method, wich is faster than Adam in the parallelization setting. We employ cross-entropy as the loss function because this is a multiclass classification problem. Each experiment is run for 100 epochs. In order, to make a fair comparison, we extracted the same spatial dimension in 3D patches from the input volume for the dataset with the use of the PCA dimension reduction method (Tamani et al. 2019).

3.2 Classification Results

The results, in this paper, are presented and analyzed at the dataset level. We, first, present the accuracy per class. Then, we use the evaluation criteria of overall accuracy (OA), average accuracy (AA), and Kappa coefficient (Kappa) to evaluate the overall performance of the different approaches. The overall accuracy (OA) represents the percentage of correctly classified samples, while the average accuracy (AA) gives the average result of classification accuracies per class which are measured from the confusion matrix. The Kappa coefficient (Kappa) provides information of the agreement percentage between the classification map and the ground truth map. Finally, the training time of the model is expressed either in seconds (s) or minutes (min) (Fig. 2).

For our tests, we used the following three methods: CPU, GPU, and multithreading DP. Our approach uses DP has the best results in terms of accuracy or processing time. Training and test groups are randomly divided into 30% and 70% of the data, respectively. The percentage of OA, AA, and Kappa for the different methods is shown in Table 1. According to Table 1, the DP method outperforms all the compared methods while maintaining the minimum standard deviation. The hierarchical representation of a spectral-spatial 3D-CNN is the base of all the models which characterized its high accuracy due to its richness of input data and its complexity than 2D CNN.

4 Discussion

The quality of the classification map of the GPU and DP is much better than the other methods. Among GPU and DP methods, the map generated by DP in the small segment is better than those of the GPU. Figure 3 shows the proposed method's accuracy and loss convergence for 100 epochs of training and validation sets. The fast convergence of our method can be seen by the fact that it is achieved in about 50 epochs.

Table 1 displays the computational efficiency of the DP model in terms of training and testing time. Compared to the CPU and GPU, the proposed model is more efficient. The table of test results demonstrates the impact of spatial dimension on the DP model's performance.

In fact, the OA is 97.17% of CPU while it is 96.82% for the GPU and the DP's 98.82%. The GPU is the one with the lowest classification rate, with an OA of 96.82%. Furthermore, Table 1 displays the classification rates obtained for Pavia University. In fact, compared to CPU and GPU, the proposed DP also offers better results with an OA of 97.32%. Despite the slight decrease in performance of each model, the proposed method remains able to outperform the other methods in all cases, as shown by the experiment results.

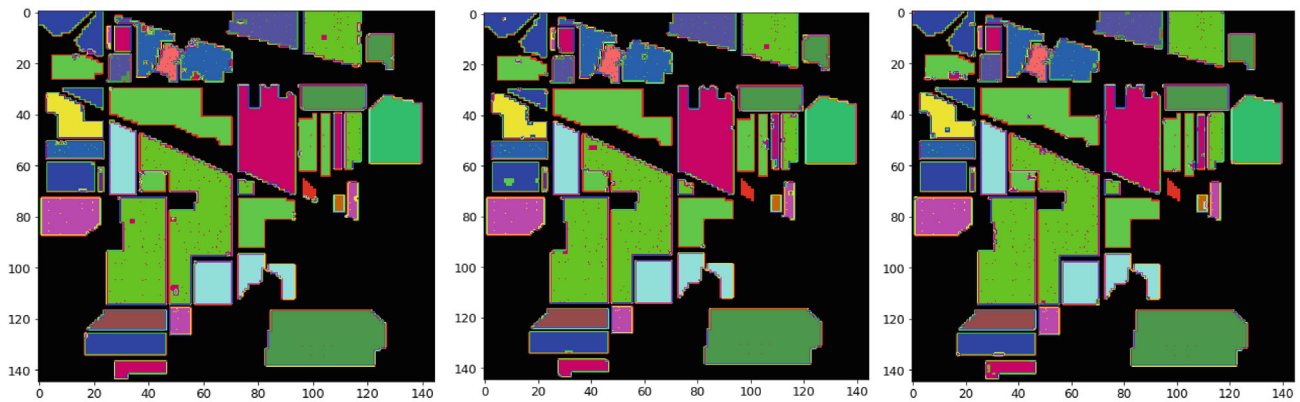


Fig. 2 Classification map for IP using (1) CPU, (2) GPU, (3) DP

Table 1 Tests results

Results	CPU	GPU	DP
AA	98.53	98.07	98.82
OA	97.17	96.82	97.32
Kappa	98.33	97.80	98.66
Time	30 min	1 min, 20 s	50 s

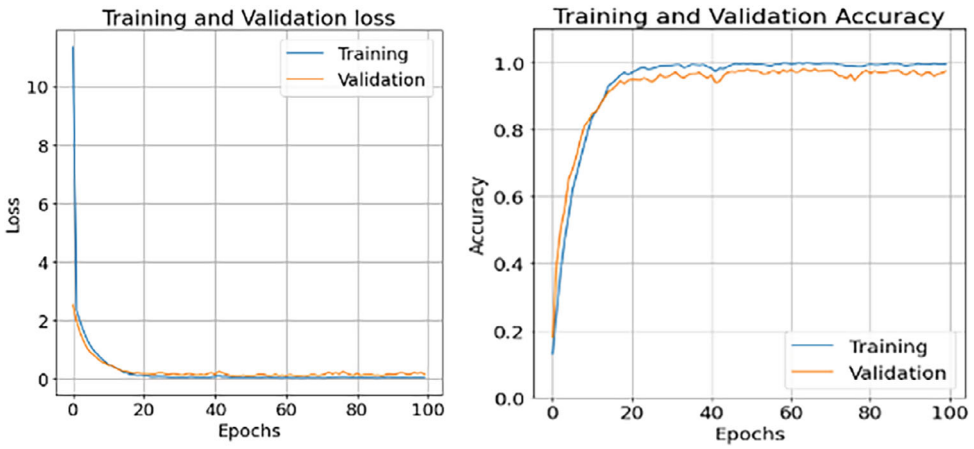


Fig. 3 Accuracy and loss convergence versus epochs over the IP data set with DP

5 Conclusion

With ever-increasing data sizes, processing HSI requires significant computing resources. The developments cited throughout this paper will have the effect of reducing this pressure by reducing the time of calculations necessary to estimate abundance maps. The experimentation proves the efficiency of the use of the DP as a method more suitable for intensive and hard calculations. The results found are primary; our future work is to compare the following results with other types of parallelism: the model, pipeline, and hybrid.

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Evaluating GIS-MCDA-Based Soil Erosion Susceptibility Model from Very-High-Resolution Data Through Public Perception Analysis—Sali (Croatia)

Ante Šiljeg, Silvija Šiljeg, Rina Milošević, Fran Domazetović, Ivan Marić, and Lovre Panđa

Abstract

Soil erosion has become one of the critical issues encompassed within the global environmental crisis. The problem of soil loss is particularly pronounced within small islands due to the limited agricultural land area. Local perception of the problem affects the way communities organize and exploit the land resource and, therefore is considered as an important parameter in erosion research. To investigate the process of soil erosion in the settlement of Sali (Dugi otok, Croatia), we combined geospatial technology (GST) and a public perception survey. A public survey was conducted among the local population (18+ years). The erosion susceptibility model was generated using the multi-criteria GIS decision analysis (GIS-MCDA). The process was performed using 10 criteria derived from models of very-high resolution. The created model has five classes from 1 (very low) to 5 (very high). The model accuracy was validated using ROC curves based on field-determined soil erosion traces (AUC value is 0.873). The erosion susceptibility model was evaluated using the conducted public survey, where the survey results showed that the respondents do not consider erosion a significant threat. Such opposite local perception could result from the declining use of agricultural areas.

Keywords

Soil erosion susceptibility (SES) · GIS-MCDA · Public perception

1 Introduction

Soil erosion is a gradual degradation and denudation of surface soil layers, which globally affects a decline in agricultural productivity and substantial costs to the agricultural community (Borrelli et al. 2017; Montanarella 2015; Panagos et al. 2015b). Loss of nutrients and organic matter through eroded sediment reduces soil fertility, increasing the deposit of eroded material at the sea bottom (Borrelli et al. 2017; Montanarella 2015; Panagos et al. 2015b). Nutrient loss in this way results in huge financial losses and causes marine pollution (Ning et al. 2006). In the European Union (EU), it is recognized as the primary threat to existing soil deposits, which affects stability, agricultural production, and drinking water supply (Panagos et al. 2015a, 2020). The Mediterranean region has the highest overall rates of erosion in the EU (Ferreira et al. 2022; Panagos et al. 2020), lowest soil organic matter concentrations (Aguilera et al. 2013; Ferreira et al. 2022), salinization problems (Ferreira et al. 2022), and a high abundance of shallow soils (Ferreira et al. 2022; Lagacherie et al. 2018) accompanied by increasing human pressures (Ferreira et al. 2022; Guittonny-Philippe et al. 2014) and climate change vulnerability (Ferreira et al. 2022; Shukla et al. 2019). Considering the estimates of the average rate of soil loss, Croatia's territory is one of the EU's moderately endangered regions (Ferreira et al. 2022). Still, coastal parts of Croatia are significantly sensitive and vulnerable to soil erosion and have high or very high soil loss rates. Soil loss is particularly pronounced in small islands due to limited agricultural land area. Conversation strategies and soil management demand the creation of soil erosion models (Borrelli et al. 2021; Panagos et al. 2015b). Furthermore, locals' perception of the problem affects how communities exploit the land resource and, is essential to understand mitigation behavior. This research was part of the Interreg—

A. Šiljeg · S. Šiljeg · F. Domazetović · I. Marić · L. Panđa
Department of Geography, University of Zadar, Zadar, Croatia

R. Milošević (✉)
Department of Ecology, Agronomy and Aquaculture, University of Zadar, Zadar, Croatia
e-mail: rmilosev@unizd.hr

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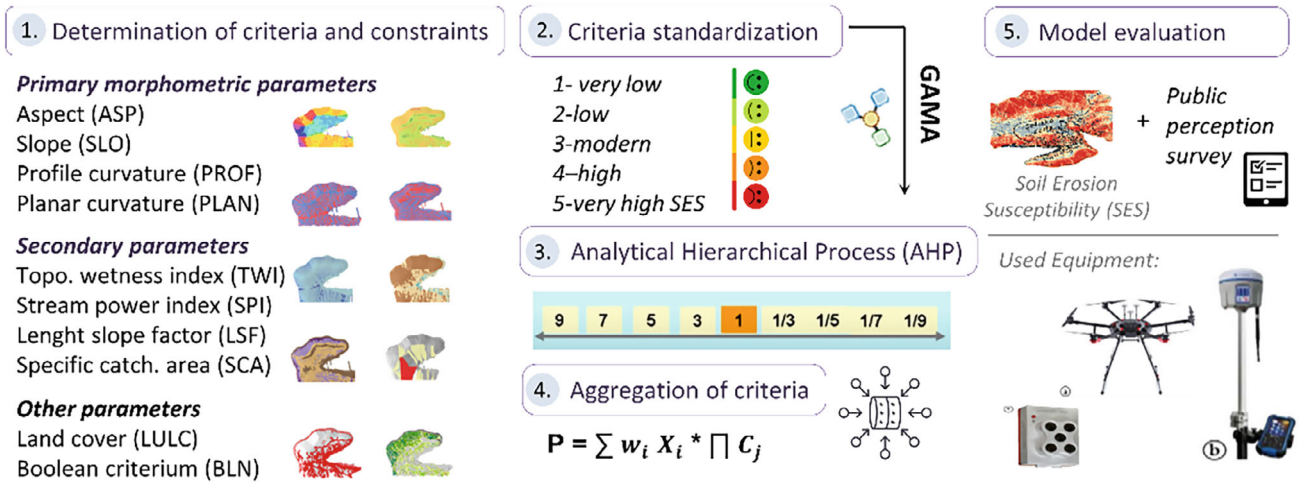


Fig. 1 Soil erosion susceptibility (SES) model

Protecting the Enclosed Parts of the Sea in Adriatic from Pollution (PEPSEA) project. The level of research is the drainage basin (235 ha) of the Sali and Saščica bays (Dugi otok, Croatia). This area has an average soil loss between 5 and 10 tonnes per hectare annually (Panagos et al. 2015a). In this study, we have integrated a public perception survey with geospatial technology (GST) to compare lay people's perception of soil erosion threat, with the soil erosion susceptibility (SES) model, generated by multi-criteria GIS decision analysis (GIS-MCDA).

2 Materials and Methods

2.1 Soil Erosion Perception (SES) Analysis

The public survey was conducted to estimate the likelihood of 33 potential environmental threats, including soil erosion. The questionnaire consists of four sections and altogether 38 questions. The linear scale was used to express the risk level from soil erosion (1—very low, 5—very high). Furthermore, the residents' opinions toward the locale's soil quality, and the sea's purity were examined. The door-to-door survey was conducted in June 2020 by three experienced interviewers. The survey involved 38 respondents, i.e., 5% of the total population of the settlement. Special care was taken to cover households in all parts of the settlement, especially in the potentially vulnerability zones. One adult (18+) per household was interviewed and the sample was stratified.

2.2 GIS-MCDA Soil Erosion Susceptibility (SES) Model

The GIS-based multi-criteria decision analysis (GIS-MCDA) was used to create the SES model based on ten criteria grouped in clusters: primary morphometric (slope (SLO), aspect (ASP), profile (PROF), and planar (PLAN) curvature), secondary morphometric (topographic wetness index (TWI), stream power index (SPI), length slope factor (LSF), specific catchment area (WAT)), and other (land cover (LULC), Boolean (BLN)). SES criteria were generated from the very-high-resolution data, primarily from a digital terrain model (DTM), created from the aerial images collected by drones (Matrice 600 Pro and Matrice 210 RTK V2). Double grid missions were used with 80% overlapping, and the flight altitude was set to 200 m with the terrain tracking option. LULC is created from multispectral orthomosaic (Red Edge-Mica Sense MX camera) applying the GEOBIA method. All criteria, except Boolean (0 or 1) are standardized on a scale from 1 to 5 (1—very low, 5—very high SES). The GAMA method was used to simplify the process (Faričić et al. 2010). Analytical hierarchical process (AHP) ranks criteria depending on their importance, i.e., the level of influence on the SES. The SLO has the highest weighting coefficients (0.299) while the SCA has the lowest (0.019). The model is validated using the ROC curves and Area Under the Curve (AUC) values based on the field-determined erosion traces (Fig. 1).

3 Results and Discussion

The analysis of surveys showed that 60.50% of respondents ($n = 38$) have estimated SES as very low (1) or low (2), while only 7.90% consider soil erosion in the settlement of

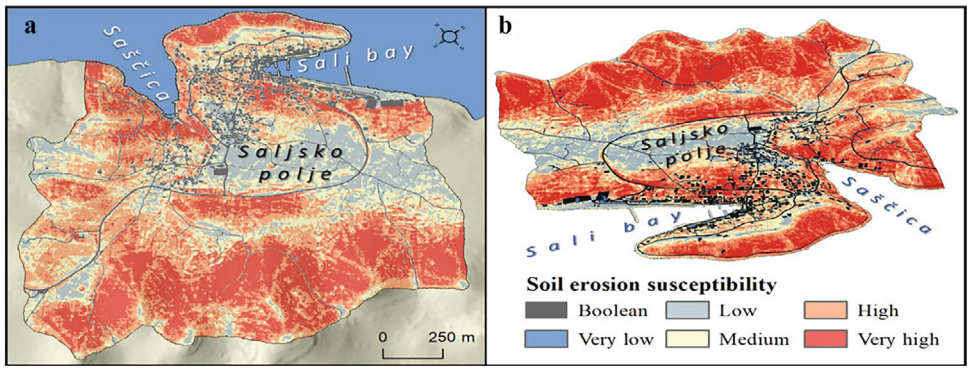


Fig. 2 Created GIS-MCDA model of soil erosion susceptibility (**a** 2D; **b** 3D model)

Sali as high (4) or very high (5). Both soil quality and sea purity around the settlement respondents are rated as low (2.89) with a standard deviation of 0.77 (soil) and 0.88 (sea). Contrarily to public perception, the SES model showed that in the drainage basin of Sali are prevalent high (4) and very high (5) susceptibility zones, constituting slightly over 55% of the research area. In line with that, zones of low (1) and very low (2) SES only comprise 13.53% of the entire area. Moderately susceptible is 31.03% of Sali. The SES accuracy is very high with an AUC of 0.873. Very high SES zones are located on the southern island ridge due to steep slopes. Steep slopes are also dominant on the N and NW slopes of Saščica Bay, where a mud flood occurred during the heavy rains in 2017. The inner parts of the settlement have a low SES. There is located botanical reserve, Saljsko Polje, with an olive grove protected as a special feature of the landscape. In the narrow coastal zone, where concreting dominates, the SES level is generally low. This is especially pronounced in the eastern parts of Sali Bay around the "Mardešić" fish processing factory. Residential objects are also in low SES zones. This contrast between SES and public perception is possibly affected by the process of depopulation and decreased utilization of agricultural land, which is typical for Croatian islands (Faričić et al. 2010). In the past, residents built dry stone walls to protect arable land (Fig. 2).

4 Conclusion

This study has shown that the SES perception is dominantly low and very low (1 and 2). Residents do not consider soil erosion a significant threat because most agricultural land is in the inner low-incline parts of the settlement. Still, as a defense against erosion in the past, residents constructed dry stone walls with multiple functions. Furthermore, it is essential to emphasize that soil erosion is a gradual process, which is usually not easily noticeable to the general population until it causes drastic changes to the land. Opposite to residents' opinion, the SES model provided different viewpoints and showed a slight prevalence of high (4) and very high (5) SES zones in the total area, mainly located at steeper slopes of island ridge and Saščica Bay. Residential buildings and most agricultural lands are located in the low SES zone. In the future, we advise adopting digital surface model (DSM) rather than DTM for SES modeling, which would incorporate dry stone walls in the study. Additionally, measuring the amount of eroded material in the sea can be useful for a better understanding of coastal soil erosion.

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Environmental Impacts of Natural Hazards and Environmental Risk Assessment

Flood Frequency Analysis for Jukskei River Catchment

Jake Thuketane, Rebecca Alowo, and German Nkhonjera

Abstract

Floods are environmental impacts of natural hazards and as such risk assessment of flood events is necessary because it can help with water resource management, it can offer protection from potential flood damage, and the stream flow estimation has a significant financial impact. For 2, 5, 10, 25, 50, 100 and 200 return periods, peak discharge values are estimated using four widely used statistical methods: normal distribution, Gumbel distribution, log-Pearson type III (LP III) and log-normal distribution method. The study uses annual discharge data from Neitgedacht station on the Jukskei River over a 56-year period (1966–2021). In terms of the criteria for selecting the best distributions, this was based on results, where Gumbel's and log-normal's laws judged to be better, The log-normal deviates the most from the other methods during the 25 years return period when the values only begin to vary widely from one another. The method with the highest estimated flood values was the log-normal distribution, with the highest value of 1382.481 m^3/s for the 200 years return period. The log-Pearson type III distribution estimated the lowest flood values, followed by the normal distribution and then Gumbel distribution. Due to their maximum flood values, the log-normal distribution and Gumbel distribution are the preferable distributions. Results indicate that compared to normal and LP III, log-normal distribution and Gumbel distribution provide better flow discharge values. Given the environment and location in which the Jukskei River is located, it is recommended that that those living in informal settlements, especially those that have been constructed below the 1:100-year flood line, relocate to a safer area to safeguard them from flooding.

Keywords

Flood · Log-Pearson type III · Log-normal distribution · Flood frequency analysis

1 Introduction

Various statistical methods are established for the estimation of peak discharge values at the Neitgedacht gauging station in the Jukskei River basin, South Africa (Sanyal and Lu 2017). The impact and risk of a flood on a specific area are assessed using a broad process known as a flood risk assessment (Bates et al. 2018). Flooding hazards are divided into three categories: primary hazards that occur because of contact with water. Floodwaters can transport more sediment as suspended loads due to their rapid velocity (Izinyon et al. 2017). When floodwaters recede, the velocity is usually significantly reduced, and sediment is deposited (Bates et al. 2018). After the floodwaters recede, everything, including the interiors of buildings, is usually covered in a thick layer of stream-deposited mud (Izinyon et al. 2017). Secondary effects that occur because of flooding, such as service disruption, health impacts such as famine and disease and tertiary effects are the long-term effects. Long-term effects such as the location of river channels being altered, and new channels emerging, leaving the old ones dry (Brewitt and Colwyn 2020). Floods have far-reaching consequences, including disease epidemics caused by floods. Infectious disease outbreaks are widespread, especially in developing countries. Malaria, typhoid and cholera outbreaks are also prevalent after floods in tropical nations (Izinyon et al. 2019).

J. Thuketane · R. Alowo (✉) · G. Nkhonjera
University of Johannesburg, Johannesburg, South Africa
e-mail: ralowo@uj.ac.za

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2 Literature Review—Gaps Within Flood Frequency Analysis Studies Done in Jukskei River

A flood frequency analysis study was carried out in Jukskei River, whose main objective was to determine whether using sensor web technologies to predict and monitor floods in Alexandra Township is feasible (Engineering Group 2024). The two main sources of information used are online SRTM DEM data and historical rainfall data (Ali et al. 2016). The Jukskei River was described using the SRTM DEM that had been hydrologically adjusted (Foudi et al. 2015). In Fig. 1, to calibrate and validate the purposes of calibrating and validating flood modelling, historical rainfall data was utilized (Solin and Skubincan 2014). Three different forms of data are used by the HEC-HMS 3.5 (a hydrological modelling software): grid data, time-series data and paired data (Cutter 2021). Whether from local or remote sensors, observations and measurements provide the data needed by the sensor web enablement (SWE) components.

The existing gap with this flood frequency analysis study in the Jukskei River and many others before is that the model's ability to predict peak discharge cannot be regarded as credible. It's important to address this gap because there is a need to develop solutions to lessen flood damage in the Jukskei River catchment, especially in the Alexandra Township informal settlements of the Setswetla Squatter Camp. As a result, this research has attempted to address this gap.

3 Materials and Methods

3.1 Research Design

This study used a quantitative approach. Secondary data obtained from the Department of Water and Sanitation (DWS) was used in this study. Four statistical techniques—Gumbel's Distribution, normal distribution, log-normal distribution and log-Pearson Type III distribution—were used to assess the discharge data. The discharge data was then analysed, and graphs were subsequently created. Plots of peak flood values against predetermined return periods of (5, 10, 20, 25, 50, 100 and 200) were made. To show the trend of the peak flood values, graphs were drawn. Microsoft Excel was used for all calculations and graphing.

3.2 Data Collection

Precisely/specifically, the data used in this study are annual maximum discharge values recorded from the A2H023-Nietgedacht station. The discharge data was provided by the DWS. The data provided spans from 1966 to 2021. The 56 years old data is used to ensure the credibility of the analysis carried out. As this is annual data, the information is limited up to the year 2021; 2022 has not yet ended. The A2H023 station was chosen from all the other three stations that were provided because it is the closest to the river flowing through the Alexandra Township informal settlements. Several databases were accessed. These included: gauged precipitation information, from the South African

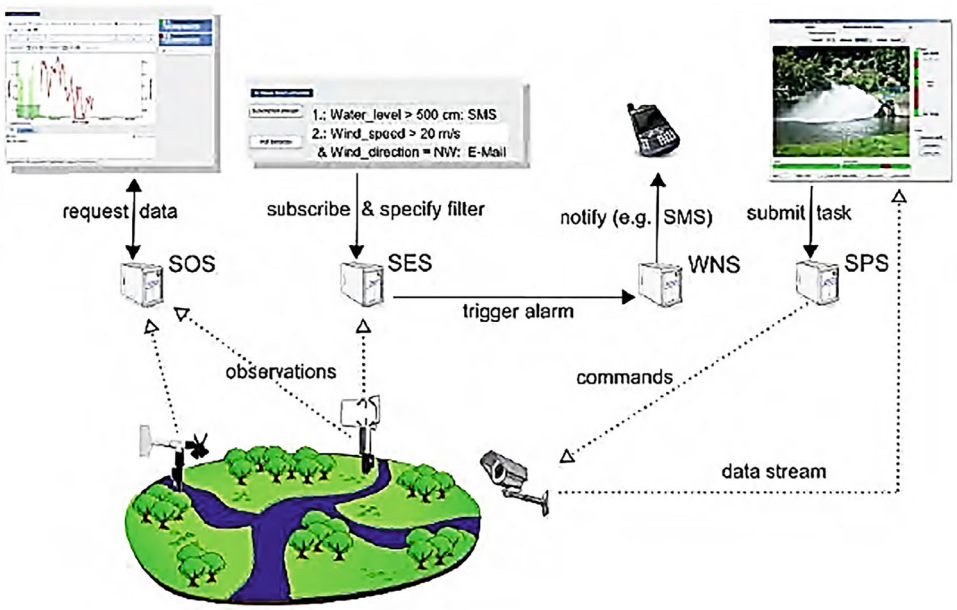


Fig. 1 Application of the SWE components to hydrology. *Source* UNISDR (2019). Available from: http://www.mdpi.com/1424-8220/11/3/2652

Weather Service database, water sheets, neighbourhood, and area regions and water use management systems.

3.3 Statistical Analysis Techniques and Modelling Approaches Used in the Study

For the analysis of flood frequency using four statistical methods, the maximum discharge data of the Jukskei River from 1966 to 2021 (56 years of flood data) were taken into consideration. To prepare for the analysis using the methods, data on annual peak floods was compiled between 1966 and 2021. The letter (m) represents the rankings. The log of each discharge value is required to be calculated for the log-normal distribution and log-Pearson type III distribution. In this case, it is given as $Z = \log x$, x being the discharge data. After $(Z - \overline{Z})2$ and $(Z - \overline{Z})3$ were calculated with $\overline{Z}$ being the mean value of Z. The following formula was used to determine the return period T:

$$T = (n + 0.2)/(m - 0.4) \quad (1)$$

where

n the number of values in the data set
m the rank.

To complete the table, the exceedance probability of each discharge using the formula:

$$P = 1/T \quad (2)$$

For the normal distribution and Gumbel Method, the mean and standard deviation were computed from the given annual discharge data. Excel was used to calculate the method.

4 Results and Discussion

4.1 Comparison of Flood Values

The results presented in Table 1 and graph in Fig. 2, are a comparison of the estimated flood values for the four statistical methods. The methods predicted peak flood values that, as shown by the plotted graph, do not differ significantly

Table 1 Comparison of results obtained

T	Gumble (Qe)	LP type III (Qe)	LN distribution (Qe)	N distribution (Qe)
2	265.2002956	281.8716209	242.3365341	287.4575179
5	402.3858624	422.6464451	430.0984253	407.6321613
10	493.2144459	485.7336161	578.8140692	469.8402121
25	607.9766019	539.1099912	794.8840785	536.2897208
50	693.1137251	565.4240383	973.2820757	578.7043009
100	777.6222091	583.6520409	1167.831431	616.8774229
200	861.8223359	596.5032376	1382.481300	653.2229063

Source Researchers

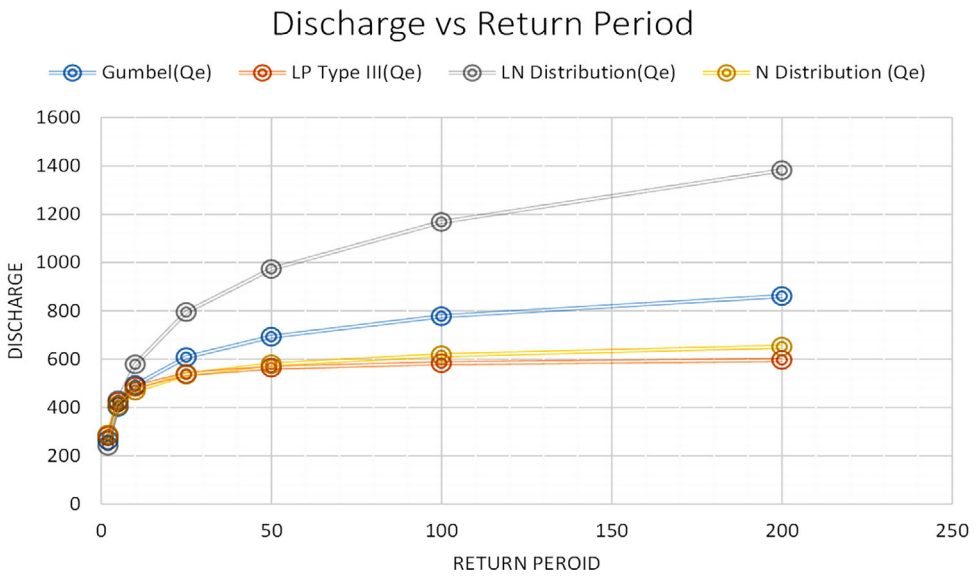


Fig. 2 Plotted graph of the estimated flood values for four statistical methods. *Source* Researchers

from one another. The Log-Normal deviates the most from the other methods during the 25 years return period when the values only begin to vary widely from one another. The method with the highest estimated flood values was the log-normal distribution, with the highest value of 1382.481 m^3/s for the 200 years return period. The log-Pearson type III distribution estimated the lowest flood values, followed by the normal distribution and then Gumbel distribution.

Due to their maximum flood values, the log-normal distribution and Gumbel distribution are the preferable distributions to consider given the results shown above. Both estimated peak flood values for the 200 years return period are greater than the highest recorded discharge value from the station which is 729,152 m^3/s.

4.2 Risky of Occurrence

Table 2 shows the key relationships. Tables 2 and 3 present/show that flood at return periods, 2, 5 and 10 are possible to occur whilst return periods 25, 50, 100 and 200 are rare to occur.

Table 2 Relationship between the return period, the annual exceedance probability, and the annual non-exceedance probability for any single given year

Return period (years)	*P* (annual exceedance probability) 1/return period	1 − *P* (annual non-exceedance probability
2	0.50 (50%)	0.50
5	0.20 (20%)	0.80
10	0.10 (10%)	0.90
25	0.04 (4%)	0.96
50	1.02 (2%)	0.98
100	0.01 (1%)	0.99

Source Researchers

Table 3 Probability of occurrence of the floods

Occurrence value (OV)		Probability of occurrence	
Rating	Value	Percentage	Description
Not present	0	0	Item/operation is not present in lab
Rare	1	1–10	Rare
Possible	2	10–50	Possible
Likely	3	50–90	Likely
Almost certain to certain	4	90–100	Almost certain to certain

Source Researchers

5 Conclusion and Recommendations

The maximum and minimum discharges are discovered at 200 year and two years return periods, respectively, based on annual discharge values over the previous 56 years. The graphs' shapes are typical of nature, and they do not intersect with one another. Gumbel max often produces the most flood flow, whilst regular distribution produces the lowest discharge. In this instance, the predictions for the peak flood discharge were highest for the log-normal distribution and lowest for the log-Pearson type III distribution. Hence, the log-normal distribution method is preferred to estimate peak flood values in this study. The goal of the research in other areas was to develop solutions to lessen flood damage in the Jukskei River Catchment, especially in the Alexandra Township informal settlements (Setswetla Squatter Camp). Therefore, a major indicator of hydrological modelling and development for water resources engineering is the calculation of peak discharge values. For data gathering and future accurate flood analysis, the Jukskei River needs more gauging stations. Given the environment and location in which the Jukskei River is located, it is recommended that the river's flood potential be evaluated using additional gauging stations. It is also recommended that those living in informal settlements, especially those that have been constructed below the 1:100-year flood line, relocate to a safer area to safeguard them from flooding, after they have relocated, a structure that can limit risks for those who live next to the stream can be built using the peak flood values. This is the implication of this research.

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Managing Land to Reduce Sediment Yield in the Fincha Watershed, Ethiopia

Motuma Shiferaw Regasa and Michael Nones

Abstract

Like other African countries, Ethiopia is experiencing serious environmental issues such as soil erosion, which significantly lowers the country's productivity and causes poverty and food insecurity. Previous research investigated the impact of Land Use Land Cover (LULC) on soil erosion, but very few scholars focused on predicting future trends. To address this knowledge gap, in the present study, LULC conditions for 2050 are predicted using the land change modeller (LCM) tool, and then the soil and water assessment tool (SWAT) was applied to quantify the risk of soil loss and evaluate the efficacy of best management practices (BMPs) in reducing erosion and sediment outputs. The research was performed using data collected from the Ethiopian Ministry of Water, Irrigation and Energy Department (MOWE), combined with LULC maps prepared based on Landsat satellite imagery. Maps depicting the historical trends observed in the last three decades were used to predict the 2050 conditions, taking advantage of LCM potential. To investigate possible solutions for reducing soil loss, two commonly used management practices (filter strip and terracing) were implemented in SWAT and their effects were investigated by comparison with the baseline scenario. The SWAT model pointed out that, before applying these practices, the estimated 2050 mean annual sediment yield across the Fincha watershed is 46.20 tons ha^{-1}. At the same time, by applying filter strip and terracing, the simulated annual sediment yield is expected to be 18.60 and 11.17 tons ha^{-1}, respectively. This means the proposed management practices (MP) are effective in reducing soil erosion at the watershed scale, having an efficiency of about 60% and 76%, respectively. It is worth noticing that the effectiveness of these practices varies significantly across the sub-watersheds. This study demonstrates the effectiveness of MP in reducing soil erosion at both the watershed and the sub-watershed scales and can be used for planning future land management policies, aiming to reduce the expected soil loss, assuring a sustainable development of the Fincha region.

Keywords

Ethiopia · Fincha watershed · Land Use Land Cover · Land change modeller · SWAT

1 Introduction

Across Africa, increasing urbanization and consequent large-scale deforestation have resulted in soil erosion and land degradation, particularly in Ethiopia's Highlands. According to previous studies (Leta et al. 2021; Regasa and Nones 2023), this region has extremely high soil erosion rates as a result of irresponsible land management, overgrazing, deforestation and excessive agricultural production. Soil erosion and sediment deposition can cause problems, using impoverished or depleted soil, decreasing water retention or soil moisture and exacerbating natural hazards (Dibaba et al. 2021). To counteract these negative effects, a major effort should be made to reduce soil erosion across Ethiopian watersheds.

The physical, process-based soil and water assessment tool (SWAT) was used in the Fincha watershed was applied to quantify the quantity of soil loss and evaluate the efficacy of best management practices (BMPs) in reducing erosion and sediment outputs. The SWAT model was chosen for its accuracy in replicating both the location and spatial variability of water and sediment flows. Multiple factors, such as soil, climate, slope steepness and soil and water manage-

M. S. Regasa (✉) · M. Nones
Department of Hydrology and Hydrodynamics, Institute of Geophysics Polish Academy of Sciences, Warsaw, Poland
e-mail: mregasa@igf.edu.pl

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ment scenarios, can be investigated via the SWAT model, to eventually locate areas exposed to high erosion risk, and prioritize BMPs. Such investigations can considerably assist decision-makers, stakeholders and practitioners in developing adequate land management policies and plans, to allow for a more suitable development of the Fincha watershed.

2 Material and Methods

2.1 Study Area

The Fincha watershed is located about 300 km north of Addis Abeba in Ethiopia's Horroo Guduruu Wallaggaa Oromiyaa regional state, Upper Blue Nile Basin, between latitudes 9° 9′ 53″ and 10° 1′ 00″ north and longitudes 37° 00′ 25″ and 37° 33′ 17″ east (Fig. 1). The area is essential for both national and international hydro-politics because it serves as the downstream connection to the Nile basin which goes crossing the neighbouring countries (Regasa and Nones 2023).

2.2 Input Data

The SWAT model requires the integration of spatial and temporal data for analyzing management techniques and determining the spatial distribution of soil loss. LULC maps were created based on satellite imagery (Regasa and Nones 2023), while soil maps were received from the National Metrological Agency (NMA), Ethiopia, and Digital Elevation Models (DEM) were obtained from the Ministry of Water, Irrigation and Energy (MOWE), Ethiopia. The temporal datasets, gathered from MOWE as well, comprise information on stream flow and climatic data. Soil, LULC and weather data, along with the digital elevation model (DEM) obtained from USGS, were used to build, calibrate and validate the SWAT model.

The effectiveness of the model was evaluated by looking coefficient of determination, the Nash–Sutcliffe simulation efficiency and per cent bias. The selected sensitivity parameter was evaluated using the *p*-value and *t*-stat value based on earlier studies (Regasa and Nones 2023).

2.3 Scenarios for Land Management Practices

Maps depicting the historical trends observed in the last three decades were used to predict the 2050 conditions, taking advantage of the LCM potential (Tarawally et al. 2019). The SWAT model was then used to investigate multiple scenarios that account for the influence of BMPs on

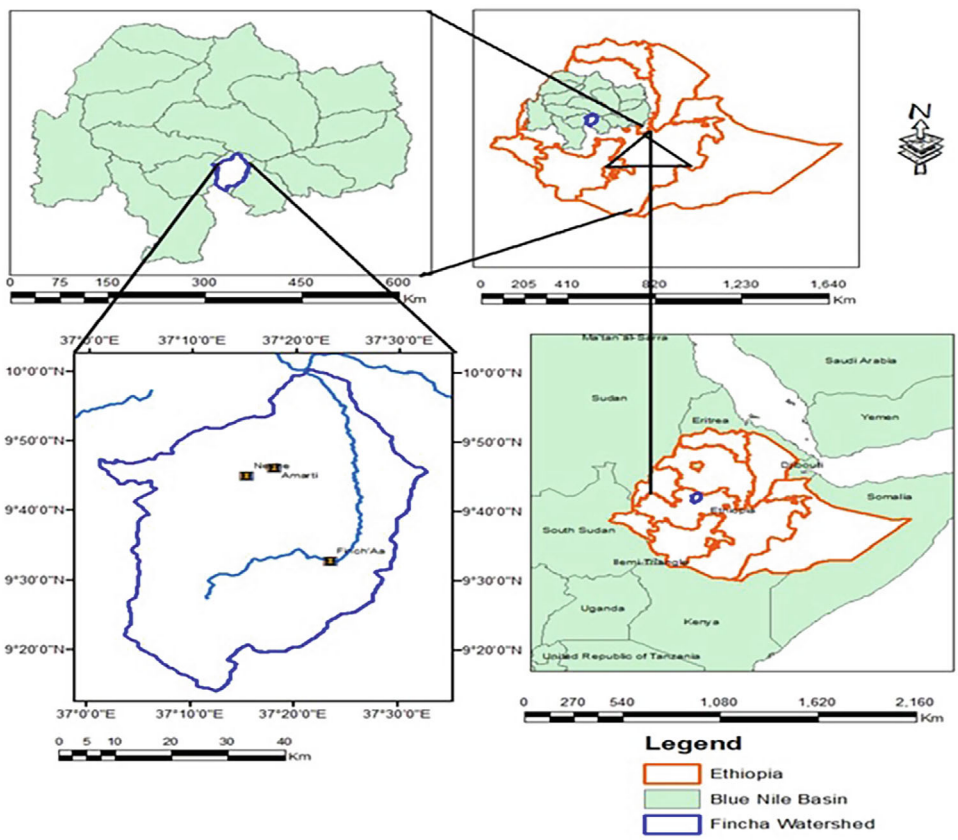


Fig. 1 Fincha watershed location, Oromiyaa regional state, Ethiopia

sediment reduction in comparison to the baseline scenario (i.e. no management practices). Two management techniques, namely filter strips, and terracing, were considered and simulated in SWAT by changing modelling parameters such as the curve number, slope length, erosion control practice factor and filter strip width.

To simulate the impact of filter strips on sediment trapping, a filter width of 5 m was assumed. Similar studies in the Ethiopian highlands, such as those by Nadew et al. (2018) on the Guder watershed in the Blue Nile Basin and Tsegaye and Bharti (2022) on the Rib watershed in Ethiopia, aided in determining this value. Following literature evidence (Dibaba et al. 2021; Dibaba and Ebsa 2021), to simulate slope terracing in agricultural areas, the management support practice factor was set to 0.32, the length of the slope was reduced by 50% with respect to the baseline scenario.

To determine the BMP effectiveness, Eq. (1) was applied.

$$\text{BMP effectiveness } [\%] = 100 \cdot \frac{(SY_{BL} - SY_{MP})}{SY_{BL}} \quad (1)$$

where SY^{MP}—sediment yield [tons ha^{-1} $year^{-1}$] following the implementation of the BMP and SY_{BL}—baseline sediment yield [tons ha^{-1} $year^{-1}$].

3 Results and Discussion

Implementing BMPs is critical in managing highly-anthropized watersheds, as this can help in reducing soil erosion and sediment yield, both of which affect water bodies.

Figure 2 depicts the sediment yield calculated for the 2050 scenarios (Fig. 2a), as well as the reduction of sediment yield for the two selected BMPs (Fig. 2b).

According to the observed results, the entire Fincha watershed is anticipated to have a sediment production of 53.98 tons ha^{-1} $year^{-1}$ in 2050, if no management practices will be implemented. Filter strip and terracing were effective in greatly reducing it, achieving 22.25 and 12.78 tons ha^{-1} $year^{-1}$, respectively. This corresponds to a watershed-wide average reduction of 60 and 76% reduction compared to the baseline scenario. for each According to these findings, the terracing method is more effective in reducing soil erosion rate than the filter strip method at the watershed scale, but, depending on the sub-watershed conditions, it might happen that the filter strip will be more effective.

Even if the average annual sediment output of sub-watersheds upstream of the Fincha Dam is lower than the average annual sediment yield of the entire watershed, the sediment volume entering the reservoir annually remains relatively high. In particular, 3.4, 0.89, and 1.1 million tons $year^{-1}$ for baseline, filter strip and terracing, respectively, can reach the Fincha Dam lake (Fig. 3), which has a storage capacity of 660 million m^3.

Despite the uncertainties associated with the lack of detailed information on the hydro-morphological characteristics of all the investigated sub-watersheds (Bekele and Gemi 2021), the current results indicated a similar efficiency in reducing sediment yield erosion rate when compared to previous model simulations performed in the same area (Regasa and Nones 2023) or similar regions. For example, Tesfahunegn et al. (2013) revealed that BMPs can reduce sediment yield in Ethiopian catchments by up to 72% when compared to the baseline (i.e., no management practices) situation. The testing of BMPs for the watershed is used to reduce soil erosion rate below tolerable soil erosion rate for crop production (11 tons ha^{-1} $year^{-1}$), as stated by Dibaba et al. (2021).

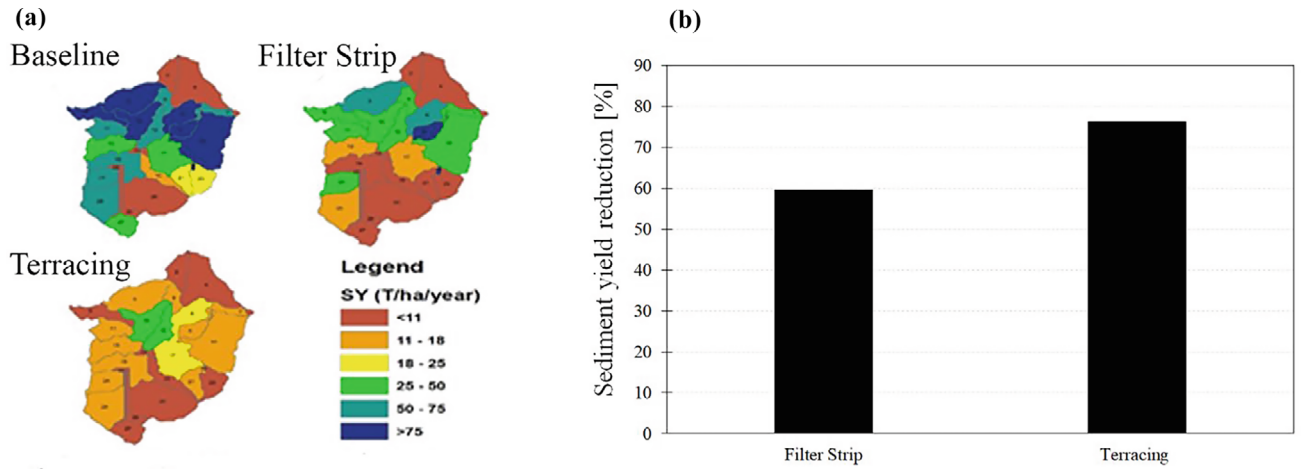


Fig. 2 **a** Sediment yield in 2050. Maps referring to baseline, filter strip and terracing scenarios. **b** Effectiveness of both BMPs in the Fincha watershed

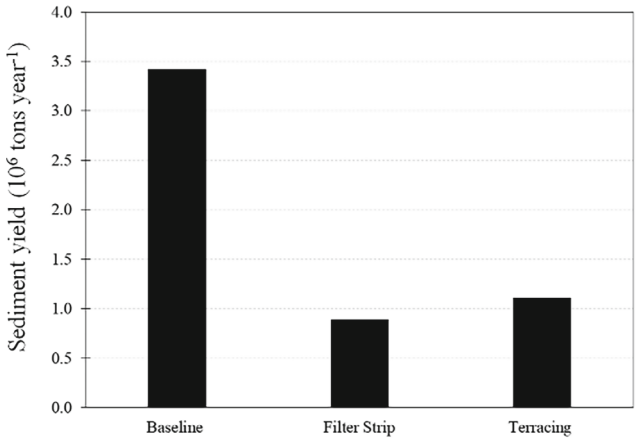


Fig. 3 Annual sediment yield entering the Fincha Dam reservoir from the sub-watersheds located upstream with and without testing of the selected BMPs

In a country like Ethiopia where financial constraints are prevalent, generally it is not possible to carry out watershed management activities or soil and water conservation measures over the entire watershed at the same time. Therefore, priority should be given to sub-watersheds at high risk of soil erosion or more vulnerable to promote sustainable development of the basin's land and water resources. Such prioritization can be derived from studies similar to the one presented here.

4 Conclusions

Soil erosion is a major issue in countries where agriculture dominates the economy, because it can significantly reduce agricultural output. This study looked at the impacts of two BMPs on soil erosion and the output of related sediments in Ethiopia's Fincha watershed. The watershed-wide effectiveness of filter strip and terracing is 60% and 76%, respectively, meaning that terracing represents the BMPs to reduce soil loss at the watershed scale, while differences may arise at the sub-watershed scale.

The current findings demonstrate that soil erosion remains quite high even after BMPs testing, emphasizing that additional soil and land management techniques, such as biological measures, are needed to achieve tolerable soil erosion rate. In addition to lowering erosion at the watershed scale to boost agricultural production, BMPs can help with local issues such as excessive sedimentation in dam reservoirs.

Finally, the current findings can be utilized to aid decision-makers and planners in developing and implementing appropriate soil conservation practices and strategies to decrease soil erosion and associated sediment yield, particularly in locations with high erosion rates or high socioeconomic interest.

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Contribution of HVSR and Geological Investigations in Seismic Microzonation: A Case Study in Eastern Agadir (Western Morocco)

Ismaail Khadrouf, Ouafa El Hammoumi, Najib El Goumi, and Mostafa Oukassou

Abstract

Agadir has undergone rapid economic and urban growth, necessitating rational land-use planning. In addition, the area is located in an active seismotectonic regime within a deep alluvial basin. Previous destructive earthquakes, including the 1960 Agadir earthquake (Mw = 5.9) resulting in significant loss of life (12,000) and extensive destruction (over 75% of the city), highlight the area's vulnerability to site effects and seismic hazards. This study aims to conduct the first seismic microzonation of this area using the horizontal to vertical spectral ratio (HVSR) method. Furthermore, geological and geotechnical investigations were carried out at several locations. Ambient noise was recorded at 70 sites for 20 min using a Daqlink seismograph connected to a LE-3D/5 s MkIII triaxial geophone. The dominant frequency (f_0) and the amplification factor (A_0) were calculated by applying the H/V spectral ratio method using GEOPSY software and following the guidelines of the SESAME project. Subsequently, the seismic vulnerability index (K_g) was calculated to identify weak soils. The dominant frequency map shows that the f_0 is between 0.3 and 14 Hz, with lower values ($f_0 < 2.5$ Hz) observed in the alluvial fans and terraces units, and medium to high values (3–14 Hz) observed in the marly limestone and the lacustrine limestone units. Additionally, analysis of the H/V curve's shape shows that the study area has several types of curves, reflecting the geological complexity of the field. The A_0 map is mainly consistent with f_0 values, and high amplification values are located in the northeastern and southwestern parts where unconsolidated alluvial fans and sand dunes are present. The seismic vulnerability map (K_g) shows that weak soils are located within the sand dunes and the alluvial fans zone, especially in the Oued Issen zone. In addition, based on an examination of tectonic structures, it was determined that the Oued Issen zone is affected by a blind fault, known as the Oued Issen fault.

Keywords

Agadir · HVSR · Microzonation · Site effects · Dominant frequency (f_0) · Amplification factor (A_0) · Seismic vulnerability index (K_g)

1 Introduction

Ghabt Admin represents the eastern extension of Agadir City. Recently, this area has experienced rapid economic and urban growth, necessitating new land-use planning for a safer urban extension. On the other hand, Ghabt Admin area is located in an active tectonic regime and lies within a deep alluvial basin (Aït Hssaine and Bridgland 2009). Devastating earthquakes have occurred in the Agadir region both in historical epochs and recently. The first historically reported is the 1731 Santa Cruz earthquake, of intensity IX on the EMS scale (El Mrabet 2005). The 1755 Lisbon earthquake of VIII on the EMS scale, produced violent shaking in Agadir and caused catastrophic damage in most Moroccan coastal cities (Silva et al. 2021). The earthquake that occurred on 29 February 1960 (Mw = 5.9) in the reverse fault South Atlas Front, which is located in the southern margin of the High Atlas, and the resulting high level of damage (destruction of over 75% of the city) and loss of life (12,000 lives) are still in memory (Cherkaoui and Hassani 2012). This geological and seismotectonic framework makes this area under site effect and prone to seismic

I. Khadrouf (✉) · O. El Hammoumi · M. Oukassou
Laboratory of Applied Geology, Geoinformatics and Environment, Department of Geology, Faculty of sciences Ben M'sick, Hassan II University, Casablanca, Morocco
e-mail: ismaail.khadrouf-etu@etu.univh2c.ma

N. El Goumi
Soil Experimental Center, Public Laboratory for Trials and Studies, Casablanca, Morocco

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activity. Therefore, conducting a microzonation study to evaluate the site-specific condition and identify weak soil areas is necessary. The horizontal to vertical spectral ratio (HVSR) method is a field test based on ambient noise measurement and analysis that helps determine specific soil properties. This technique is prioritized in seismic microzonation studies due to its low cost, simplicity in data acquisition and processing, as well as its environmental friendliness (García-Jerez et al. 2007; Navarro et al. 2014). This study aims to provide the first seismic microzonation maps of this area, including the dominant frequency map (f_0), amplification factor map (A_0) and seismic vulnerability index map (K_g). To achieve this, sites for ambient noise measurements were selected, ensuring their distribution across the geological units. Additionally, various geological and geotechnical investigations were carried out to illustrate the lateral and vertical variations in the soil units and to create a lithological map, which aids in interpreting the results obtained from the ambient noise analysis.

Geologic and Seismotectonic Setting

The study area is situated in the northwestern part of the Souss basin, which is located in central-western Morocco. This faulted syncline basin is bordered by the High Atlas Mountains to the north and the Anti Atlas to the south. Both mountain belts were interconnected in-depth, beneath the Souss basin with a Paleozoic basement and are covered with deep Cretaceous-Eocene and Plio–Quaternary deposits of fluvial-lacustrine and aeolian origin (Ambroggi 1963). The fluvil-lacustrine deposit in the Souss basin include lacustrine limestone, marly limestone, conglomerate, alluvial fans and terrace deposits. Aeolian sediments consist of aeolian dunes and sand field. From a seismotectonic point of view, the tectonic evolution of the Souss basin is related to the Triassic-Liassic rifting and the Cenozoic inversion of the High Atlas system, resulting in numerous thrust and fold structures (Proust et al. 1977). The South Atlas fault, located at the northern edge of the Souss basin, represents the main active structure in the region, which slipped recently in the magnitude 5.9 Agadir 1960 earthquake (Laville et al. 2007).

2 Data and Methodology

Microtremor data have been measured at 70 locations using a Daqlink seismograph connected to a LE-3D/5 s MkIII triaxial geophone. Surveys have been carried out at 125 Hz for at least 20 min for each site. The guidelines of the SESAME project (site effect assessment using ambient excitations) were applied to ensure that measurements were done with adequate criteria and to check the reliability of the results. To obtain the H/V peak amplitude from the recorded data, the Geopsy software was used. The window length was 25 s, within the frequency range of 0.2 Hz to 15 Hz. Several filters were applied to minimize the noise and control the results. These included a band-pass filter, short-term average and long-term average ratio (STA/LTA), cosine window, the damping value, the horizontal spectrum rotation and Konno and Omachi smoothing with a value of 40 (Konno and Ohmachi 1998).

Amplitude spectra of the selected windows were computed using a fast Fourier transform. H/V peak amplitude was obtained by averaging the two horizontal component spectra and then dividing them by the vertical spectrum for each window. The standard deviation (SD) was estimated based on the average of these resulting curves. Consequently, the dominant frequency (f_0) and amplitude (A_0) were obtained.

The seismic vulnerability index (K_g) indicates the extent to which a subsurface soil is susceptible to soil deformation during an earthquake (Nakamura 2000). The estimation of this index involves squaring the peak value of the HVSR curve and then dividing it by the value of the predominant frequency. Areas with low seismic vulnerability indexes are expected to experience minimal damage in the event of an earthquake. Conversely, areas with high seismic vulnerability indexes are more vulnerable and likely to suffer damage during earthquakes. The integration of microtremor data with geological and investigations plays a crucial role in understanding the seismic behaviour of sub-soil. For this purpose, geological observations, boreholes and trial pits were conducted.

3 Results and Discussions

The results of this research are summarized in maps below. Data from geological and geotechnical surveys were plotted in a summary lithological map. The resulted maps includes the dominant frequency map (f_0), amplitude map (A_0) and the vulnerability index map (K_g). It can be noticed from Fig. 1a that the sediments of the study area have been classified into four main lithological units: marly limestone and lacustrine limestone rocks, alluvial fans and glacial-fan deposits, alluvial terrace deposits and sand dunes sediments. The alluvial fans consist of heterogeneous sediments, including sandstones, silts and conglomerates, which vary in compactness depending on the location. The glacial-fan deposits consist of lacustrine limestone covered by a thin silty crust. The terrace deposits consist of silts, sandy silts and alluvium.

The dominant frequency map (see Fig. 1b) shows that the f_0 values range from 0.3 Hz to 14 Hz. Relatively low f_0 values (0.3–2 Hz) were obtained in the glaci-fans, terraces and sand dunes zones. Boreholes and trial pits conducted in those areas show heterogenous and thick unconsolidated deposits. Tagragra's dome and limestone plateau show comparatively medium to high f_0 values ranging between 4 to 14 Hz. Homogenous rocks units are located in those areas. HVSR curves analysis shows that the study area exhibits several types of peaks at different frequencies, such as unclear peaks, broad

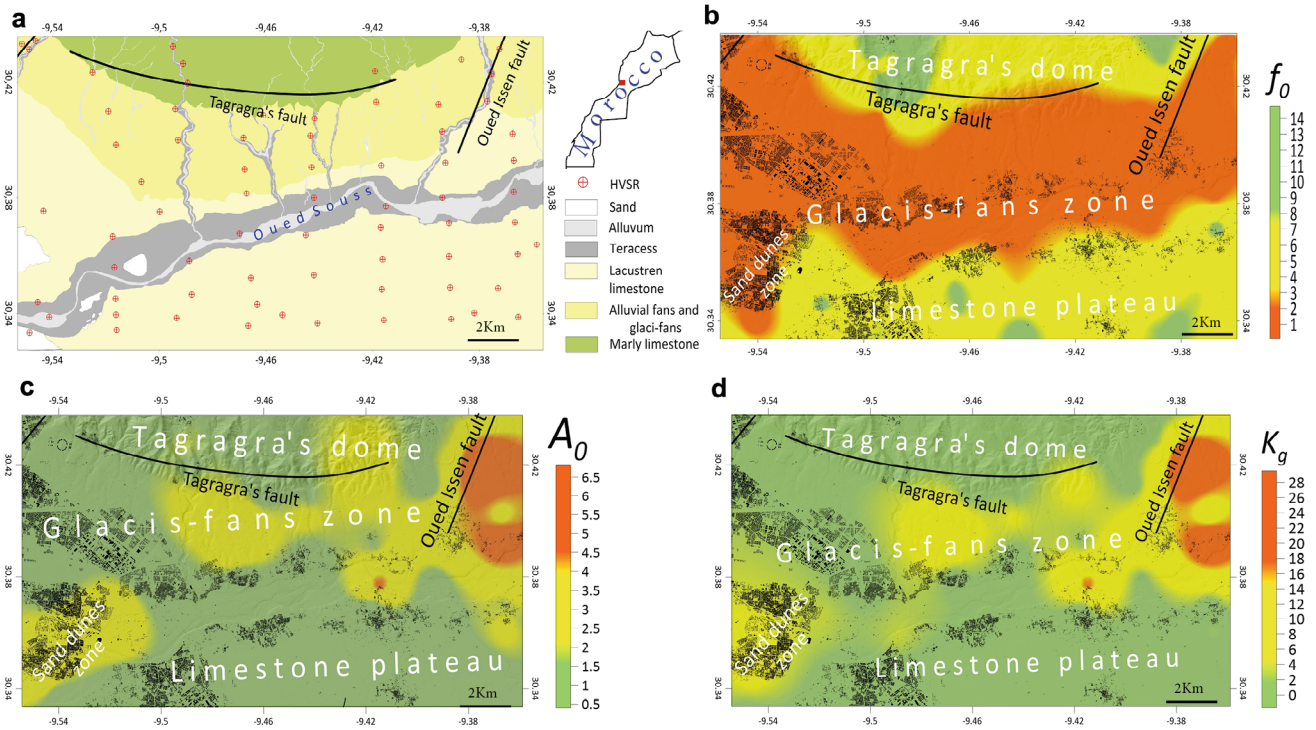


Fig. 1 Geoinvestigations and ambient noise data results. **a** Lithological map of the study area. **b** Dominant frequency map (f_0). **c** Peak amplitude map (A_0). **d** Seismic vulnerability index map (K_g)

peaks, two/multiple peaks and clear peaks. As mentioned in the literature (Molnar et al. 2022), there is a relationship between the shape of the H/V curves and the geometry and impedance contrast level of the subsurface soil. However, our study area shows multiple types of peaks in the same lithological unit, which complicates distinction of any possible patterns.

Peak amplitude values (A_0) (see Fig. 1c) are ranging from 0.5 to 6.5. High A_0 values (4.5–6.5) are located in the Oued Issen area, which consists of a relatively recent alluvial fan of unconsolidated deposits. Medium A_0 values (2–4.5) are obtained only in some part of the alluvial fans area and in the eastern part of Tagragra's dome, as well as in the sand dunes. However, The A_0 results remains qualitative since no measurements noise from large earthquakes are available. Seismic vulnerability index map shows that the K_g values vary between 0.1 to 28 (see Fig. 1d). High K_g values are obtained in Oued Issen area, which consists of unconsolidated alluvial sediments affected by a blind fault (hidden by the alluvial fans). Medium K_g values (414) are obtained in the sand dunes zone and in some part of the alluvial fans.

4 Conclusion

Microtremor surveys have been conducted and calculated at 70 locations using the HVSR method in the eastern side of the Agadir city. It has been determined that the f_0 values are between 0.3 and 14, the A_0 values are between 0.5 and 6.5, and the K_g values are between 0.1 and 28. Relatively low f_0 values were obtained in glacial fan and sand dune areas. High A_0 and K_g values were obtained in the Oued Issen alluvial fan, which is affected by a blind fault. The f_0 values are mainly consistent with A_0 values and the distribution of lithological units.

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The November 2020 Damaging Hydrogeological Event Affecting the Calabria Region (Southern Italy)

Tommaso Caloiero, Eugenio Filice, Loredana Marsico, Fabio Zimbo, and Olga Petrucci

Abstract

The present study describes the damaging hydrogeological event (DHE) occurred between the 20th and 22nd of November 2020 resulting in considerable damage on the east side of Calabria (southern Italy). A comparison procedure between this event and other DHEs affecting Calabria and, as described in previous work, was applied to assess event severity. Following this procedure the 2020 DHE was classified as an "extraordinary event", frequently occurring in autumn and characterized by "very high rainfall severity" and "moderately high damage levels." The case study has been enriched by presenting the evolution of meteorological framework of the event against that of other past cases in literature. The meteorological situation, quite common in autumn in Calabria (i.e., DHEs of 1921, 1953, 1959, and 1971), results from Atlantic troughs descending in the Mediterranean with the consequent formation of minimum surfaces conveying high-humidity air from south with the enhancement of convective phenomena.

Keywords

Damaging hydrogeological event · Flood · Landslide · Calabria

T. Caloiero (✉)
CNR-ISAFOM, Rende, Italy
e-mail: tommaso.caloiero@isafom.cnr.it

E. Filice · L. Marsico
Multi-Risk Functional Center, Catanzaro, Italy

F. Zimbo
Independent Researcher, Dipignano, Italy

O. Petrucci
CNR-IRPI, Rende, Italy

1 Introduction

Floods and landslides are among the most hazardous natural events with direct and significant negative effects on society and on the human–environment system (Pollock and Wartman 2020). The concomitant occurrence of rainfall-induced floods and landslides resulting in damage to people and properties, significant economic losses in agriculture and huge damage to transport assets constitutes a Damaging Hydrogeological Event (DHE) (Petrucci 2013). As the IPCC report highlights, there has been worldwide increase in DHEs (IPCC 2013). For example, in the past twenty-year periods 1980–1999 and 2000–2019 (CRED: UNDRR 2020), the CRED's emergency events database (EM-DAT)—the world's largest database on the occurrence and effects of more than 24,000 technological and natural hazard-related disasters from 1900 to the present day—evidences an increase of about 150% and 50% of floods and landslides, respectively. The present study applies a procedure described in detail in past papers (Aceto et al. 2016) to appraise the severity of an event that involved the coastal city of Crotone, on the Ionian coast of Calabria (Italy), and its environs (Fig. 1). Furthermore, the paper describes the characterization of the meteorological framework of the event to determine how frequently it contributes to causing damaging events and to provide an outline of the meteorological precursors of damaging events in Calabria.

2 Materials and Methods

A DHE consist of both a rainfall event (RE) and a damage event (DE). This study applies the methodology by Aceto et al. (2016) to analyze the DHE occurred in Calabria in November 2020. The damage resulting from a specific DHE can be summarized and normalized by calculating a damage score (D_{score}) by means of the following Eq. (1):

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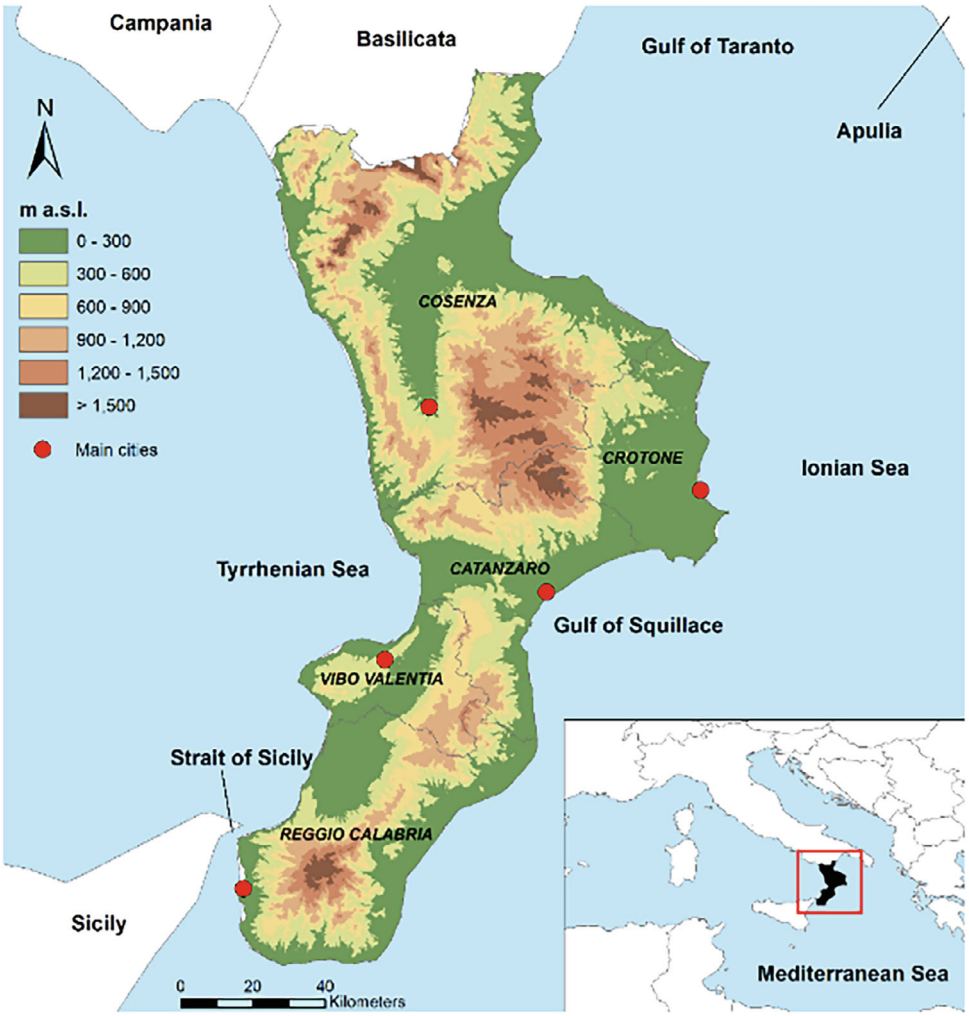


Fig. 1 Calabria region and its position in the Mediterranean basin

$$D_{\text{score}} = \left(\frac{\text{IDA}_j}{\text{IDA}_{\max}} + \frac{\text{DI}_j}{\text{DI}_{\max}} + \frac{\text{NoV}_j}{\text{NoV}_{\max}} \right) / 3 \qquad (1)$$

where IDA_j, DI_j, and NoV_j are the damage indicators of the event j, and $\text{IDA}_{\max}$, $\text{DI}_{\max}$, and $\text{NoV}_{\max}$ are the maximum value of each damage indicators calculated based on the historical series of most severe Calabrian DHEs. For each DHE the percentage of the damaged regional area corresponds to the index of damaged area (IDA). The damage index (DI) is a relative evaluation of direct damage which considers six main types of damageable elements. To provide a further indication of the severity of damage the number of victims (NoV) is also used.

To calculate the he rainfall score (R_{score}), the return period (T) of the maximum daily rainfall at each gauge present in the area affected by the damage event was considered. Equation (2) allows the calculation of the R_{score} based on a series of return period classes (based on those used in the Calabrian Hydrogeological Plan), and by estimating the percentage of gauges within these classes:

$$R_{\text{score}} = c_0 \frac{\sum_{i=1}^{n} i \cdot P(T)_i}{\sum_{i=1}^{n} P(T)_i} \qquad (2)$$

where n is the number classes, i is a return period class, $P(T)_i$ is the percentage of gauges in each i class, and c_0 is a graphic scale factor.

The DHE can be classified through the results of the combination of both D_{score} and R_{score} as follows: ordinary, (low damage/rain values), extraordinary (very high rainfall severity/moderately high damage levels) catastrophic (severe damage resulting from non-exceptional rainfall) and major catastrophic (high damage generated by exceptional rain).

3 Results

3.1 Synoptic Overview of the November 2020 Event

A trough toward the Western Mediterranean easily descended on November 19th, thanks to solid a anticyclone on the Atlantic, giving rise in the early morning of November 20th to low pressure at ground level in the leeward of Alps. As the trough further descended southwards, the low pressure crossed the Tyrrhenian Sea arriving in the Strait of Sicily on November 21st afternoon, taking on sub-tropical features. The low pressure further traveled south on the morning of November 22nd, the trough elongating with respect to the main flow. Three main phases characterized the event: (1) rain on Basilicata and severe storm on Crotone area on the afternoon of November 20–November 21 early morning; (2) rain affecting Crotone and surroundings and the Ionian coast between November 21 early morning and the evening; (3) severe storm affecting the northern part of the Crotone area on the night of and November 22.

3.2 Event Rainfall and Damage Analysis

The maximum rainfall values recorded in Crotone lasted 1 h (73.6 mm), 9 h (186 mm), and 12 h (212.6 mm), respectively. Three stations near Crotone city recorded a 6-h maximum rainfall (> 100 mm). At the same time, values over 100 mm in the 9-h period were recorded at eight stations along the Ionian coast, while 150 mm were recorded over a 12-h period in seven rain gauges near Crotone city. When considering the rainfall return period, for the Crotone rain gauge, it was calculated to exceed 1000 years for the maximum daily rainfall. Yet, the rest of the area affected only registered rather non-extraordinary daily precipitation with the exception of one gauge located in the northeast sector of the Crotone province with over a 200-year return period.

The DHE most heavily affected the port city of Crotone. Water inundated several neighborhoods, with over one meter of mud swallowing cars and inundating basements. Debris from the sea submerged the seafront, flooding stores in the city centers causing enormous damage. Mud and water also flooded the railway tracks that run parallel to the coast and perpendicular to the main river network. When the levees of the Esaro river (near the Crotone urban area) broke, numerous people were evacuated as a precaution. Power shortages affected over 70 houses. Also, shortages of drinking water caused by minor landslides and debris infiltrating aqueducts occurred. Finally, local farmers association registered huge losses and damage to agriculture.

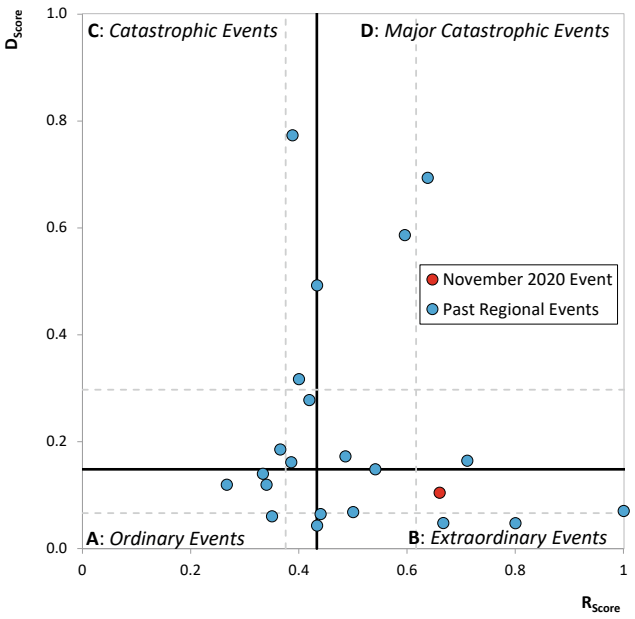


Fig. 2 Chart classifying the analyzed event according to its magnitude

3.3 The Severity of the November 2020 Event

In order to measure the gravity of the event, the chart by Aceto et al. (2016) has been used (Fig. 2).

The historical database of the Damaging Hydrogeological Events in Calabria was used in the creation of this chart by choosing the 21 most sever events in the region since the 1920s (Aceto et al. 2016). Based on this chart, the November 2020 DHE resulted to be classified as an extraordinary event. In fact, in spite of the event affecting a limited sector of the region and precipitation occurring only for few days, it presented a high R_{score} but low D_{score} values since no casualties were recorded. Generally, extraordinary events can occur in all seasons, though most frequently in autumn.

4 Discussion

The DHE under investigation was triggered by a synoptic situation not unlike that that caused the event of 25th–27th October 1921. Both showed a trough elongating over the Mediterranean basin to the west (in tear-off or cut-off); both gave rise to low pressure on the ground along the Tyrrhenian sea rapidly descending south toward the North African coasts (1921 event) or Tunisia (2020 event). The events of 1st–5th November 1953, 7th–11th November 1953, 13th–14th November 1959, and 29th September–2nd October 1971 presented similar characteristics, albeit with differential southward trajectories. Such parallels between the events

give rise to new questions and potential future investigations, such as defining a more detailed meteorological framework classification for the early recognition of an upcoming DHE with a certain expected degree of severity over a specific area. The results of this study may significantly improve regional disaster preparedness and management strategies. It is worth pointing out that considering the triggering rainfall intensity alone does not provide meaningfulness to the event. In fact, rainfall damage potential is strictly related to the affected area' climate and terrain characteristics. At the same time, severity cannot be measured only in terms of observed damage, since the latter may be affected by the presence or absence and distribution of elements at risk. Consequently, an event severity cannot be evaluated without considering the local climate and human activities.

5 Conclusions

The present study analyzed the 20–22 November 2020 DHE affecting the Calabria region. The paper first offered a synoptic investigation of the event; then, it focused on the recorded precipitation and damage caused. The study underlined that DHE's severity requires a systematic approach for its assessment and for enabling public administrations to distribute recovery funds in a more accurate way. Furthermore, since DHEs frequently hit Calabria, civil protection interventions may greatly benefit from the understanding of the meteorological occurrences that can trigger heavy rainfall with consequent damage.

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Analysis of Migration of Six Phthalate Esters in the Soil of Patna Municipal Area, India

Aseem Kumar Anshu, Preety Sinha, Rittika Pandey, Kumari Gouri, Subhash Kumar Saw, and Nirmala Tripathi

Abstract

Context/purpose: A large quantity of phthalic acid esters (PAEs) is produced and used for manufacturing plastic-based products globally every year. Due to the ubiquitous application of plastics, it is inevitable for humans and animals to be exposed at significantly high levels. PAEs are considered to be endocrine disruptors with the perilous effects on human health. Methods: Soil samples of 45 municipal wards of Patna, India, were collected at the depth of 30 and 50 cm. The samples were extracted using microwave assisted extraction technique. The ultra high performance liquid chromatography (UHPLC) was standardized for the quantification of six phthalates, including dimethyl phthalate (DMP), diethyl phthalate (DEP), dibutyl phthalate (DBP), dihexyl phthalate (DHP), di-(2-ethylhexyl) phthalate (DEHP) and diisodocyl phthalate (DIDP). Results: We have observed highest quantity of DBP and lowest quantity of DHP in soil at the depth of 30 cm as well as 50 cm. We have found the mean concentration of Σ6 phthalates was highest in the sample sites located between 1.5 and 2.5 km from the bank of Ganga River at the depth of 30 cm whereas at the depth of 50 cm, the highest mean concentration of Σ6 PAEs was observed in the samples sites located within 1.5 km at the edge of Ganga River. Interpretation: The migration of PAEs varied significantly from the type of soil texture. The soil texture of the samples sites closer to the Ganga River was coarser and provided faster migration resulting in the higher mean concentration of Σ6 phthalates at 50 cm. The fine soil texture of samples sites located at 1–5 to 2.5 km from Ganga River made it suitable for the slower migration due to which highest mean concentration was higher at 30 cm. Conclusion: We have found high amount of six key phthalates in the soil samples of Patna urban area collected at the depths of 30 and 50 cm. Since the city of Patna is composed mainly of alluvial soil, which makes it suitable for the efficient migration of phthalates. However, more data on underground contamination and agricultural land contamination with phthalates could unmask the ambiguity.

Keywords

Phthalate esters · Soil · Ganga · Patna · PAEs

1 Introduction

Large quantities of phthalic acid esters (PAEs) are produced globally every year for manufacturing plastic-based products. Production of phthalate and its application in plastics at such a large scale make it inevitable for humans and animals to be exposed at significantly high levels (Casals-Casas and Desvergne 2011). It has been reported that PAEs may have teratogenic and carcinogenic effects on humans (Blount et al. 2000). It has been documented that children are more exposed to phthalates, possibly due to plastic toys (Frederiksen et al. 2011). Phthalates have been demonstrated to be endocrine disruptors (Anand-Ivell et al. 2018). Additionally, PAEs have been documented to induce testicular

A. K. Anshu (✉) · P. Sinha · K. Gouri
Department of Zoology, Anugrah Narayan College, Patna, Bihar, India
e-mail: asim87anshu@gmail.com

R. Pandey
Department of Zoology, Jagjiwan College, V.K.S University, Arrah, Bihar, India

S. K. Saw
Department of Biotechnology, Magadh University, Bodh Gaya, Bihar, India

N. Tripathi
University Department of Zoology, Sido Kanhu Murmu University, Dumka, Jharkhand, India

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toxicity including sperm quality, sperm mobility, asthenozoospermia, cryptorchidism, and hypospadias in laboratory animals (Anand-Ivell et al. 2018).

According to a study, the soil of urban areas of Guangzhou city, China has been observed to be severely contaminated with PAEs (Ma et al. 2022). Another study reports a high concentration of PAEs in the soils and road dust collected from the streets of Novi Sad city, Serbia (Škrbić et al. 2016). Likewise, dimethyl phthalate (DMP), diethyl phthalate (DEP), butyl benzyl phthalate (BBP), dibutyl phthalate (DBP), diethyl hexyl phthalate (DEHP), and di-n-octyl phthalate (DnOP) have been estimated to be significantly high in the water and sediments of River Kaveri (Selvaraj et al. 2015).

The present study is aimed to quantify the ∑6 phthalate esters, including DMP, DEP, DBP, dihexyl phthalate (DHP), DEHP, and diisodocyl phthalate (DIDP) in the soil of 45 randomly selected municipal wards of Patna by MAE for extraction and UHPLC for the analysis. Additionally, the migration of selected phthalate esters were also analyzed on the basis depths of the soil in relevance to soil textures throughout the city of Patna located on the bank of River Ganga.

2 Materials and Methods

Sampling: Soil samples were collected from randomly selected 45 municipal wards of Patna urban agglomeration (Fig. 1). Dumpsites were targeted for the sampling at each municipal ward. Samples were collected in glass bottles at the depth of 30 and 50 cm from the surface and transported immediately back to the laboratory for storage at − 20 °C. Sampling sites were categorized into three groups: G1 (sites located within 1.5 km from the bank of River Ganga), G2 (sites located within 1.5–2.5 km from the bank of River Ganga), and G3 (sites located beyond 2.5 km from the bank of River Ganga). Based on the location of the municipal wards from the bank of River Ganga, G1 included municipal wards (W23, W24, W25, W26, W27, W37, W40, W41, W42, W49, W58, W59, W60, W64, W65, W66, W67, W69, W70, W71, and W72), G2 municipal wards (W21, W28, W35, W36, W38, W43, W47, W48, W55, W57, W61, W62, W63, and W68) and G3 municipal wards (W2, W3, W4, W12, W13, W14, W16, W18, W45, and W56).

Extraction: Soil samples were dried and ground using mortar and pestle. Fine particles were collected through sieving and added with acetonitrile (1:5). The mixtures were closed in air-tight glass flasks and were further run into the microwave at 100 °C for 20 min.

Standard Solution: Phthalate standard solutions, including DMP, DEP, DBP, DHP, DEHP, and DIDP were obtained from Sigma-Aldrich and prepared for variable concentrations by serial dilution (1, 5, 10, 50 and 100 µg/ml).

UHPLC Conditions: Ultra high performance liquid chromatography (UHPLC) system Dionex Ultimate 3000 supplied by ThermoFisher Scientific India Pvt. Ltd. was used for the quantification of ∑6 phthalates. Each sample run included A = water and B = acetonitrile. The gradient program was set up as 80% B (0–7 min), 100% B (7–11 min), and 80% B (11–20 min).

Quality Assurance and Quality Control: Blanks ($n = 5$) underwent extraction and analytical procedures parallel to the samples. However, a very low level of ∑6 PAEs was observed (2.83–58.71 ng/ml) and these contributions from the blank were corrected in the samples. The limit of detection (LOD) and limit of quantification (LOQ) were determined for the ∑6 PAEs with a signal to noise ratio of 3:1 and 10:1, respectively. The samples ($n = 5$) were spiked at the concentrations of 1 and 10 ng/ml with the mixed standards and were analyzed to observe the recoveries. The mean recoveries for the ∑6 PAEs in the spiked samples ranged from 83.77 to 109% with relative standard deviation ranging from 4.55 to 6.02%.

3 Results

The developed method was used for determining the levels of PAEs in the soil samples of Patna municipal wards. The mean of DMP, DEP, DBP, DHP, DEHP, and DIDP in soil samples collected at the depth of 30 cm were calculated to be 47.59 µg/g, 21.43 µg/g, 67.44 µg/g, 20.56 µg/g, 43.76 µg/g, and 25.53 µg/g, respectively with p-value = 0.0001. DBP was found to be present at the highest and DHP at the lowest mean concentration in soil at the depth of 30 cm. The mean of DMP, DEP, DBP, DHP, DEHP, and DIDP in soil samples collected at the depth of 50 cm were observed to be 49.33 µg/g, 30.88 µg/g, 60.19 µg/g, 17.79 µg/g, 35.11 µg/g, and 32.02 µg/g, respectively with significance 0.0001 (Fig. 2).

The total concentrations of the ∑6 phthalates in the municipal wards grouped according to the distance from river Ganga were analyzed at the different depth of the soil (30 and 50 cm). It was observed that ∑6 phthalates were the highest among G2 as compared to G1 and G3 at the depth of 30 cm, whereas the ∑6 phthalates were highest among G1 as compared G2 and G3 at the depth of 50 cm. It must be noted that the levels of ∑6 phthalates among municipal

wards of G3 were significantly lower than other groups at both the depths (30 and 50 cm) (Fig. 3).

4 Discussion

Given its vast applications, PAEs have reportedly been observed in various environmental components such as soil (Pivnenko et al. 2016) and water (Yang et al. 2018). Different phthalate esters were estimated to be as high as 25.68 μg/g of soils collected from Southwest China (Ma et al. 2022) and PAEs ranging from 0.05 to 10.4 μg/g of soil collected from suburban farmland, and wasteland in Tianjin, China (Tan et al. 2016).

The river Ganga is highly contaminated with bioorganic waste, which allows the adsorption of phthalate molecules to the lipid rich waste and deposit at the sediments and migrate to the soil. Numerous other studies also add to the fact by showing high concentrations of PAEs in sediments of rivers and oceans (Yang et al. 2018).

In a recent study by Tan et al. (2016), it was clearly demonstrated that PAEs in fine sand (53–250 μm diameter) tend

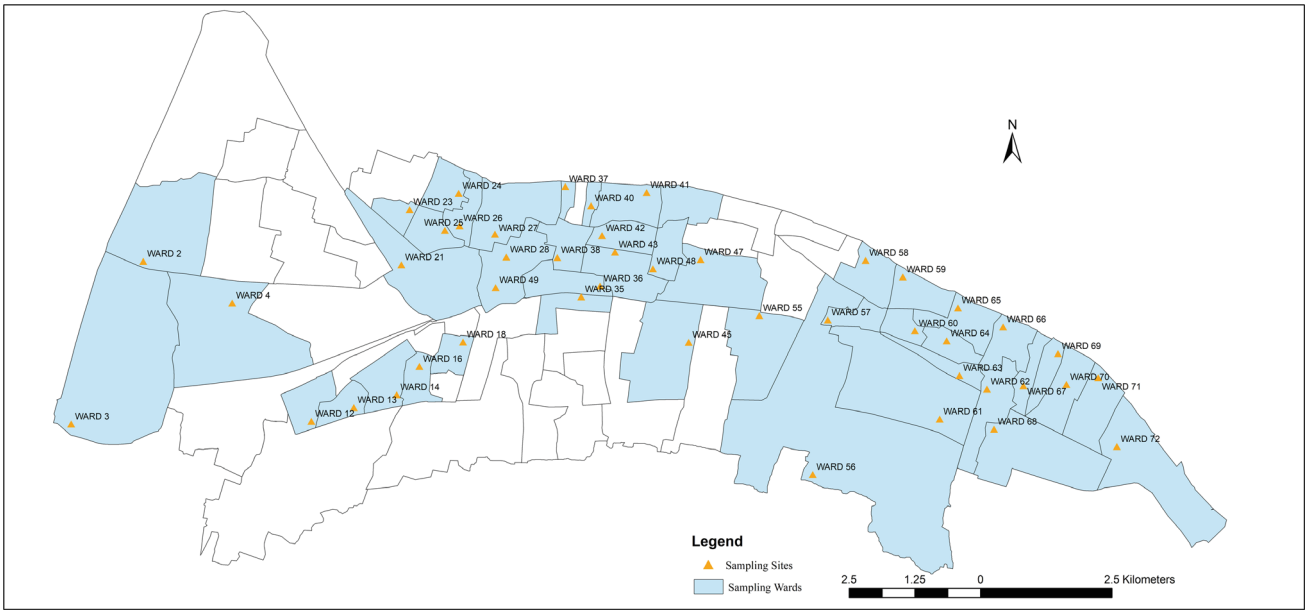


Fig. 1 Map of Patna urban agglomeration with wards demarcated by Patna Municipal Corporation indicating sampling sites

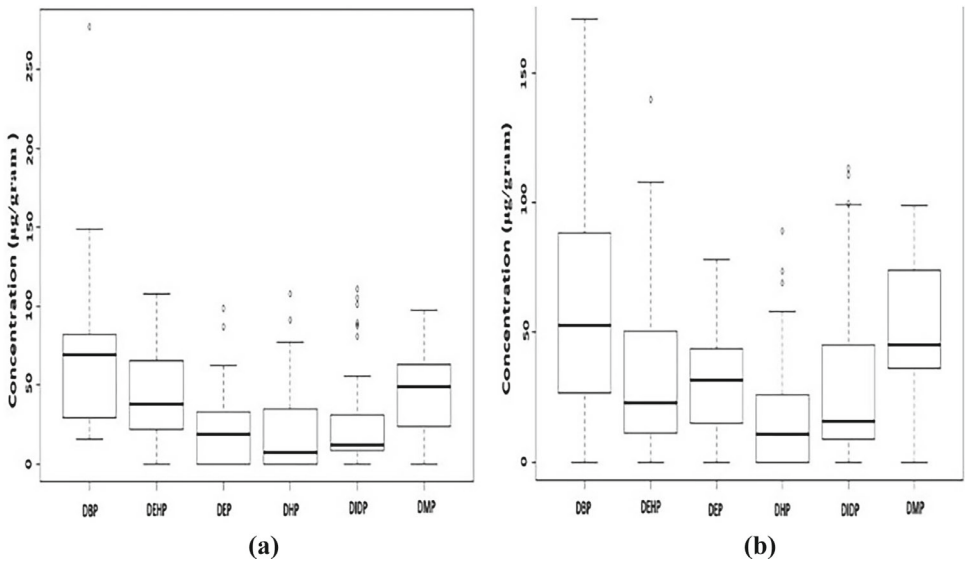


Fig. 2 Average concentrations (all wards) of six PAEs at the depth of 30 cm (**a**) and 50 cm (**b**)

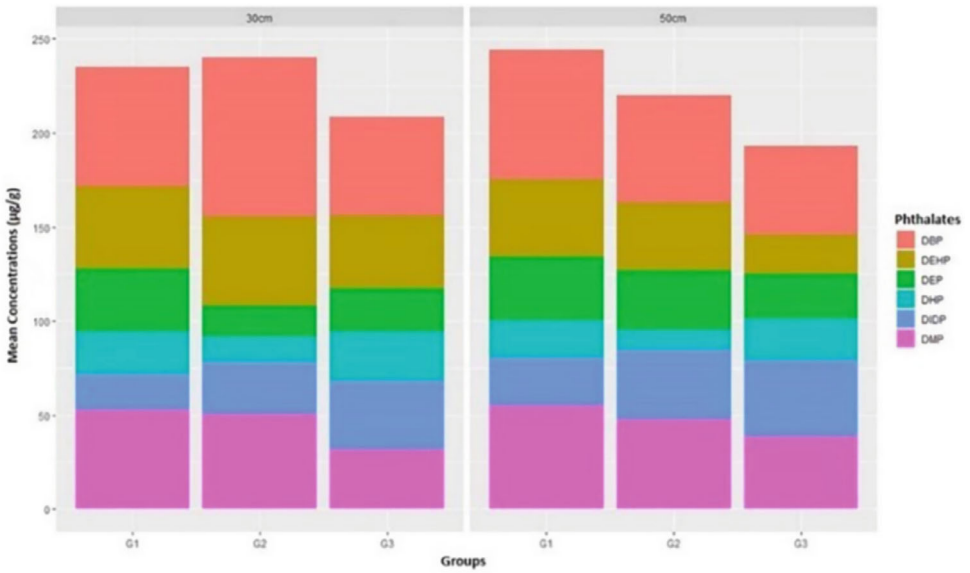


Fig. 3 Levels of concentrations of ∑6 phthalates through groups based on distance from the bank of the river Ganga at the depth levels of 30 and 50 cm (right)

to accumulate more amount of PAEs at the depth of 20 and 40 cm as compared to other soil particles coarse sand (250–2000 µm), fine silt (20–53 µm) and clay (< 2 µm) at the depth of 20 and 40 cm.

5 Conclusions

The current study presents the quantity of contamination of six phthalates, i.e., DMP, DEP, DBP, DHP, DEHP, and DIDP in soil of Patna municipal area. We have found high amount of six key phthalates in the soil samples of Patna urban area collected at the depths of 30 and 50 cm from 45 wards. The average concentrations of DMP, DEP, DPP, DBP, DHP, DEHP, and DIDP at the depth of 30 and 50 cm were found to be significantly high. Since the city of Patna is composed mainly of alluvial soil, it makes it suitable for the deposition of phthalates. Moreover, fine particles of the soil allow smooth migration of the PAEs in soil. However, more data on underground contamination and agricultural land contamination with phthalates could unmask the ambiguity.

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Modeling of Extended Landslide Movement Caused by Climate Change Events

Hizia Zerarka, Mustapha Akchiche, and Florent Prunier

Abstract

The Mediterranean area is affected by climate change, caused by extreme rainfall, flooding, heat waves, dryness, and fire hazards. In contrast, these phenomena directly influenced soil and rock's physical and mechanical characteristics, which led to many landslides in this area. The change of pluviometry and temperature in the Mediterranean area intensified rock alteration, implying that water is the most crucial factor that triggered the instability induced by climate change. The study was focused on the landslide of the Ain El Hammam (AEH) region. In addition, the propagation of this movement and these instabilities is observed yearly as the weakness of the schistose rock mass. The landslide (AEH) is an old slip, which was reactivated at the end of 2008, 2011, and in 2016 after an intense rainfall period, and its area was expanded each time. To identify the limit of his propagation, numerical modeling by finite element method was used to simulate the influence of multiple factors, such as precipitation, non-saturation, and pore pressure fluctuation, using the Plaxis® calculation software. To detect unstable areas in the landslide, two Matlab® programs were used to calculate equivalent plastic deformation and the second-order work of Hill bifurcation criterion to predict the instabilities area. The numerical results were compared by monitoring the topometric measurements of the new area affected by this landslide. So, that defines the direction of the movement and its deformation mechanism. As a result, was detected a weak layer of schistose rock responsible for the movement in the area, which was extended because of the profound alteration, which was caused by underground flow, and decreased the mechanic's characteristics of the layer, which justified the propagation of instability with a time. In conclusion, extreme climatic events, particularly intense precipitation, weaken the strength of the rock in the Mediterranean region and trigger the development of many potential landslides. A new program to predict and quantify hazardous areas in the region should be developed.

Keywords

Climate change · Landslide · Second-order work · Monitoring · Alteration

1 Introduction

Landslides are influenced directly by rainfall due to climate change's impact on evaporation and precipitation. More frequent and intense rainfall events lead to more landslides in the Mediterranean area. This study focused on the landslide of the city of Ain El Hammam (AEH), which is located 50 km east of the capital of the city of Tizi Ouzou (Algeria) (Fig. 1).

The landslide AEH is an old slip reactivated at the end of 2008 after intense rainfall. The movement of slop depends on the heavy precipitation and fluctuation of groundwater (Table 1).

In the study area, it was observed that this landslide reactivation would occur after each rainfall event and its evolution of unstable area in depth and width, year by year.

The most crucial factors for the reactivation of this landslide were identified to be the hydraulic factors, which were determined through numerical modeling of the slip site. In order to simulate the triggering of sliding, the modeling of precipitation during the rainiest month was conducted,

H. Zerarka (✉)
University of Blida 1, USDB, Soumaa, Algeria
e-mail: zerarkahizia@yahoo.fr

M. Akchiche
University of Houari Boumedienne USTHB, Algiers, Algeria

F. Prunier
INSA, Lyon, France

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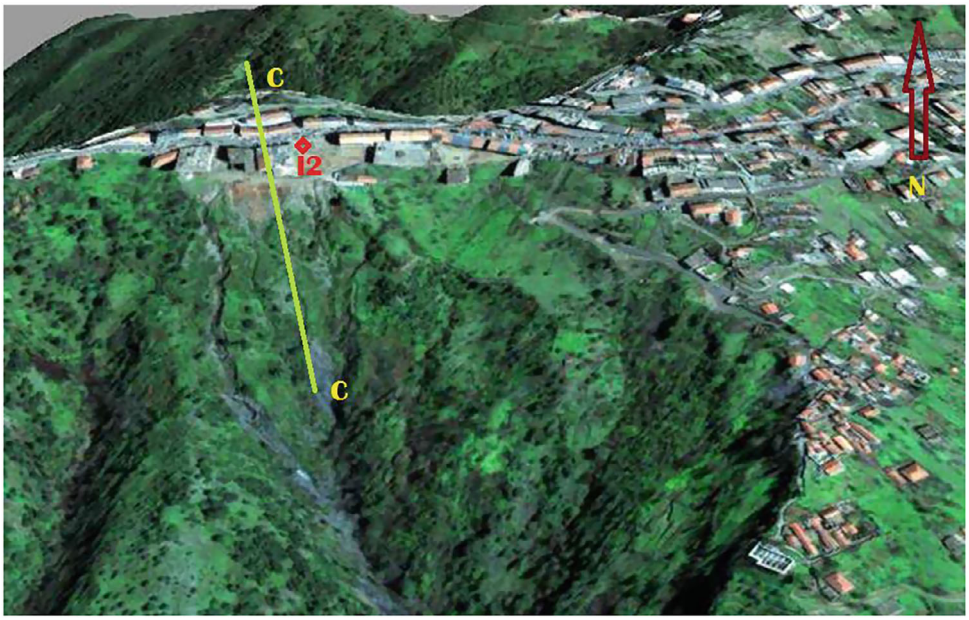


Fig. 1 Satellite view of the location of the Ain El Hammam landslide

Table 1 History of the movement of the landslide of AEH

Period	Main observations	Landslide evolution
1969–1970	Start disorder	Cracks on the pavement and in the building
1970–1972	The investigation during this period indicated that the instability was about the layer of backfill and clay schistose coverage	Lateral and vertical development
By the 1990s	Slope urbanization (R + 5 building, school, and bank) induced noticeable instability	Lateral and vertical development
2002–2004	Reappear of disorders after heavy precipitation	Lateral and vertical development
In 2006	Building cracking and roadway subsidence along Boulevard Amirouche following storm rainfall	Lateral and vertical development
November 2008	Heavy rainfall triggered a major reactivation phase	Lateral and vertical development
2008–2009	Active movement during this rainy period (992 mm) landslide during a wet period (annual rainfall 992 mm), the displacement is amplified to achieve peak displacements in March–April, causing severe damage (building dislocation, pavement fissures, and pipeline failures)	Downslope (lower slope) development
2009–2011	Activity seemed much less	Slow evolution
2011–2015	Cracks observed in sidewalks and pavements; opening of joints between buildings and adjacent sidewalks	Downslope (lower slope) development

considering the transient groundwater flow as the main cause (refer to Fig. 2). "The piezometric measurements indicate that the groundwater level is 8 m. To accurately represent the water retention curve, the Van Genuchten (1980) model was employed to incorporate non-saturation in the layers above the water table. These model parameters were determined by Plaxis based on correlations with the particle size and permeability of the specific soils" (Laouafa et al. 2010).

2 Numerical Modeling

Numerical modeling using the finite element method was employed to determine the propagation limit of the landslide. This modeling approach considered multiple factors such as precipitation, unsaturation, and pore pressure fluctuation. The AEH slope profile was included in the model, taking into account its morphology, current exploitation loads, and climatic loads. The computation was performed under the assumption of plane strains (refer to Fig. 2) and utilized a hydromechanical coupled formulation.

To represent the non-saturation of the layers above the water table, the Van Genuchten (1980) model was utilized to describe the water retention curve. The parameters of the Van Genuchten model were determined based on correlations with the particle size and permeability of the soils. It was determined that the hydraulic factors were the most critical for the reactivation of the landslide. Additionally, the precipitation of the rainiest month, which triggers sliding through transient groundwater flow, was also modeled (refer to Fig. 3). The groundwater level was measured to be 8 m based on piezometric measurements (Zerarka et al. 2018).

To detect the unstable area, Tow Matlab® programs are developed, one to calculate the second-order work by Hill criterion and the second to calculate the equivalent plastic deviatory deformation (Zerarka et al. 2018).

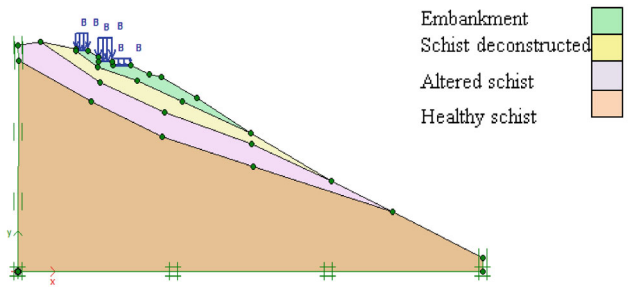


Fig. 2 Cross-section in the middle of the landslide of AEH

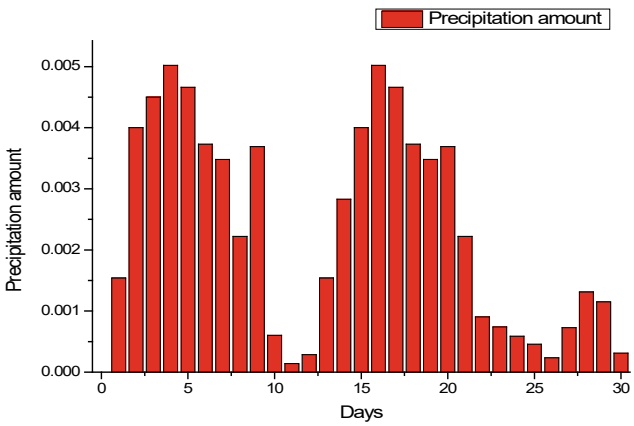


Fig. 3 Daily variation of precipitation (view of Plaxis model)

2.1 Hill Criterions

Hill (1958) proposed a stability criterion for elastoplastic materials. After this work, a strain–stress state is used in instability if the deformation can be continued in a loading direction without external energy input. As a result, a volume V of a material system is stable if any pair ($d\sigma$, $d\varepsilon$) connected by their constitutive model satisfies (Darve et al. 2004):

$$\int_V d\sigma \cdot d\varepsilon dV > 0 \tag{1}$$

at the scale of representative elementary volume (REV), this expression reads:

$$w_2 d\sigma \cdot d\varepsilon > 0 \tag{2}$$

2.2 Equivalent Plastic Deviatory Deformation ε_{eq}^{p}

The primary objective of the modeling is to determine the stress and strain fields using a hydromechanical finite element coupled formulation

$$\varepsilon_{eq}^{p} = \sqrt{\frac{2}{3}\left(\varepsilon_{d1}^{p2} + \varepsilon_{d2}^{p2} + \varepsilon_{d3}^{p2}\right)} \tag{3}$$

The hydromechanical finite element coupled formulation precisely takes into account the factors affecting this field: mechanical actions, climate conditions, and water.

3 Results

3.1 HILL Criterion

The first Matlab® program gives the results of numerical modeling under the effect of hydromechanical conditions, introducing the fluctuation of the groundwater effect and intense precipitation in the transitional flow regime, enabling the study of the evolution of the AEH slope failure (Zerarka et al. 2018).

The results regarding the second-order work w_2 are presented for the cut C–C (see Fig. 1). These results show a large zone of instability appearing in the embankment and the destructed shale layer where w_2 is negative (Hill 1958) (see Fig. 4).

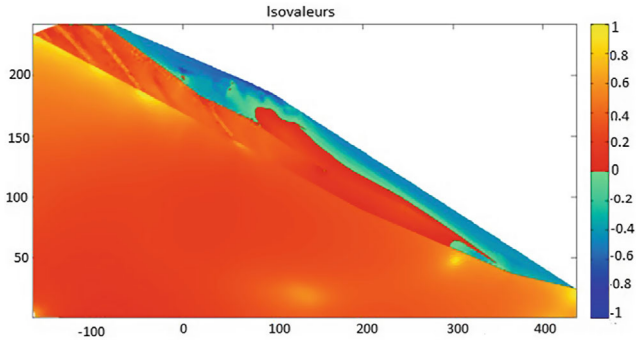


Fig. 4 Second-order work of section C–C

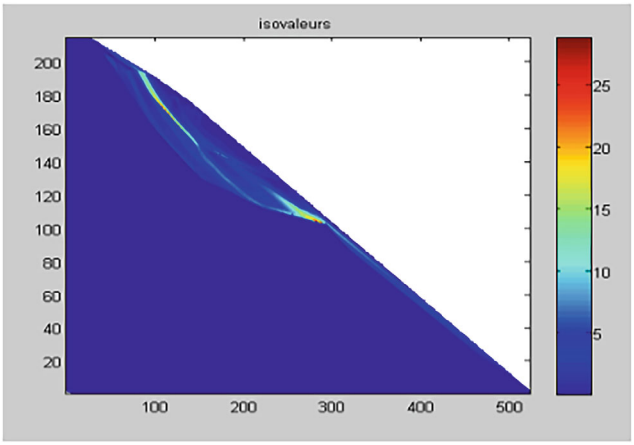


Fig. 5 Equivalent deviatory strain of the section C–C

3.2 Equivalent Plastic Deviatory Deformation ε_{eq}^{p}

The second Matlab program provides the results of the plastic deviatory deformation ε_{eq}^{p}. The morphology derived from modeling aids in identifying the deformation mechanisms within the slope. The analysis reveals the shape of the sliding surface, and ε_{eq}^{p} offers accurate representations of the ground deformation state (Zerarka et al. 2018) (see Fig. 5).

4 Discussion

According to the results of the second-order work w_2 and the equivalent plastic deviatory deformation on the cut of the middle of the landslide, was noticed a large zone of instability appeared in the embankment layer, destructed schistose rock and some part of the jointed schist layer, were w_2 negative, and the sliding circle through the calculation of equivalent plastic deviatory deformation. To validate the numerical model, these results are with the topometric measurements (see Fig. 6), which present the direction and the degree of displacement of the landslide as a function of time.

Lastly, it was observed that the slope's displacement increases in the months of heavy precipitation, confirming the presence of a new slip zone responsible for these displacements.

5 Concluding Remarks

The Ain El Hammam landslide remains active and features a complex structure. This complexity necessitated numerical modeling to refine the analysis of slope behavior and its long-term response, utilizing equivalent deviatory strain and comparing these findings with area measurements. The results indicate that the slope is unstable and confirm the presence of a new slip surface in the southern part of the city. Topographic monitoring corroborated these findings,

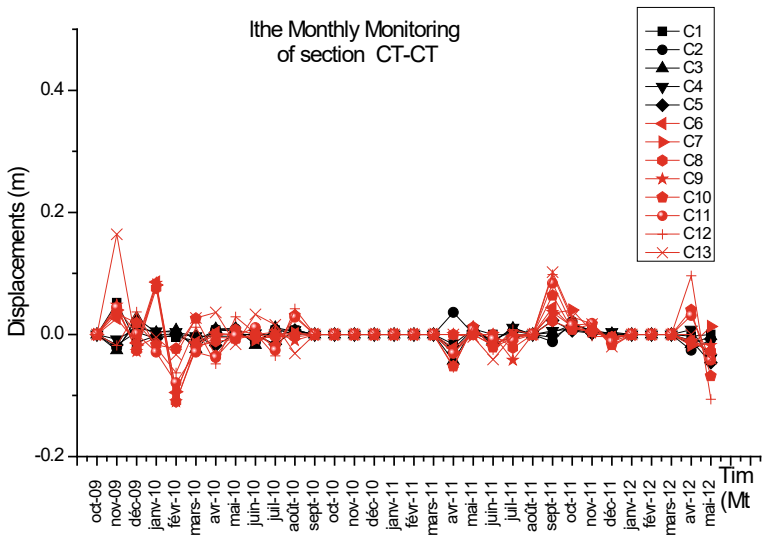


Fig. 6 Displacement of topographic points along the CT–CT section (center of the landslide)

showing significant movement in that area. Considering the site's geology and the numerical results, the slide propagation direction aligns with the natural foliation of the schist.

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Monitoring of Soil Degradation and Vulnerability by Applying the EPM Model Within Taglueft Basin: Application in the Asif N Ouififen Catchment (Central High Atlas/Morocco)

Mohamed Rizki, Hasan Ouakhir, Nadia Ennaji, and Mohamed Abahrour

Abstract

Different studies in Mediterranean areas show a high soil erosion rate in agricultural areas due to herbicides and ploughing processes. Conversely, low soil loss rates were observed in rangelands due to the impact of vegetation cover. In Morocco, as confirmed by FAO, soil erosion is the main factor contributing to the soil loss and the environment. Additionally, in the mountainous regions of the Rif in Morocco, the annual loss of soil exceeds 25 ton/ha/yr. In the High and Middle Atlas, the values of soil degradation ranged from 2 to 15 tone /ha/yr. The present article aims to assess and evaluate the dynamics of soil degradation and evaluate its spatial distribution by using the empirical EPM model (erosion potential model) in mountainous Mediterranean-type catchments. The Asif N Ouififen catchment, located in the Central High Atlas, belongs to the Taglueft basin and covers an area of 50.16 km^2. It is characterized by fragile lithology and vulnerable soil, with a dominance of marls and sands (56.11%). The climate in this area is Mediterranean with continental influence and a semi-arid tendency. In terms of land use, bare land and forest cover dominate the study area. The methodology used is based on the main factors of the EPM model (slope, rainfall and temperature, soil protection, and soil erodibility), which were obtained using GIS software. The results indicate a high vulnerability to degradation of soil within the studied catchment, with a high soil loss rate exceeding 800 $m^3/km^2/yr^{-1}$. Various factors explain this high amount, such as the high erodibility of lithology and land cover dynamics. Consequently, understanding the influence of change of land uses on soil degradation is crucial for implementing effective land management practices and erosion control measures to preserve soil health and sustainably manage land resources.

Keywords

Soil erosion assessment · Asif N Ouififen catchment · EPM model · Central high atlas (Morocco)

1 Introduction

The degradation of soil is a critical environmental problem, particularly within the Mediterranean zones, where agricultural activities and natural factors contribute to significant soil loss rates (Rodrigo-Comino 2018). Several studies have shown that agricultural areas with herbicide use and ploughing processes experience higher rates of soil erosion, while range lands with vegetation cover tend to have lower soil loss rates (Singh et al. 2011). In Morocco, soil erosion has been identified as a major factor leading to soil degradation and environmental deterioration, especially in mountainous regions like the Rif and the Pre-Rif, as well as the High and Middle Atlas (Mosaid et al. 2022; Gourfi et al. 2020).

As per the reports from the Food and Agriculture Organization (FAO), soil erosion rates in the Rif mountains can surpass 30 tones/ha/yr, while in the Pre-Rif regions, it varies between 15 and 25 tones/ha/yr (Zhang et al. 2021). Besides, the High and Middle Atlas regions experience soil erosion rates ranging from 2 to 15 tones /ha/yr, as reported

M. Rizki
University of Med 5, Letters and Human Sciences Faculty of Rabat (Morocco), Laboratory (STHP), Rabat, Morocco

H. Ouakhir
Higher Institutes of Nursing and Health Technology Professions, Demography and Environment, Beni Mellal, Morocco
e-mail: h.ouakhir@usms.ma

N. Ennaji (✉) · M. Abahrour
University of Sidi Mohamed Ben Abdallah (Fes-Sais), Polydisciplinary Faculty of Taza (Morocco), Laboratory of SHDD, Taza, Morocco
e-mail: nadia.ennaji@usmba.ac.ma

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(Bagherzadeh and Daneshvar 2011). Such erosion rates raise serious concerns for the sustainability of agricultural lands and the preservation of the natural environment in these vulnerable areas (Noori et al. 2016).

This research seeks to investigate soil erosion dynamics and evaluate its spatial distribution in mountainous catchments with a Mediterranean climate. The study utilizes the empirical EPM model (erosion potential model) for analysis, focusing on the Asif N Ouififen catchment which situated within the Central High Atlas of Morocco.

2 Study Area and Methodology

2.1 Description of the Study Area

The catchment of Asif N Ouififen, located in an impressive geographical expanse, exhibits a diverse range of characteristics.

This catchment is a part of the Taglueft basin, covering an area of 50.16 km^2. The altitude ranges from 961 to 2607 a.s.l. The catchment displays significant variations in elevation. The lithology of this headwater is composed of a mix of blue limestones, shale, and marls, forming a complex geological foundation. It is characterized by delicate lithology with a prevalence of marls and sands (56.11%). In terms of land use, the study area is dominated by bare land and forest cover (Fig. 1).

2.2 Methodology

2.2.1 The Model of EPM

The erosion potential model (EPM) is a specialized tool designed to assess soil erosion and sediment yield (Gourfi et al. 2020). This model considers four crucial factors: surface geology, which encompasses rock and soil properties; topographic characteristics, including elevation and slope; climatic elements, such as rainfall intensity and temperature; and change of land cover patterns (Ennaji et al. 2024). The formula employed for calculating the mean annual gross erosion W (m^3/yr) is provided following this equation:

$$W(\mathrm{yr}) = T \times H_{\mathrm{yr}} \times \pi \times z^{3/2} \tag{1}$$

The measurement of the mean annual gross erosion (Wyear in m^3/yr) involves the utilization of the temperature coefficient (T), which can be determined through two methods: one based on the average of air and temperature (t in °C) and the other utilizing satellite images (Singh et al. 2011).The calculations are demonstrated below:

$$T = \left(\frac{t}{10} + 0.1\right)0.5 \tag{2}$$

The value of T represents the annual average of temperature (°C). Additionally, the intensity of erosion coefficient, denoted as z, is acquired using this equation:

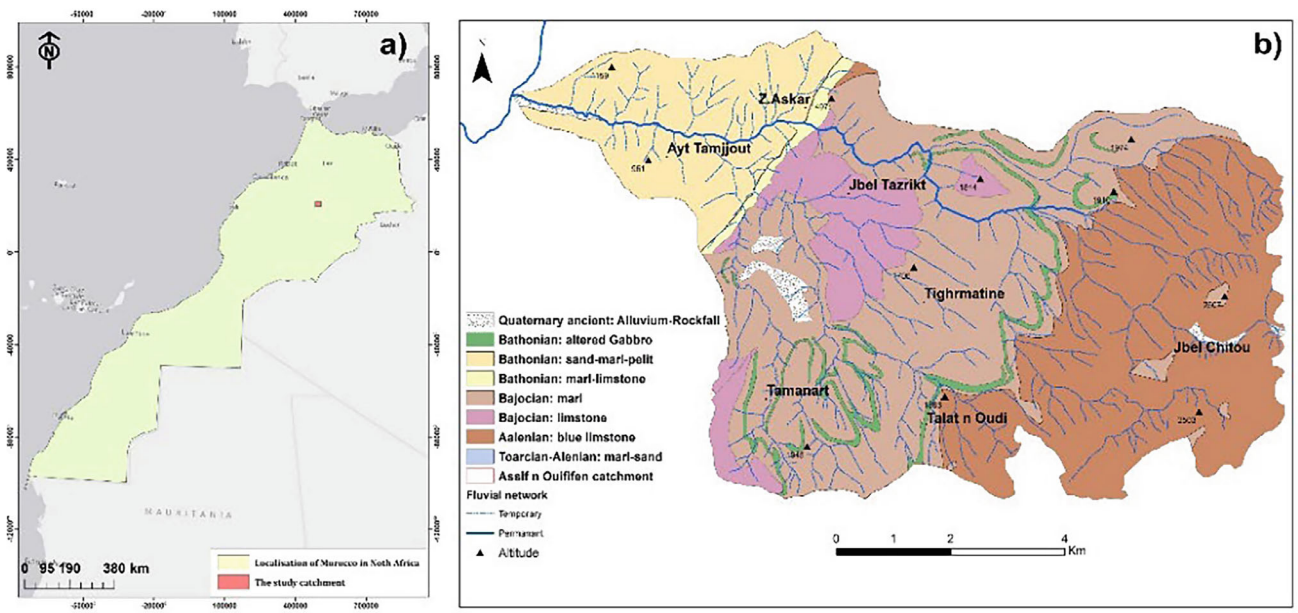


Fig. 1 Localization of Morocco within the North of Africa (**a**) and the lithology map of the studied catchment (**b**)

$$Z = Y \times X_a \times \left(\Psi + j_a^{0.5}\right) \quad (3)$$

The Y coefficient denotes the erosion resistance of the rock and soil, contingent upon the distinct geology and soil type, and it spans a range of 1–0.25(Singh et al. 2011). X_a is associated with the coefficient of land use, exhibiting a variability range from 1 to 0.05 (refer to Tables 2 and 3). Conversely, Ψ functions as the parameter representing the erosion process observed in the field, taking into consideration apparent erosion phenomena, and its values range from 1 to 0.1, contingent upon the degree of erosion severity.

2.2.2 Validation of the Model

The validation of EPM results is crucial to assess the accuracy and reliability of erosion predictions. In this context, a comprehensive fieldwork campaign was conducted, coupled with monitoring the dynamic changes of gullies over a 2-year period, spanning from 2020 to 2023. The fieldwork involved on-site observations, data collection, and measurements of erosion features, allowing researchers to compare the EPM's estimated erosion intensity coefficients with the actual erosion rates observed in the field.

3 Results

3.1 The Dynamic of Soil Erosion Rate

The presented Table 1 shows the results of factors used in the EPM model. Among the identified erosional types, "slight erosion" generally indicates a low level of erosion, which might not pose an immediate threat but still requires monitoring and conservation efforts to prevent further degradation. Moderate erosion indicates a higher level of soil loss compared to slight erosion and might have more significant impacts on the landscape and agricultural productivity.

Furthermore, "Heavy erosion" suggests a substantial loss of topsoil, which can lead to land degradation and reduced soil fertility. At the highest levels, "Strong and very high erosion" signifies severe soil loss, posing significant environmental challenges, including reduced water quality and increased sedimentation in water bodies. In the most extreme cases, "Excessive erosion" leads to the formation of badlands, characterized by severely eroded and barren landscapes. Rehabilitating badlands requires specialized restoration approaches to prevent further degradation. This comprehensive understanding of erosion types is crucial for planning effective soil conservation and erosion control measures in the region.

Table 1 Presentation of the factors of EPM results (Y, X_a, Z, and W)

Y			
Y coefficient	Degree of resistance	Area (ha)	Area (km^2)
<0.10	Hard rock erosion resistant	533.63	53
0.10–0.30	Rock moderate erosion resistance	397.593	04
0.30–0.60	Rock with little resistance	345.433	03
0.60–0.90	Rock without erosion resistance	577.926	06
X_a			
X_a coefficient	Degree of resistance	Area (ha)	Area (km^2)
<0.01	Dense forest and matorral	544.708	50
0.01–0.30	Damaged forest and dense matorral	1396.35	14
0.30–0.60	Cultivated land, mixed use land	2581.78	26
0.60–0.94	Rocky areas without vegetation and pastoral areas	2143.51	21
Z			
Z coefficient	Areas erosion categories	Area (ha)	Area (km^2)
0.13–0.33	Very slight erosion	3505.09	35.05
0.33–1.04	Slight erosion	753,98	7.530
1.04–2.03	Medium erosion	364.19	3.63
2.03–3.17	Areas strong erosion	1695.98	16.03
3.17–7.63	Severe erosion areas	334	4.01
W			
W coefficient (m^3/km^2/yr^{-1})	Erosion type and degraded areas		Area (ha) (%)	Area (km^2)
Slight erosion	1–1000 (slight)	5905.65	88.58	59.05
Moderate erosion	1001–2500 (moderate)	289.84	04.34	2.890
Heavy erosion	2501–3000 (high)	254.26	03.81	02.54
Strong and very high erosion	3000–4300 (very high)	170.63	02.55	01.70
Excessive erosion and badland	4301–6000 (severe)	36.03	0.74	0.36

3.2 Validation of EPM Model

Figure 2 illustrates two monitoring gullies that exhibited significant erosion dynamics, particularly widening, notably at the outlet of the study area.

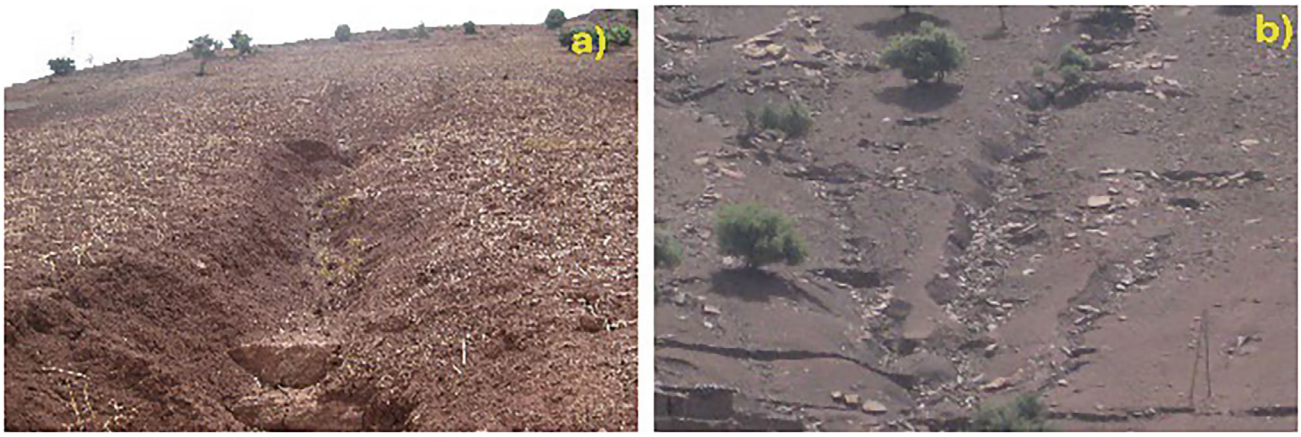


Fig. 2 Dynamic of gully erosion in the areas of red clays (**a**) and the marls (**b**) within the downstream of the studied catchment

The findings reveal a noteworthy progression in gully width, with an increase ranging from 0.5 to 23 cm^{-1} over the span of 2 years. The presence of this phenomenon can be attributed to various factors, including concentrated and intense rainfall patterns over specific periods and areas, the prevalence of fragile lithology mainly consisting of limestones and marls, and the local community's agricultural practices, which often involve excessive exploitation of natural resources (refer to Fig. 2).

4 Conclusion

To sum up, the High and Middle Atlas regions, particularly the studied catchment, face a pressing environmental issue of soil degradation. Agricultural practices and the presence of delicate lithology are among the key contributors to considerable soil loss rates in these areas. The research concentrated on analyzing soil erosion dynamics and spatial distribution within the Asif N Ouififen catchment in the Central High Atlas, utilizing the erosion potential model (EPM).

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Assessing the Impact of Fecal Pollution on Human Health Risks: A Study on Fecal Sludge Management in Northeastern Thailand

Achara Taweesan, Patimaphon Phuraya, and Thammarat Koottatep

Abstract

In the northeastern region of Thailand, the presence of liver fluke infections (LFI) persists despite the national policy of annual helminth infection control. This study aimed to evaluate the factors related to fecal sludge management (FSM) practices that impact the prevalence of LFI. Additionally, it aimed to develop a sanitation fecal sludge diagram (SFD) to assess the status of FSM practices in specific study areas: Khaem Subdistrict in Uthumphon Phisai District and Bu Sung Subdistrict in Wang Hin District, Sisaket Province. Data were collected through questionnaire surveys, in-depth interviews, and observations among 800 volunteer habitants. The factors considered in FSM practices encompassed socio-demographic characteristics, personal hygiene practices, and FSM behaviors. Multiple regression analysis was conducted by the statistical package for the social sciences (SPSS) to identify the factors significantly associated with LFI prevalence. A total of 598 responses (75%) were collected, and the missing data (25%) were obtained through key informant consultations. The characteristics of the participants in both study areas were mostly in the age group over 55 years, the upper elementary education group, the income group of <10,000 baht per month, and a majority of the participants identified themselves as farmers. In Khaem Subdistrict, the knowledge of LFI being <80% was identified as a significant factor associated with LFI. The consumption of fermented fish and the consumption of raw fish in spicy condiment were significant factors associated with LFI in the Bu Sung Subdistrict. The results indicated that a lack of knowledge about LFI and specific dietary habits were linked to higher infection rates. For overall fecal sludge management, the Khaem Subdistrict had 19% of safely managed facilities, while the Bu Sung Subdistrict had 16% of safely managed facilities. The study also revealed that both study areas had low rates of safely managed fecal sludge practices, emphasizing the need for regular monitoring, improved sanitation facilities, and behavioral changes to mitigate health risks. For this purpose, it is crucial to regularly initiate and promote the use of on-site sanitation facilities among the population.

Keywords

Fecal sludge management practices · Liver fluke infections · Sociodemographic factors · Personal hygiene · Northeastern Thailand · Helminth infection control measures

1 Introduction

Sanitation stands as a fundamental pillar for safeguarding human well-being, fostering child development, and propelling societal and economic progress. Regrettably, global access to basic sanitation remains inadequate, with a mere 68% of the world's population enjoying such facilities, and a paltry 39% having access to properly managed sanitation. This crisis is particularly pronounced in low- and middle-income nations, where the formidable challenge of fecal sludge management continues to escalate (WHO/UNICEF 2021). For instance, in Thailand, a seemingly promising 93% of households boast improved sanitation, as reported by WHO/UNICEF (2017). However, the issue of water contamination persists due to the dearth of suitable treatment infrastructures and inadequate maintenance

A. Taweesan (✉)
Department of Environmental Science, Faculty of Science, Ramkhamhaeng University, Bangkok, Thailand
e-mail: acharataweesan@gmail.com

P. Phuraya · T. Koottatep
School of Environment, Resources and Development, Asian Institute of Technology, Khlong Luang, Thailand

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of existing facilities. The unfortunate consequence is the direct discharge of sewage and septage into rivers, drains, wetlands, and landfills (AECOM International Development 2010), resulting in dire repercussions for both the environment and human health.

Within this intricate tapestry, fecal sludge management (FSM) emerges as a linchpin of public health infrastructure, casting a substantial influence over community well-being, and the broader ecosystem. In regions grappling with waterborne diseases, like Northeastern Thailand, effective FSM practices stand as an imperative bulwark against disease transmission and an enhancer of overall public health. Notably, the prevalence of liver fluke infections (LFI), a parasitic flatworm with grievous health implications, looms large in these areas. LFI, the root cause of liver fluke, inflicts a formidable health burden upon Northeastern Thailand, precipitating a spectrum of gastrointestinal and hepatobiliary disorders. The life cycle of LFI involves intermediary snail hosts and definitive fish hosts, with human infection predominantly stemming from the consumption of inadequately cooked or raw fish (Lustigman et al. 2012; WHO 2021). Thus, the efficacy of FSM practices assumes a pivotal role in breaking the transmission cycle of LFI by curtailing the contamination of water bodies with infected fecal matter, thereby tangibly diminishing the prevalence of LFI.

Despite the unequivocal significance of FSM practices, the extant status of these practices in Northeastern Thailand and their potential ramifications on LFI rates remain, regrettably, areas that have not been thoroughly explored. Further research is warranted to uncover the intricate interplay between FSM, waterborne diseases, and the health of communities in this region (WHO/UNICEF 2021; Thaewnongiew et al. 2014). The specific objectives of this study are as follows: (i) to assess and analyze the current state of fecal sludge management (FSM) practices in two communities in Northeastern Thailand with a high prevalence of LFI; (ii) to identify and examine factors related to FSM practices that may influence the prevalence of LFI within the studied communities; and (iii) to propose effective mitigation measures for FSM practices that are targeted at preventing the transmission of LFI and mitigating its impact on public health.

2 Methodology

The study conducted from January to March 2021 in two communities in Sisaket Province, namely Khaem Subdistrict, Uthumphon Phisai District, and Bu Sung Subdistrict, Wang Hin District (Fig. 1), aimed to investigate the relationship between fecal sludge management (FSM) practices and the prevalence of liver fluke infections (LFI). These communities were chosen due to their history of LFI prevalence and were selected based on a calculated sample size of 373 and 391 individuals for Khaem and Bu Sung Subdistricts, respectively, considering a 10% contingency. The decision to select approximately 1000 households for data collection was determined as detailed below (Mensah 2014).

$$n = \frac{Z^2 * p * (1 - p)}{E^2},$$

where: n is the required sample size

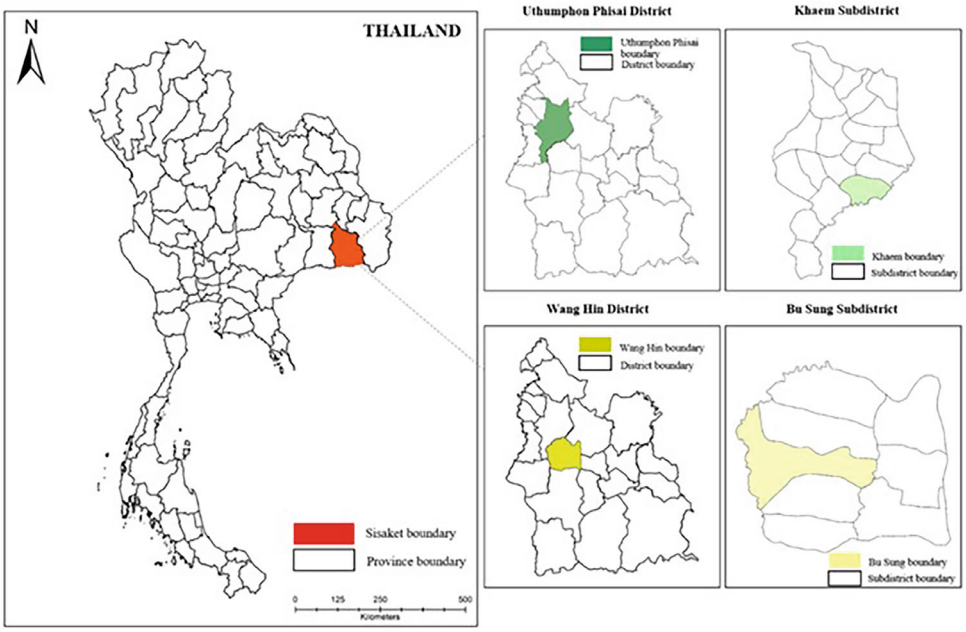


Fig. 1 Location of study areas in Sisaket Province

Z is the Z-value corresponding to the desired confidence level (1.96 for 95% confidence).

p is the estimated proportion of the population with the characteristic of interest (0.5 for maximum variability).

E is the margin of error (precision) desired for the estimate (0.3).

A random sampling technique was employed to select participants. The study utilized a cross-sectional descriptive approach with a quantitative research method. Socio-demographic, personal hygiene, and FSM practice data were collected through various tools, including questionnaire surveys, in-depth interviews, and observations. The collected information was categorized into socio-demographic characteristics, personal hygiene behaviors, and FSM practices. Prevalence data for LFI were obtained from helminth examination reports based on practical tests conducted between 2015 and 2019 at local hospital centers within communities. Helminths, parasitic worms that can infect humans and other animals, were the focus of these examinations.

To investigate the potential factors contributing to LFI prevalence, a multiple regression analysis was performed. The dependent variable included a range of FSM-related factors, such as socio-demographic aspects, personal hygiene behaviors, and specific FSM practices. These factors were examined in relation to the independent variable, which was the prevalence of LFI. The study aimed to identify significant factors emerging from the analysis of FSM practices and explore their connection with LFI prevalence. In conclusion, this study in two communities in Sisaket Province sought to understand the relationship between FSM practices and the prevalence of LFI. Through comprehensive data collection, analysis, and regression modeling, the study aimed to uncover significant factors within FSM practices that contribute to LFI prevalence. The findings of this research contribute to a deeper understanding of FSM practices and their impact on public health in the context of LFI prevalence.

3 Results and Discussion

3.1 Status of Existing FSM Practices in Specific Study Areas: Khaem Subdistrict in Uthumphon Phisai District and Bu Sung Subdistrict in Wang Hin District, Sisaket Province

For Khaem Subdistrict, the survey encompassed 371 participants across 12 villages, providing insights into fecal sludge management within households. The distribution of toilet types within households revealed that 100% had toilets, with 96% utilizing pour-flush toilets and 4% using flush toilets. On-site sanitation technologies predominantly featured single cesspools and a series of two cesspools. In terms of on-site sanitation technology output, approximately 94.3% exclusively received black water, while around 5.7% received a combination of graywater and blackwater. The SFD diagram for Khaem Subdistrict depicted the containment stage, showcasing single and two cesspools with specific characteristics. Interestingly, only 19% of excreta flow was considered safely managed, while the remaining 81% was categorized as unsafely managed.

For Bu Sung Subdistrict, the data collected from 364 individuals residing in 22 villages offered valuable insights into FSM practices within households in Bu Sung Subdistrict. The study revealed a predominant use of pour-flush toilets (77%) and flush toilets (23%), while on-site sanitation technologies varied between single cesspools, a series of two cesspools, and residential septic tanks. Approximately 82% of on-site sanitation facilities received exclusively black water, with the remaining 18% receiving a combination of graywater and blackwater. The SFD for Bu Sung Subdistrict depicted the containment stage, where only 16% of excreta flow was considered safely managed, underscoring the need for enhanced management practices. During the emptying stage, 84% of excreta from on-site sanitation facilities were emptied, primarily by the Bu Sung Subdistrict Municipality (84%), with the private sector and other local governments contributing to the rest. Notably, only 23% of emptied fecal sludge underwent proper treatment at the sludge drying bed, revealing a significant gap in effective treatment infrastructure.

3.2 Factors Related to FSM Practices and Their Impact on the Prevalence of LFI

3.2.1 Khaem Subdistrict

The study revealed that specific factors played distinct roles in influencing LFI prevalence. Notably, the age, history of defecation within 30 m of water bodies, knowledge of LFI, and emptying of fecal sludge by another local government nearby their area significantly contributed to LFI prevalence (Adjusted $R^2 = 0.31$) as shown in Fig. 2. This study suggests that several factors contribute to the prevalence of LFI in a particular area. These factors include the age of the population, a history of defecation near water bodies, knowledge gaps about proper sanitation practices, and the inadequate management of fecal sludge by another nearby local government. These elements collectively lead to unsanitary conditions and insufficient FSM, potentially contaminating water sources and increasing the risk of waterborne diseases. The proximity to water bodies and the potential influence of neighboring local govern-

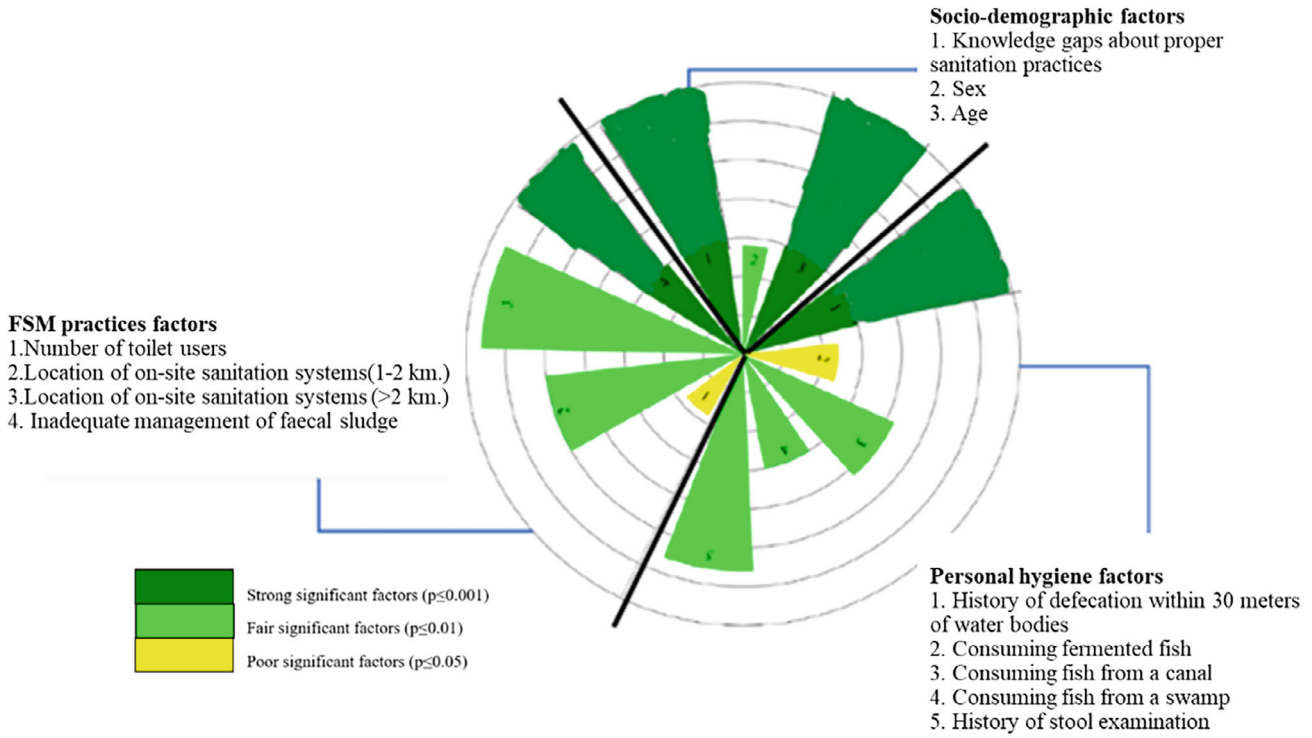


Fig. 2 Factors of the FSM services affecting the prevalence of LFI in Khaem subdistrict

ments further compounds the challenge, highlighting the need for comprehensive efforts to improve sanitation infrastructure, education, and collaborative governance for effective LFI reduction as mentioned by Koottatep et al. (2021) and Taweesan et al. (2015).

3.2.2 Bu Sung Subdistrict

The prevalence of lymphatic filariasis (LFI) in the Bu Sung Subdistrict is strongly influenced by specific factors. Firstly, the consumption of raw fish with spicy condiments and fermented fish without proper hygiene practices may contribute to foodborne illnesses, especially in areas with inadequate sanitation and limited access to clean water. These practices suggest a potential lack of awareness or facilities for proper food handling and storage. Secondly, the substantial impact of on-site sanitation systems located more than two kilometers away underscores the critical importance of accessible sanitation facilities. When sanitation options are distant and inconvenient, it can encourage open defecation and unsanitary waste disposal methods, contributing to the overall issue of LFI, as illustrated in Fig. 3. Addressing these factors necessitates a comprehensive approach that includes improved sanitation infrastructure, hygiene education, and enhanced accessibility to clean facilities (Suwannahitatorn et al. 2019; Nakbun et al. 2018).

4 Conclusion

In conclusion, this comprehensive study delved into the intricate relationships between various factors and the prevalence of LFI within two distinct communities in Northeastern Thailand, namely Khaem Subdistrict, Uthumphon Phisai District, and Bu Sung Subdistrict, Wang Hin District, Sisaket Province. By employing multiple regression analyses, the research uncovered significant factors influencing LFI rates in each community.

For Khaem Subdistrict, the analysis revealed that factors such as age, history of defecation within 30 m of water bodies, knowledge of LFI, and emptying of fecal sludge by another local government nearby their area exerted notable influences on LFI rates. These findings underlined the importance of knowledge dissemination and careful fecal sludge management practices to mitigate LFI risk. On the other hand, in Bu Sung Subdistrict, consuming raw fish with spicy condiments and fermented fish, and the location of on-site sanitation technologies more than two kilometers from water bodies emerged as influential factors affecting LFI. This emphasized the significance of dietary habits and the strategic placement of sanitation facilities in the prevention of LFI.

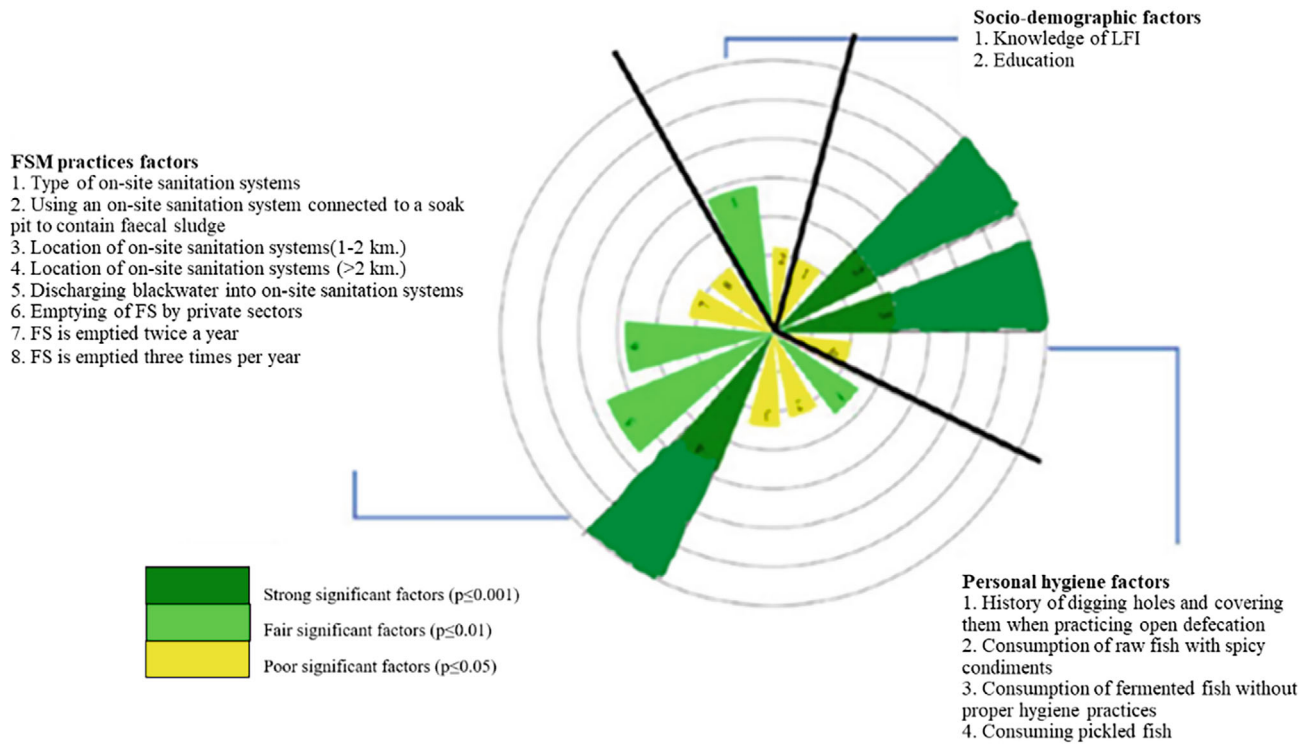


Fig. 3 Factors of the FSM services affecting the prevalence of LFI in Bu Sung subdistrict

The adjusted R^2 values of 0.31 and 0.26 for Khaem Subdistrict and Bu Sung Subdistrict, respectively, indicated moderately reliable models. The findings aligned with previous research, reinforcing the association between certain dietary practices, sanitation access, and LFI risk. Collectively, these results underscore the need for tailored interventions targeting specific factors to effectively combat LFI in these communities. Education campaigns promoting proper dietary habits, improved sanitation practices, and enhanced knowledge dissemination can play pivotal roles in reducing LFI rates. Furthermore, these findings contribute valuable insights that can inform public health strategies not only in the studied regions but also in similar contexts worldwide, ultimately working toward the betterment of community well-being and disease prevention.

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Long-Term Changes of Particulate Matter Concentrations and Source Contributions in Northern Thailand

Thongchai Kanabkaew, Nontawach Aek-akkararungroj , Jitarin Noomahun, and Supat Wangwongwatana

Abstract

This study aims to evaluate the changes in particulate matter concentrations during a 10-year period (2011–2020) and assess their source contributions. Air quality and meteorological data were collected from selected permanent air quality stations in the northern part of Thailand from the Pollution Control Department (PCD). The data were divided into two periods: Period 1 (2011–2015) and Period 2 (2016–2020). Statistical analysis was conducted to identify the differences in particulate matter concentrations between the two periods. Since $PM_{2.5}$ data were unavailable for Period 1, the analysis of concentration changes focused only on PM_{10}. Additionally, the conditional bivariate probability function (CBPF) was used to identify sources at a selected station in Chiang Mai Province. The results revealed significant differences ($p < 0.01$) in PM_{10} concentrations between the two periods, with concentrations around 5–10 $\mu g/m^3$ higher in Period 1 compared to Period 2. Both PM_{10} and $PM_{2.5}$ concentrations during the dry season (November–April) were significantly higher ($p < 0.01$) than those during the wet season (May–October). To identify sources, Chiang Mai, the largest city in terms of urban development and a major tourist area in the region, was explored. The CBPF analysis showed that PM_{10} and $PM_{2.5}$ during the 10-year period mainly originated from nearby and distant sources, which can possibly be attributed to traffic and biomass burning emissions, respectively.

Keywords

Particulate matters · Source identifications · Air quality assessment · Biomass burning · Conditional bivariate probability function

1 Introduction

Currently, Thailand is facing a significant air pollution problem, ranking among the top in the world, particularly concerning particulate matter with a diameter of <10 and 2.5 μm (known as PM_{10} and $PM_{2.5}$, respectively) (Son et al. 2023). This has been a persistent concern for several years due to its adverse effects on public health. As a result, there has been a call for government policies to manage particulate matter pollution, particularly $PM_{2.5}$ (UNFCCC 2023).

The areas mostly affected by air pollution and receiving significant attention from the population are mainly in and around Bangkok and its vicinity. These areas are densely populated due to their important economic hubs, tourist attractions, and industrial estates. The air pollution exceeding the standards has led to health concerns, particularly among vulnerable groups such as the elderly, children, and individuals with respiratory conditions (Kampa and Castanas 2008). Beyond the Bangkok metropolitan area, the northern region of Thailand has also experienced air pollution over the past several years. Chiang Mai, a significant tourist destination, has reported high concentrations of $PM_{2.5}$, making it the top-ranked city in the world for air pollution on certain occasions.

The study (Supasri et al. 2023) conducted in northern Thailand highlights the severe air pollution issues caused by biomass burning practices and traffic emissions, with associated health risks, particularly respiratory diseases attributed to particulate matter. Using disability-adjusted life years (DALYs) as a metric, these findings underscored the critical health implications of particulate matter pollution, empha-

T. Kanabkaew (✉) · N. Aek-akkararungroj · J. Noomahun · S. Wangwongwatana
Faculty of Public Health, Thammasat University, Pathumthani, Thailand
e-mail: thongchai.k@fph.tu.ac.th

T. Kanabkaew · S. Wangwongwatana
Collaborating Center for Clean Air and Climate Change (CCCACC), Thammasat University, Pathumthani, Thailand

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sizing the need for targeted interventions to mitigate the adverse effects of PM_{10} and $PM_{2.5}$ on public health in the region.

Various factors contribute to air pollution in northern Thailand, including natural factors related to weather changes and geographical features, such as the hilly terrain that traps pollutants. Human activities, such as open burning and high traffic density, also play a significant role. Due to favorable meteorological conditions and the addition of biomass burning emissions during the dry season, the concentrations of PM_{10} and $PM_{2.5}$ generally exceed the national ambient air quality standards (NAAQS). National and local governmental agencies have implemented several measures to reduce pollution in this northern region. Considering the severity of air pollution, studying the changing intensity of pollutants in the northern region of Thailand is crucial. The objectives of this study were to investigate the changes of PM_{10} and $PM_{2.5}$ during 2011–2020 and characterize the potential contribution sources.

2 Methods

In this study, the primary dataset comprised air quality data and related meteorological information (including wind speed and wind direction) collected from selected stations in the northern region of Thailand. The data spanned from 2011 to 2020. This aims to provide an understanding of the changes and intensities of air pollutants during the specified timeframe in the northern Thailand. The data will be based on the available information during that period. The station names and locations for the air quality monitoring stations in the northern region of Thailand used in this study are in Table 1.

To compare PM_{10} and $PM_{2.5}$, the dataset was divided into two time periods: Period 1 (2011–2015) and Period 2 (2016–2020), aiming to examine alterations in concentration differences. Statistical analysis using a t-test was employed to identify disparities in particulate matter concentrations between these two intervals. Given the absence of $PM_{2.5}$ data during Period 1, the assessment of concentration changes exclusively centered around PM_{10}.

For source identification, the study focused on Chiang Mai, the region largest urban center with significant urban development and a prominent tourist destination. The analysis utilized the conditional bivariate probability function (CBPF). This approach relies on assessing the likelihood of pollutant concentrations surpassing predefined thresholds corresponding to various wind speed and wind direction ranges. The CBPF value within each threshold range can pinpoint potential pollution emission sources influencing the monitored location (Uria-Tellaetxe and Carslaw 2014; Agibayeva et al. 2023). In this research, the analysis using CBPF involved utilizing data on PM_{10}, $PM_{2.5}$, wind speed, and wind direction obtained from station 36t (Yuparaj Wittayalai School, Chiang Mai).

3 Results

3.1 Changes of Particulate Matter Concentrations

From the study, it was found that the concentration of PM_{10} in Period 1 was generally higher compared to Period 2 at several stations with a significant difference of $p < 0.01$ (see Table 1). For instance, Station 35t in Chiang Mai had an average PM_{10} concentration of 41 $\mu g/m^3$ during Period 1, while it was 29 $\mu g/m^3$ during Period 2. Similarly, Station 73t (Chiang Rai) exhibited a decreasing trend in PM_{10} concentration during Period 2 (49 $\mu g/m^3$) comparing to Period 1 (59 $\mu g/m^3$). However, at some stations like Station 39t (Lampang), the average PM_{10} concentration during Period 2 (37 $\mu g/m^3$) was lower than that during Period 1 (40 $\mu g/m^3$).

Furthermore, we compared the PM_{10} and $PM_{2.5}$ concentrations during the burning season (November–April) and the non-burning season (May–October) (see Table 2). PM_{10} and $PM_{2.5}$ concentrations surge due to extensive agricultural burning and forest fires, exacerbated by dry and cool

Table 1 Mean PM_{10} concentrations in period 1 and period

Station code	Location and province	Mean PM_{10} (SD) in $\mu g/m^3$	
		Period 1	Period 2
35t	Chiang Mai Provincial Administrative Center, Chiang Mai	41 (32)	29 (19)
36t	Yuparaj Wittayalai School, Chiang Mai	44 (32)	47 (29)
37t	Lamphang Meteorological Station, Lampang	49 (39)	45 (35)
38t	Ban Sop Pada Health Promotion Hospital, Lampang	47 (32)	36 (29)
39t	Ban Dong Health Promotion Hospital, Lampang	37 (36)	40 (35)
40t	Mae Mo Regional Waterworks Authority, Lampang	48 (33)	45 (31)
57t	Chiang Rai Office of Natural Resources and Environment, Chiang Rai	46 (41)	41 (36)
73t	Mae Sai Public Health Office, Chiang Rai	58 (54)	49 (53)

Table 2 PM_{10} and $PM_{2.5}$ concentrations in burning and non-burning seasons

Station code	Mean PM_{10} (SD) in $\mu g/m^3$		Mean $PM_{2.5}$ (SD) in $\mu g/m^3$	
	Burning season	Non-burning season	Burning season	Non-burning season
35t	48 (32)	23 (11)	45 (33)	18 (9)
36t	61 (35)	30 (12)	44 (31)	16 (9)
37t	69 (39)	25 (14)	45 (28)	13 (8)
38t	56 (34)	25 (16)	36 (37)	24 (6)
39t	54 (43)	22 (12)	39 (32)	11 (12)
40t	65 (34)	27 (14)	43 (26)	12 (8)
57t	62 (46)	25 (15)	44 (40)	16 (17)
73t	74 (67)	31 (16)	60 (68)	16 (16)

weather. Conversely, in the non-burning season characterized by the wet season, PM_{10} and $PM_{2.5}$ concentrations tend to decrease as agricultural burning diminishes and rainfall helps to mitigate pollution. This comparison captures the interplay between seasonal variations, human activities, and environmental conditions regarding the variation in PM_{10} and $PM_{2.5}$ concentrations in the area. Results confirmed that the PM_{10} and $PM_{2.5}$ concentration during the burning season was consistently higher than that during the non-burning season. The differences in concentration were tested and found to be statistically significant at $p < 0.01$ using a *t*-test. For instance, at Station 36t (Chiang Mai), the average PM_{10} concentration during the burning season was 61 $\mu g/m^3$, whereas during the non-burning season, it was 30 $\mu g/m^3$. The average $PM_{2.5}$ concentration during the burning season was 44 $\mu g/m^3$, while during the non-burning season, it was 16 $\mu g/m^3$.

3.2 Source Contributions

CBPF plots of PM_{10} and $PM_{2.5}$ for Chiang Mai during 2011–2020 were indicated in Fig. 1. It was found that high concentration of PM_{10} was from the distant source while that for $PM_{2.5}$ high concentration was from both nearby and distant sources.

High PM_{10} concentrations primarily emanated from distant sources, suggesting external factors influenced their concentration. Conversely, elevated $PM_{2.5}$ concentrations were attributed to both nearby and distant sources, implying a dual influence of local and external factors on their presence.

4 Discussion

The study findings reveal significant temporal and seasonal variations in PM_{10} and $PM_{2.5}$ concentrations across different monitoring stations. During Period 1, PM_{10} concentrations were generally higher compared to Period 2 at several stations, with distinct variations observed. Furthermore, a seasonal analysis indicated consistently higher PM_{10} and $PM_{2.5}$ concentrations during the burning season, which spans from November to April, compared to the non-burning season from May to October. This suggests a clear influence of seasonal factors, possibly linked to biomass burning (forest fires and agricultural activities) (Nurzahziani et al. 2020) and meteorological conditions (Bran et al. 2022), on particle concentrations.

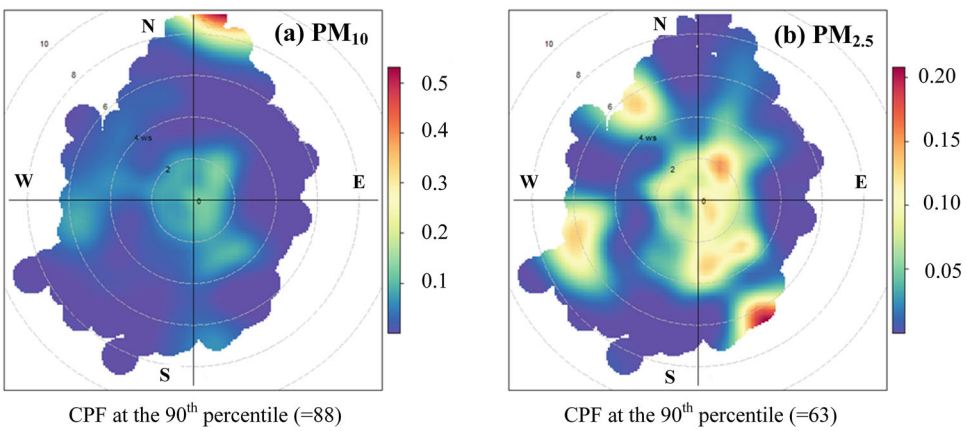


Fig. 1 CBPF plots of PM_{10} (**a**) and $PM_{2.5}$ (**b**) for Chiang Mai, Thailand

The CBPF plots illustrate the source contributions for PM_{10} and $PM_{2.5}$ concentrations in Chiang Mai between 2011 and 2020. The plots unveil distinct patterns: PM_{10} high concentrations were predominantly linked to distant sources, indicative of external influences shaping their concentrations. In contrast, elevated $PM_{2.5}$ concentrations exhibited a more complex origin, arising from both local and distant sources. This duality suggests an intricate interplay between emissions within the region such as traffic emissions and those transported from afar such as biomass burning emissions (Punsompong et al. 2021; Suriyawong et al. 2023).

The study underscores the intricate interplay of various factors, including local and external sources and atmospheric conditions that contribute to particulate matter pollution dynamics. The study approach enhances our understanding of the diverse origins of particulate matter, contributing valuable insights for devising effective air quality management strategies tailored to the specific sources (Tiyapairat 2012; Pardthaisong et al. 2018) influencing PM_{10} and $PM_{2.5}$ concentrations in Chiang Mai and northern Thailand.

5 Conclusions

The comprehensive analysis of particulate matter concentrations in Chiang Mai and northern Thailand offers an understanding of air quality dynamics. Findings reveal temporal variations, with PM_{10} concentrations during Period 1 often surpassing Period 2 at various stations. Seasonal trends consistently show higher PM_{10} and $PM_{2.5}$ concentrations during the burning season. CBPF plots highlight distant source dominance for PM_{10} and complex local-distant interplay for $PM_{2.5}$. Based on our results, the observed decreasing trend of PM_{10} during the 10-year period can be attributed to the rigorous implementation of measures. However, it is crucial to continuously implement, monitor, and evaluate these measures as both PM_{10} and $PM_{2.5}$ concentrations still exceed Thailand's NAAQS, particularly in the dry season. This study provides vital insights into particulate matter origins, serving as a foundation for tailored air quality management strategies. Acknowledging diverse sources empowers policymakers to mitigate pollution, fostering healthier environments and public well-being in Chiang Mai and northern Thailand.

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The Flooding Events of September 2022 in the Marche Region (Central Italy): Disaster Analysis and Solutions for the Reduction of Hydraulic Risk

Piero Farabollini, Fabrizio Bendia, Margherita Bufalini, and Marco Materazzi

Abstract

On 15th and 16th September 2022, the territory of the Marche Region (in central Italy) experienced a very intense meteorological event with an amount of rain fell in 5–6 h in correspondence of some rain gauges of 419 mm/m^2 (at Cantiano), 380.8 mm (at Frontone), 197 mm (at Sassoferrato), and 10.4 mm/m^2 (at Senigallia). The highest intensity of the event has been recorded in the inner areas close to the Apennines ridge, where a lot of landslides and hydraulic problems, mostly affecting the minor hydrographic network, occurred. Following, along the middle-lower sector of the hydrographic basins, flooding phenomena caused 13 victims and diffused damages to buildings and infrastructures. The cost of the reconstruction was estimated at one billion euros. The town of Senigallia, an important historical, cultural, and tourist town of around 40,000 inhabitants located at the mouth of the Misa River was entirely flooded and one of the most injured localities. This work aims to collect all the data available (oral witnesses, official data provided by the institutions, and detailed aerial and field surveys) in order to provide a detailed reconstruction of the event. All data will be organized and managed using geographic information system and performed with hydrologic-hydraulic numerical models (HEC-HMS, HEC-RAS). The multidisciplinary approach allowed us to estimate the maximum flood discharge with return times of 50, 100, and 200 years. The results of the present study will be used to suggest proper intervention and solutions in order to prevent future disasters both in the inner areas and in the urban territory of Senigallia.

Keywords

Flood events · Hydrological-hydraulic models · Hydraulic risk reduction · Senigallia

1 Introduction

The intense rain fell during September 2022 in the Marche region, although it occurred mostly in the Apennine area, also affected the entire foothill portion up to the river mouth. Data recorded by the "Sistema Informativo Regionale Meteo-Idro-Pluviometrico" monitoring systems of the Civil Protection of Marche Region (Sistema Informativo Regionale Meteo-Idro-Pluviometrico (SIRMIP) 2020) show that in the afternoon-evening of the September 15th, 2022, the rainfall intensity recorded at the rain gauge in Cantiano (PU) was the most intense in the last 10 years. In particular, the cumulative rainfall recorded on this day was 419 mm/m^2 (Fig. 1).

It is not possible to quantitatively define the data of the flood and the quantities of flowing water because the study involved many streams and thus many hydraulic sections and because it is impossible to quantify the actual flow rate as this can be affected by several factors. In particular, it can be influenced by the presence of transported sediment rather than the presence of transported live vegetation (trees, trunks, and other material eradicated from the riverbed), which could incisively distort the measurement of the flow rate in any section.

However, we can say that the maximum flood discharge at the Misa River mouth has been calculated with Giandotti's method and a return time of 200 years in 607.24 m^3/s (Assetto di Progetto media e bassa valle del fiume Misa 2016).

Unfortunately, the flood caused thirteen victims and created damage to structures and infrastructures, bringing out all the critical issues of an anthropized area with a widespread lack of river network management.

P. Farabollini · F. Bendia (✉) · M. Bufalini · M. Materazzi
School of Science and Technology—Geology Division, University of Camerino, Camerino, Italy
e-mail: fabrizio.bendia@unicam.it

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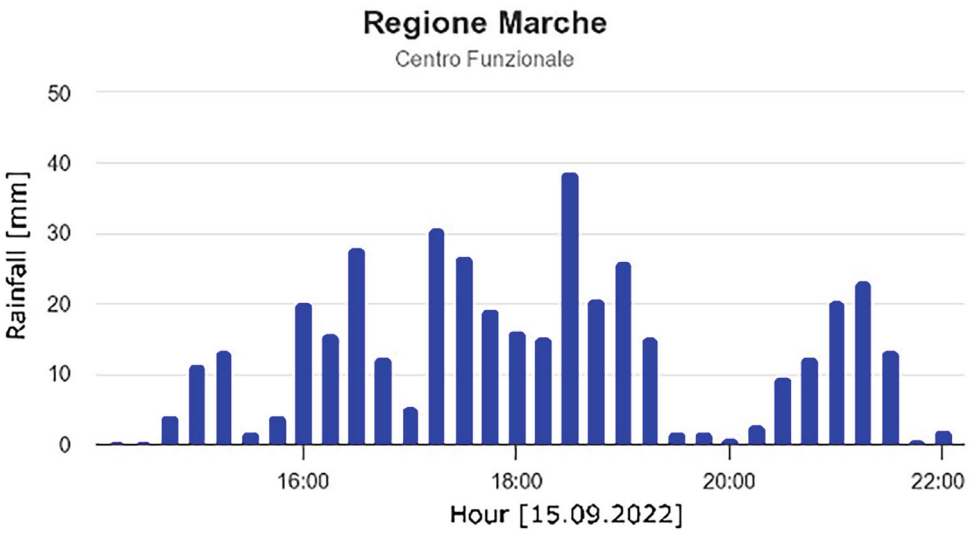


Fig. 1 Rain gauge of Cantiano (PU), sensor 2972

In this work, our research group carried out field surveys and hydrologic-hydraulic modelling in specific portions of the river basin to detect the critical issues encountered, intending to suggest interventions for hydrogeological and hydraulic risk mitigation.

2 Materials and Methods

The first part of the work involved the execution of field surveys along the valleys of the Burano, Metauro, Cesano, Misa, Nevola, Sentino and Sanguerone Rivers. The surveys covered the localities of Cantiano, Cagli, Serra Sant'Abbondio (province of Pesaro- Urbino), Sassoferrato, Pergola, Serra de' Conti, Senigallia (province of Ancona) (Fig. 2).

During the surveys, critical issues both in mountain and valley territory have been analyzed, each one with specific peculiar features. The river context can be considered very various because many waterways in the northern portion of the Marche Region have been interested in the flood and then analyzed by our research group, from their source to the confluence or mouth. Anyway, it is possible to define three different river environments: a western, purely mountainous, where rivers flow in narrow valleys within the Apennine limestone reliefs (Sassoferrato, Pergola, Serra Sant'Abbondio, Cagli, Cantiano). An intermediate one, characterized by wider valleys in the foothill area of the Apennine ridges (Serra De' Conti) and an easternmost, in which the watercourses have flow rates with totally different dynamics with respect to the others and they flow in almost exclusively flat environments close to the coastal area (Senigallia).

All the data have been collected in GIS software, where all useful thematic layers have been reported. Among these: the regional technical map; the cartography map of the Italian Military Geographic Institute; the historical maps of the



Fig. 2 Precise location of the Marche Region in Italy, with the areas covered by on-field surveys and object of interventions

Gregorian cadastre (to understand the hydrographic network modification interventions conducted in the past) (Coltorti et al. 1995); the shapefiles of the hydrographic networks and the catchment areas; the orthophotos acquired over several years for spatiotemporal analysis, the LIDaR digital elevation model; geological and geomorphological cartographies (CARG project); hydraulic and geomorphological hazard maps such as the "Piano di Assetto Idrogeologico (PAI);" the post-event cartography of the copernicus emergency management service; other post-event analysis maps drawn up by the technical offices of the interested municipalities and civil protection.

This work allowed us to survey all those areas where structures (both private and public) and infrastructures (bridges, roads, and pipes) were mostly damaged, defining each precise situation, to recognize the critical issues that caused it (both natural and anthropic origin). Secondly, it has been very useful to confirm or map new flooding or landslide areas (useful for future PAI updates). The final aim is to envisage interventions, to be implemented in the medium term, to reduce both hydraulic and hydrogeological risks.

3 Results

Rivers in mountainous areas show different characteristics with respect to those in foothill areas. The mountain ones present a steeper profile, their valleys have a narrower riverbed, and the watercourses often etch the geological bedrock (which in this Apennine section is predominantly represented by limestone and marly-limestone Formations). The hydrographic network is usually convoluted; this is attributable to a rocky riverbed and to the presence of many obstructions along the stream often originating from landslides, eroded bank portions or, sometimes, the presence of dead vegetation, which can partially occlude the flow diverting it. The landscape is usually rural, not much anthropized, except for some localized villages, and there is a large presence of wooded areas.

In these mountain reaches, the phenomena observed evidenced the presence of widespread landslides (also debris flows); the most critical issues were due to an improper anthropization of the territory (buildings within flood areas, undersized bridges and hydraulic crossings, channelization, presence of buried hydraulic weirs) (Surian and Rinaldi 2003), scarce or absent maintenance of the hydrographic network (presence of overflowing riverbed and occluded by vegetation which partially occluded the hydraulic section). It was precisely the poor maintenance of the riverbeds that led to the accumulation of dead vegetation near river crossings (bridges), causing them to flood on the upstream side and in all the surrounding areas due to the "dam effect" (Fig. 3b). The accumulation of the material often leads to the collapse of the bridge or of the temporary vegetation barrier, resulting in frightening floods pouring downstream, described by survivors as "walls of water," a "tsunami" capable of dragging anything away and therefore attribute to a "flash flood."

Riverbeds in valley areas show a totally different dynamic, with a lower profile but, as a consequence, greater flow rates and amplitude of the hydraulic section. Human action during the time acted subtracting to the river its floodplains, through embankment works, due to the need for more areas to be allocated to crops and, most recently, urban and industrial settlements.

Therefore, during a flood event, the river cannot dissipate its energy along the valleys, and it often overflows where the fluvial section is undersized or dangerous breakages in the riverbanks (due to structural deficiencies or animal burrows) are created (Fig. 3e). This can cause flooding events with large losses in human and socio-economic terms.

The poor maintenance of the riverbed has amplified the situation generating the same problems described above. This caused much greater damage with respect to the mountain areas because, in the last century, civilizations have developed more along the valley plains and, therefore, large cities have been involved (like the same Senigallia).

Other criticalities, also encountered in the mountain sectors, were referred to stretches of the river intubated, which sometimes exploded following the overpressures created during the flooding (as seen at Cantiano, Serra Sant'Abbondio and Sassoferrato), eroding and damaging the surrounding area.

4 Discussion and Conclusions

The possibility of managing geomorphological and hydraulic issues through GIS software, drone-acquired aerial imagery, and LiDAR surveys (Fig. 3d), availability of historical maps and thanks, to the specific support secured by the application of hydrologic-hydraulic numerical models (HEC-HMS, HEC-RAS) (Anees et al. 2016) made it possible to focus the problem and to dispose of a very detailed spatial overview, which allowed for multi-temporal and multi-scale confronts, useful for understanding the hydro-geomorphological dynamics of the various areas and the maximum flood discharge, evaluating different scenarios.

The suggested interventions in mountainous stretches mostly involved structural and non-structural interventions, such as the cleaning of the watercourse from dead vegetation in the riverbed, the restoration of the hydraulic sections, the raising of the embankment height, bank defense works (i.e., gabions, retaining walls, etc.), the restoring of hydraulic weirs filled with sediment, the

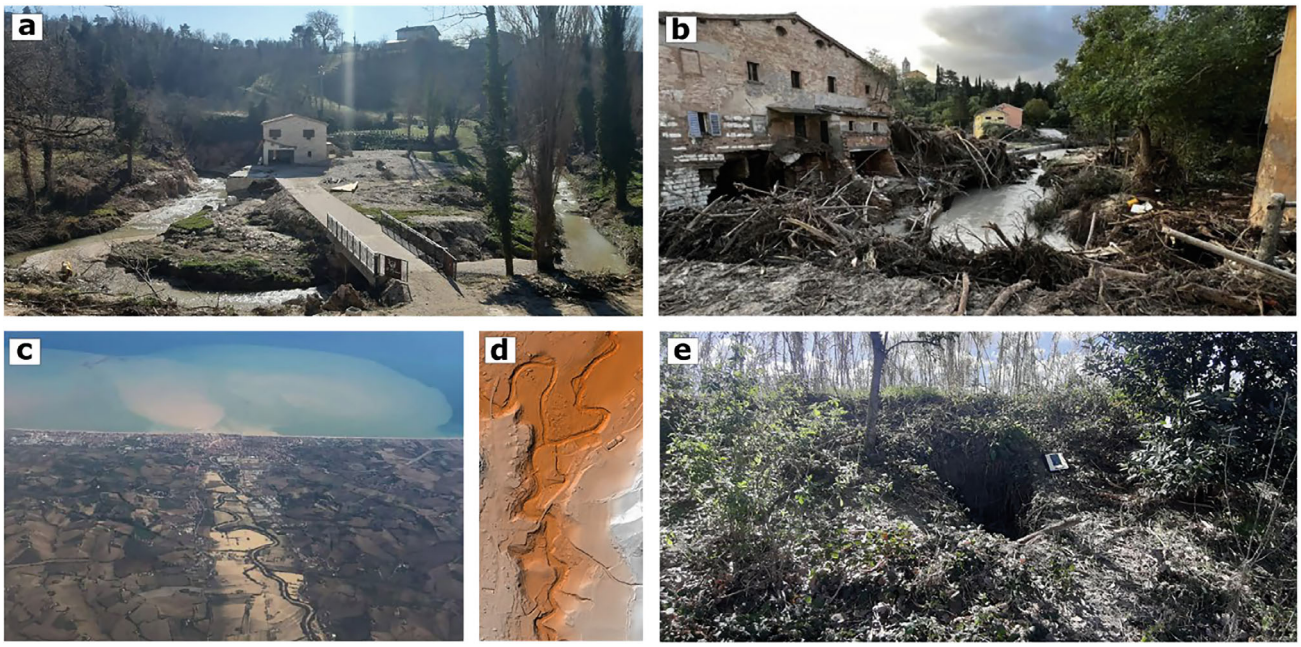


Fig. 3 **a** Post-event image of a completely flooded building in Sassoferrato; **b** the devastation in Pergola; **c** Misa River seen from above the day after the flooding; **d** LiDAR image caught by drone; **e** one of the metric burrows along the embankment in Misa River, Senigallia

restoring open-cut culverted sections where possible, and restoring damaged covers.

The abovementioned interventions were surveyed also in the foothill area. In addition to this, in the embankment sections, they were also detected discontinuous and heterogeneous embankment geometries, sometimes interested by cavities created by animal burrows (Ceccato et al. 2022), with variable heights above the surrounding alluvial plain, which made it necessary for its restoration and its constant maintenance during the time.

Furthermore, large portions of overflooded areas and river bars have been detected. This situation "drowned" the trees present in the riverbed and considerably reduced the outflow section, making a cleaning and restoration action necessary.

In the plain areas (in particular for different kilometers upstream from the Misa River mouth) a general disconnection between the watercourse and its floodplain has been detected, because of the presence of large embankments. This implies that during floods, the watercourse cannot meander into its alluvial areas, laminating its flow and also reducing its erosive potential, except as a result of ruinous breaches or overtopping of the embankment height (Fig. 3c).

Given the critical issues listed above, as also specified in Article 6, paragraph 1, letter b of the Italian normative "Norme Tecniche di Attuazione del Piano di stralcio di bacino per l'assetto idrogeologico" it is necessary, especially in correspondence of meanders, to implement a management strategy aimed to safeguard the natural hydraulic dynamics, with particular reference to flooding and morphological evolution of the riverbeds and to encourage the maintenance or restoration of the natural features of the hydrographic network. In detail, in some cases, it was necessary to re-establish the connection between the watercourse and its surrounding floodplain through the creation of appropriate breaches in the present embankment structure (exit and re-entry gates) that will allow the natural lamination of the flood into the surrounding floodplain, to give back to the river its natural flooding areas.

Ongoing climate change is increasingly leading to a tropicalization of the climate, which requires envisaging a new urban planning approach (Bufalini et al. 2019), aimed at providing for actions of demolition and relocation of buildings falling in vulnerable areas. In conditions where technical, administrative, and social impossibilities have prevented the possibility of implementing this process, interventions aimed at mitigating hydro-geomorphological risks have been individuated and suggested with the present work in specific technical tables made available to the administrators.

This study was conducted thanks to an agreement (STI532001-Accordo Regione Marche "Studi bacino fiume Misa-Nevola"-Farabollini) between the Geology Division of the University of Camerino and the Commissarial structure of the Marche Region aimed for risk mitigation in vulnerable areas.

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The Impact of Compositional Data in Environmental Risk Assessment Through Information Theory

María Pazo, Teresa Albuquerque, Rita Fonseca, Joana Araújo, Natália Mota, Roberto Silva, and Saki Gerassis

Abstract

A water system impacted by mining activities was assessed to determine the extent of contamination, in the Trimpancho River mining system, in Spain. This system is in the Iberian Pyritic Belt, a metallogenic province in the southwest region of the Iberian Peninsula. Related pollution has been studied by multiple authors in recent decades. However, a pollution geochemical signature is not yet defined, even if, a few elements such as Cd, Cr, Cu, Fe, Hg, Mn, Pb, and Zn reach critical values, much above legislation for surface waters. Mercury is responsible for the highest level of hazard and therefore is central to defining water pollution signatures associated with acid drainage. Water samples were collected at the surface level of the streams, acidified with nitric solution, and stored in dark glass (only for Hg) and polyethylene containers at 4 °C. Samples were digested with nitric and hydrochloric solutions in a high-pressure microwave unit and analyzed in ICP-OES for the majority of metals. Hg was directly analyzed in a mercury analyzer (NIC MA-3000). Since the chemical element concentration is compositional, an analysis was conducted to quantify how the uncertainty of the states of a to-be-predicted variable (mercury) is influenced by using both raw and centered log-ratio transformation (CLR) data. For that purpose, a methodology based on information theory (IT) and implemented through a Bayesian approach was used to about the obtained results, the normalized entropy decreased from 43 (raw data) to 33% (compositional data), and a contingency table fit of 21% (raw data) was obtained compared to 71% (compositional data).

Keywords

Iberian pyritic belt · Pollution geochemical signature · Compositional data · Information theory

1 Introduction

The compositional nature of geochemical data and other geo- and environmental sciences has been studied since the 1980s, when Aitchison and Shen (1980), Aitchison (1982, 1986) started delving into the development of *compositional data analysis* (CoDa), introducing what is now known as the *log-ratio approach.* Specifically, compositional data is a representation of the parts of a whole, where each of its positive components (D) belonging to a random vector (Z) carries only relative information (Pawlowsky-Glahn and Buccianti 2011).

In this sense, it is widely recognized that the analysis and interpretation of regionalized compositions treated as raw data, although still commonly practiced, can easily lead to spurious correlations (Pearson 1897; Pawlowsky-Glahn and Egozcue 2016). Hence, the adoption of log-ratio transformation stands endorsed in the realm of environmental sciences, notably within the domains of geology and geochemistry (Rollinson 1993; Schaeben et al. 2007; Boente et al. 2022). One particularity of these analysis domains, such as contaminant flow control, is that in the field of uncertainty and probabilistic risk analysis, we can observe that both aleatory or stochastic in situ uncertainty and epistemic or subjective in situ uncertainty are entirely dependent on the quantity and quality of the available data (Sagar et al. 2018).

Therefore, the present study introduces a novel methodology based on the information theory (IT) introduced by

M. Pazo (✉) · S. Gerassis
CINTECX, Universidade de Vigo, GESSMin Research Group, 36210 Vigo, Spain
e-mail: maria.pazo@uvigo.gal

T. Albuquerque
Instituto Politécnico de Castelo Branco, Polytechnic University, CERNAS, Castelo Branco, Portugal

T. Albuquerque · R. Fonseca · J. Araújo · N. Mota · R. Silva
Institute of Earth Sciences, School of Sciences and Technology, University of Évora, Évora, Portugal

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Claude Shannon (Shannon 1948). The proposed approach recognizes the inherent significance of information theory as a differential tool for uncertainty interpretation, thereby tapping into its potential for informed decision-making a pollution geochemical signature is not yet defined and conducting probabilistic risk analysis. In this context, it also addresses the need to establish a well-informed pollution geochemical signature. For these purposes, a Bayesian machine learning (BayesianML) framework was developed to systematically assess regionalized compositions treated as raw data and establish a comparison with transformed variables using the centered log-ratio transformation (clr).

2 Materials and Methods

2.1 Data Collection

The contamination levels of the Trimpancho River mining system in Spain, located in the metal-rich Iberian pyritic belt, were assessed. Water samples were collected from surface streams and tested for various elements including Al, Ca, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb, Zn, Sulfate, Phosphate, Nitrate, and Hg. For the analysis of the metallic elements, samples were acidified using a nitric solution, stored in polyethylene containers at 4 °C, and processed using a high-pressure microwave unit with nitric and hydrochloric solutions. Analysis was conducted using ICP-OES. Mercury was determined in refrigerated samples stored in dark glass containers, using a mercury analyzer (NIC MA-3000) based on thermal decomposition, gold amalgamation, and cold vapor atomic absorption spectroscopy detection. Nitrates, phosphates, and sulfates were analyzed in non-acidified samples, nitrates by a portable photometer, and phosphates and sulfates by UV–Vis spectrophotometry.

2.2 Data Transformation

The initial step of the analysis entails the transformation of the raw data to real space (clr-coefficients) based on the centered log-ratio transformation (clr) (Aitchison 1986). To that end, the compositional data transformation was performed using CoDaPack v2 software (Egozcue et al. 2011)

$$y = \mathrm{clr}(x) = \left[\ln \frac{x}{g_D(x)}\right] = \left[\ln \frac{x_1}{g_D(x)}, \ln \frac{x_2}{g_D(x)}, \ldots, \ln \frac{x_D}{g_D(x)}\right] \quad (1)$$

where $\mathbf{y} \in \mathbb{R}^{D-1}$ and $g_D(x)$ is the geometric mean of the parts involved.

2.3 Entropy and Mutual Information

The objective of knowledge modeling and reasoning with BayesianML is to anticipate and understand the consequences of uncertainty, whether positive or negative. For that, one can express the quantification of normalized uncertainty $H_n(x)$ associated with the probability distribution of a variable X or a set of variables G as (Shannon 1948; Conrady and Jouffe 2015):

$$H_n(X) = \frac{H(X)}{\log_2(\Phi_x)} = \frac{-\sum_{x \in X} p(x_i) \log_2(p(x_i))}{\log_2(\Phi_x)} \quad (2)$$

where $x_i, \ldots, x_n$ represent the potential outcomes of X, each occurring with a corresponding probability of $p(x_i), \ldots, p(x_n)$, while Φ_x represents the total number of states of a variable X. In addition to Shannon's entropy expression, another essential parameter in information theory is the mutual information (MI). The MI conceptually describes the interdependence between two variables, X and Y, by means of their information content. Mathematically, from an entropy perspective, MI can be expressed as:

$$MI(X, Y) = H(X) - H(X|Y) \quad (3)$$

where $H(X)$ represents the marginal entropy, and $H(X|Y)$ the conditional entropy.

3 Results

3.1 Exploratory Analysis

In the first stage of analysis, a primary Bayesian model is created to evaluate the association rate of variables in terms of probabilistic relationships between nodes (Fig. 1).

In Fig. 1, a significant improvement can be observed in uncovering potential relationships between variables when transformed compositional data is employed. Additionally, the uncertainty of the CoDa model was reduced from 43 (raw data) to 33%. Among these results, the most remarkable findings were seen in the contingency table fit of the compositional data model, with a significant 41% improvement versus the raw data BayesianML network, from 21 to 70%.

3.2 Supervised Analysis on Hg

Figure 2 shows the analysis of mutual information. The upper number in the box represents the information exchanged relative to the secondary node, while the red number refers to the main node. Otherwise, the symmetric

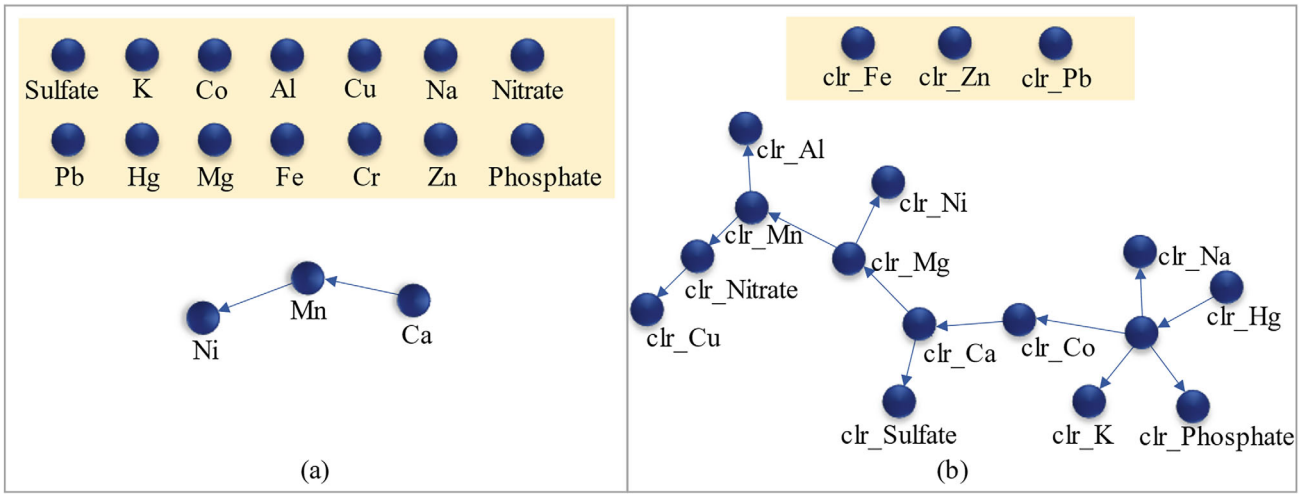


Fig. 1 Association rate analysis between **a** raw data, and **b** clr data

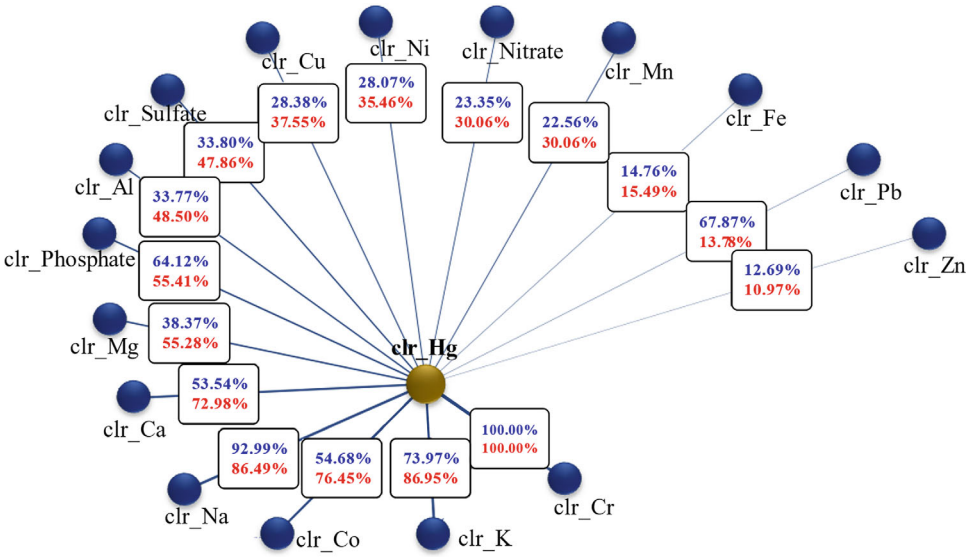


Fig. 2 Radial hierarchy layout from the highest-ranked node to the lowest-ranked information node

measure of the information exchanged between each node and the target node is graphically represented by the thickness of the arc and its distance from the target node. This symmetric representation means that the amount of information, for example, supplied by node K about Hg is the same as the amount of information Hg supplied about node K. Thanks to this information analysis, it is possible to identify the predictive importance of variables such as Cr, K, Co, Na, and Co for understanding the state of Hg, considering the available data set in February of 2022. A new campaign was conducted in February 2023 and the new dataset will be reflected in the calibration model.

4 Discussion

In mine exploration, environmental impacts, among others, the general focus, concerning geochemical signatures' definition is traditionally based on the uncertainty arising from sparse data and not on uncertainty arising from the model, even though the model is inferred, and its parameters estimated. The total Hg content of the Trimpancho River water in the present survey is the total Hg. The composition of Hg can be divided into different forms or pools, such as "dissolved" Hg, Hg associated with particulate and colloidal matter, volatile elemental Hg0, and labile (or reactive)

Hg(II) (Bank 2012). The predictive importance of variables such as Cr, K, and Co, for Mercury's fate interpretation, can be explained by the colloid particulate-bound in the Hg forms, which can have identical association with the signalized elements. Divalent mercury, readily soluble as $HgCl_2$, can finally explain the importance of Na, usually associated with Cl−, in the water column of Mediterranean Rivers.

5 Conclusions

Considering the definition of future geochemical signatures, for the Trimpancho River's pollution characterization, the relationships between elements must be evaluated considering the Hg contents in its dissolved forms, in the water column, as well as the forms in which this element occurs in the deposited sediments, which represent the largest pool of this element in these polymetallic-sulfide mining areas, which enrich in cinnabar (HgS).

The collected samples were log-centered transformed after which a BayesianML analysis was carried out using the information theory fundaments for uncertainty and mutual information quantification. The findings revealed a significant increase in understanding of the study area by exploring transformed analytical data. In addition, CoDa not only facilitated the identification of preferred associations but also provided a comprehensive framework for defining water pollution signatures. The authors believe that this approach will provide valuable insights that will pave the way for more effective management and mitigation strategies in the future.

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Sustainability and Aesthetics: Planning and Design of the Mining Industry in a Region

Soledad Bernardina Cabello Becerra, Elie Abou-Jaoude, and Rodrigo Estay Huidobro

Abstract

A new vision in mining must be established; the industry should no longer be regarded as an independent activity. Instead, resources must be managed properly to avoid impacting the environment and biodiversity. Therefore, this opportunity aims to identify the risks and impacts of mining in an Arctic region based on sustainability and the foundational pillars upon which it rests. The territory of Nunavut in Canada has become a precise area of study due to its high potential for mining gold, iron, and diamonds. However, it is situated in a region inhabited by the Inuit people, who prioritize traditional values such as gathering and hunting and possess a different worldview compared to the Western perspective. Thus, through indigenous research and experiential learning, the dynamics of the communities and their relationship with mining were evaluated to conduct a holistic analysis of sustainability in two operational open-pit gold mining projects: Meadowbank and Medialine. The same critical analysis was performed on three exploration projects: Naujaat, Angilak, and Qaiqtuq, involving diamond, uranium, and gold mining, respectively. This analysis revealed the anticipated economic, environmental, and social impacts for the future: high costs of investment, construction, operation, and closure; a geo-graphical environment affected by climate change and permafrost; and damage to the communities' identity. Therefore, solutions were considered in terms of social license, cultural identity, and circular economy. These included promoting art as a profession, fostering partnerships between companies, and increasing the development of basic services. In conclusion, it was found that the Inuit people would accept mining provided that they and their environment are considered throughout the entire process, minimizing negative effects on the ecosystem and without forcing them to renounce their cultural identity. This can be achieved through mining regulations and standards.

Keywords

Sustainability · Arctic region · Inuit · Experiential learning · Environment

1 Introduction

For decades, the mining industry was considered and analyzed as an isolated system, without considering the surrounding region, communities, and environment. This perspective has been evolving in recent years, with increasing emphasis placed on the concept of sustainability due to the experiences and voices of the people.

In mining, it is necessary to seek a balance between the pillars encompassed by the concept of sustainability: environmental, social, economic, and human, due to their interconnection. This aims to ensure the well-being of people by fulfilling their needs, not only in terms of material resources but also by optimizing their experience based on a design that adheres to sustainability and aesthetics.

Canada is one of the leading countries in mining, ranking among the top five worldwide producers of various resources. In the last 30 years, its less explored and inhabited sector has been under scrutiny due to its potential in the extractive industry: the Canadian Arctic (Minerals and Metals Facts 2023).

The resource potential in the area is as vast as its complexity, presenting challenges for communities, government, industry, and other stakeholders. There is a potentially positive economic impact, which in turn represents a risk

S. B. C. Becerra (✉) · R. E. Huidobro
Universidad Técnica Federico Santa María, Valparaíso, Chile
e-mail: soledad.cabello@sansano.usm.cl

E. Abou-Jaoude
McGill University, Montreal, QC, Canada

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to the way of life of the inhabitants and the environment. Additionally, high production costs and transportation (Encyclopedia Britannica 2022) difficulties are significant impediments for companies wishing to start operations in the region, as none of the communities have land connections, with complex climate and adverse terrain.

One of the territories in the far north of Canada is Nunavut, which has a population of 36,858, with 85% belonging to the Inuit indigenous people, distributed across 28 different communities in two million square kilometers (Statistics Canada 2022). All communities are located on the coast, except for Baker Lake.

The cold winters reach −40 °C, and the summers hover around 10 °C, resulting in constant snow and ice coverage, along with continuous permafrost underlying nearly the entire territory (Encyclopedia Britannica 2022).

For centuries, the Inuit lived a nomadic lifestyle, where the environment was dominated by kinship, with the unity of the family home and its relationships being an integral part of the community (Kral et al. 2011). Although by the mid-twentieth century most had adopted a semi-nomadic lifestyle involving hunting, fishing, and settled communities, relying on government support which began to promote the assimilation of Western life into the indigenous people.

Mining production began to consolidate in the mid-twentieth century. In 1956, the Rankin Inlet project commenced operations, extracting nickel until 1962 and becoming the first mine in Canada to employ indigenous workers (Cater and Keeling 2013). Today, the same site is home to the Medialine mine, owned by Agnico Eagle.

The same company also owns Meadowbank. This open-pit gold mine has been operating since 2010 and is located 110 km north of Baker Lake. This community has been a part of an economic transition and the negative social, cultural, and human effects it has brought (Moorhouse et al. 2020).

It should be noted that there has been a land claims agreement since 1993, which establishes the need for a land use planning regime and project assessment. The Nunavut Impact Review Board evaluates the implications of proposed projects for Nunavut (Mission of the Commission Responsible for Impact Assessment 2023).

2 Methodology

This study is conducted through the review and compilation of official reports from the territory of Nunavut, Canada, and mining companies, by investigating data that supports the identification of present risks in the region.

To identify these risks, it is essential to understand the history, context, social, cultural, and political realities of the people with whom one is working. The primary steps in risk analysis according to Pham (2011) include the recognition of threats and hazards, the identification of cause-and-effect relationships, and the weaknesses associated with risks.

For each identified ecosocial risk, the analytical technique "Event Tree Analysis" will be employed. This technique allows for the evaluation of the process and events leading to the risk, pinpointing the root cause of the impact. This facilitates the identification of prevention techniques, rather than merely mitigating losses (ICAO 2021). In this case, the technique will be applied qualitatively.

Once data collection, risk identification, and associated risk scenarios are completed, risk analysis begins with a risk matrix (Koivisto et al. 2009). This tool will assess those hazards that have the greatest impact and the highest likelihood of occurrence.

The placement of risks in the matrix largely depends on the context; therefore, it is important to thoroughly analyze the events and understand the individual circumstances of the organization or community (Ideagen 2021).

Finally, the experiential learning methodology is used, which, as described by the University of Illinois, is a philosophy that can be characterized as "…learning through experience and learning through discovery and exploration (NIU 2016)."

This approach is developed to seek solutions by considering real cases from the Kivalliq region (Meadowbank and Medialine), considering their mistakes and successes. This enables spatial planning in anticipation of exploration project.

3 Results

Through the investigation of the Baker Lake community and the influence of mining on the territory, ten ecosocial risks present in the region were identified. Each risk is critical in this specific community, particularly in recognizing the Inuit as a people who, within their perspective and forms of indigenous knowledge, do not perceive a separation between a person and their environment (Kral et al. 2011).

The ten risks are listed in Table 1, based on the quantitative and qualitative data obtained from the bibliographic information.

The Inuit heavily rely on their environment for their well-being, and the mining industry has led to changes in their way of life. Four critical issues have been identified that need

Table 1 Eco-social risks obtained from the Kivalliq region

1. Housing	6. Waste
2. Crime	7. Employment barriers
3. Caribou migration	8. Suicide
4. Health	9. Violence and sexual assault
5. Landscape disturbance	10. Food problems

to be addressed: forced relocation, Western assimilation and globalization, changes in lifestyle and economic activity due to the arrival of the mining industry, and political decisions arising from changes in the regulatory system.

The four critical points are linked to the experiences directly lived by the Inuit throughout their history. Forced relocation has led to restricted access to sedentary employment and education, which, in turn, is directly related to Western assimilation and has resulted in the introduction of diseases previously unknown to the population.

Changes in lifestyle—from being nomadic to sedentary, abandoning hunting, living in different and crowded buildings, and the arrival of unfamiliar industries affecting the landscape and the organization of wildlife—have caused distrust among the indigenous inhabitants of the Canadian Arctic.

4 Discussion

The research focuses on communities that, 70 years ago, were still nomadic, moving with the seasons in search of food and living off the land itself. In another 20 years, most of these people will have passed away, and with them, the new generations, already born in settlements, will have a different relationship with the land, thereby altering the conditions for mining companies.

Reducing, decreasing, and mitigating the risks presented by an industry when it begins to operate on ecosystems and communities is a crucial part of territorial planning. Solutions must be consistent with the ecosocial risks present in Kivalliq.

The two currently operational gold mining projects have brought both positive and negative impacts. On the one hand, income levels have increased, stimulating the local economy. However, simultaneously, certain social problems such as violence and substance abuse have begun to emerge and intensify.

In the case of exploration-phase projects, mining companies wishing to operate must invest in the communities: healthcare, infrastructure, and food services. This aims to prevent the existing housing and basic services crisis from worsening with the arrival of mining activities.

Both operational mines and exploration projects face similar socioeconomic and human challenges: implementing long-term recruitment and retention initiatives, aligning with Inuit culture, promoting work in other areas such as fishing and crafts, and mitigating pollution to avoid the deterioration of flora and fauna, among other issues.

There is still much to understand about the economic and social impacts of mining development on communities in a territory that will be undergoing changes with negative consequences due to climate change.

5 Conclusions

The communities living in the territory of Nunavut want their rights to be protected, as they must take on risks in a vulnerable ecosystem and wildlife. Although Meadowbank has been in production for over 10 years, there have been no significant improvements in terms of increased infrastructure, healthcare professionals, or food security.

Research indicates that the Inuit are experiencing a crisis of identity, making it essential to prioritize their needs, particularly in participatory institutional processes that lead to sustainability.

Communication and collaboration between indigenous leaders and local communities must be a key factor for companies to continue operating in the area, thereby securing a social license to operate.

The fragmentation of habitat caused by the mining industry is still under discussion. The land use plan will serve as a protective mechanism for the compromised ecosystem, whether due to dust, helicopter disturbances, traffic and lights, or potential contamination of animal food sources.

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Framework for Flood Mitigation Based on Analysis of European Past Floods Dataset

Suvechha Dhakal and Bipin Thapa Magar

Abstract

Floods have been an issue in most parts of the world, including Europe. Past research has been done to analyze the causes, effects, and mitigation measures. The research previously done has used different datasets for their analysis. Our research focuses on analyzing the "European Past Floods" dataset and the mitigation measures used in various parts of Europe to develop a general framework for flood mitigation and its effectiveness. We have collected the "European Past Floods" dataset from the European Union and used trend analysis on the dataset against various categories such as type of flood, effects, damage, fatalities, etc. The dataset displayed a high occurrence of fluvial floods followed by pluvial floods. The trend analysis yielded a decrease in fatalities while the total flood duration each year remained almost the same. Various mitigation measures implemented in various places are also researched to align them with the change in the dataset. We develop a list of various mitigation measures for the different types of floods. We combined the data and aligned them to form a general framework that illustrated how the types of floods have been mitigated and to what measure the trend has changed after the various measures. This gives a method to describe the effectiveness of various mitigation techniques for different cases. The framework can be used as a reference for other locations to apply their scenario to find the optimum mitigation measure to be used and their effectiveness based on past results. The research summarizes the flood dataset of Europe and the mitigation measures to provide a method for other countries to learn and implement the best measures easily and effectively.

Keywords

Flood · Trend analysis · Flood analysis framework · Optimum mitigation · Fluvial · Pluvial

1 Introduction

Flood has been a major issue all over Europe for a long time. Many reformation and mitigation techniques have been used across history but have been limited to a general area and their special circumstances. Although this approach has contributed to analyzing and mitigating the effects, the understanding of the flood impacts and the mitigation is not clear to be implemented in a different place or area. Even in different parts of Europe, people are not completely aware of their responsibilities before, during, and after the flood (Douglas et al. 2010). Further, mitigation strategies need to be resilient and methods of assessing their effectiveness are also important. So, this research focuses on generalizing the knowledge and experience gained from previous activities to help form a general framework that can represent the various types of floods and how they can be mitigated. For this, a literature review of various floods and their mitigation techniques and policies have been done along with the study of the "European Past Floods" dataset (Data.europa.eu 2023) to form a general framework for the two most evident types of floods: fluvial and pluvial, which it is expected to rise in the future (Kundzewicz and Pińskwar 2022).

S. Dhakal
Department of Civil Engineering, Sagarmatha Engineering College, Sanepa, Lalitpur, Nepal
e-mail: suvechha.dhakal@sagarmatha.edu.np

B. Thapa Magar (✉)
Department of Electronics and Computer Engineering, Sagarmatha Engineering College, Sanepa, Lalitpur, Nepal
e-mail: bipin.magar@sagarmatha.edu.np

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2 Methods

The research focuses on the study of various flood incidents in Europe in the past and how they have been mitigated by the various stakeholders involved. For this, the study has been supported by the "European Past Floods" dataset (Data.europa.eu 2023) provided by the European Union which contains information on past floods in Europe since 1980. The dataset comprises different attributes including the type, location, date, period, severity, damage dealt, etc. Although the dataset includes various features, this research selects severity and damage dealt as the major attributes to measure the trends in the flood's damage and assess the mitigation technique's impact factor. The impact has then been interpreted to draw up a framework that works as the basis for other regions or countries to mitigate the conditions in their area. The occurrence of different types of floods, along with their severity since 1980 and with the damage class, is represented in Figs. 1 and 2, respectively.

Figure 1 shows that fluvial floods are more severe and large in number than the other types mentioned, followed by pluvial floods. Similarly, Fig. 2 illustrates that fluvial floods have the highest number of damages followed by seawater and pluvial floods. It is expected that with the warming climate in the future, both pluvial and fluvial floods will rise (Kundzewicz and Pińskwar 2022). Hence, fluvial and pluvial floods are taken into consideration during the research to draw up the mitigation framework. For the mitigation measures, case studies from different countries across Europe along with their results have been collected.

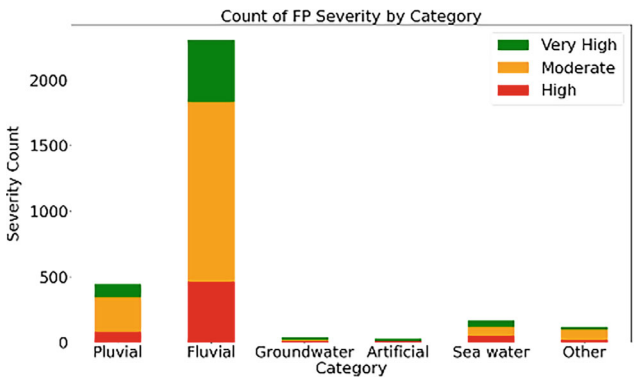


Fig. 1 Flood category versus severity count

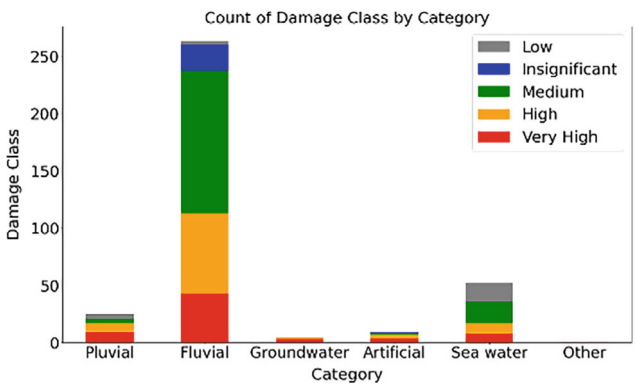


Fig. 2 Flood category versus damage count

In Spain, a 50-year paleoflood record was taken from the Pelayo River, which showed evidence of flash floods comprising either high magnitude and lower frequency or low magnitude but higher frequency (Díez-Herrero et al. 2013). This study has been limited to research, and the mitigation measures applied there can be used for other similar regions. A study of the Tormes River in Salamanca, Spain proposed a technique where they simulated the return flows so that the risk of future floods can be assessed (Criado and Martínez-Graña 2019). This could help the authorities plan for evacuation or human settlement outside risky areas. In a study of the mitigation alternatives of Navaluenga, Spain, geomorphologic data has been used to identify past floods followed by analysis and modeling to assess the best alternative for mitigation. The research resulted in the building of various dams along the tributary stream and a storm tank on the Chorreron stream (Ballesteros-Cánovas et al. 2013).

Poland is found to be susceptible to different types of floods, including pluvial, fluvial, seawater, and snowmelt. The two major reasons are the melting of ice and snow in spring and high rainfall in summer. For this, there are two solutions: "keep people away from water" or "keep water away from people" (Kundzewicz 2014). The article talks about three approaches: protection, accommodation, and retreat. Protection focuses on using techniques to protect from floods as much as possible. Accommodation refers to living with the flood and gradually learning, whereas retreat means moving away from the flood-prone areas. In the case of Poland, the primary measure has been structured to prevent the damages of floods like embankments and storage reservoirs. In recent years, people have been inclined toward legal restrictions and social awareness. Poland has also focused on developing early warning systems and terrain maps to assess risks. Any flood mitigation system should focus on combining all the technical and non-technical factors involved (Graf 2021). A study in southern Poland found that the perspectives of people and various stakeholders on a flood greatly differed. Although the government has been actively involved in mitigation, people are unaware of it, and social awareness is very important (Działek et al. 2013). Hence, Poland has a high focus on defense and preparation but is still growing in capacity building (Hegger et al. 2016).

A study in Norway focused on the pluvial floods caused by storms and how to manage them by transferring them to recharge groundwater (Boogaard et al. 2017). Digital elevation maps, used to find areas prone to urban flooding, and subsurface Sustainable Urban Drainage Systems (SuDS) have

been proposed. Pluvial and coastal flooding can also be related to subsidence and the use of sub-surface SuDS (Venvik et al. 2020). Norway also uses its National Flood Early Warning System (FEWS), which forecasts and provides information about flood levels. In addition, flood inundation maps are used to improve land use planning (Borsanyi 2014). A study in Norway after the 1995 flood highlighted a different perspective, finding that most people are unaware of the risk of flood (Krasovskaia et al. 2001).

Different countries employ different strategies from the perspective of government. Countries like Belgium, England, and the Netherlands have a clear division of responsibility between the various layers of government bodies, whereas Poland has difficulties in bottom-up decision-making (Fournier et al. 2016). So, an adaptive governance approach is suited. Also, government or private sector insurance is one of the techniques to cover up the losses (Suykens et al. 2016).

To sum up, the various techniques obtained from the research and the mitigation techniques that can be implemented have been grouped into four categories: flood mitigation structures, rules and policies, early warning systems, and social awareness.

3 Results

Figure 3 shows the total damage in each year since 1980. The figure illustrates that the damage over the years is almost stable with certain spikes, as seen in 2002. This sudden increase in damage in 2002 was caused due to record-breaking rainfall amounts and intensities in Central Europe. This alone caused approximately 9 billion Euros, 3 billion Euros, and 2.5 billion Euros for Germany, Austria, and the Czech Republic, respectively (Ulbrich et al. 2003). Similarly, in Fig. 4, number of fatalities, although irregular, is showing an overall decreasing trend. This is the result of the advancements in mitigation techniques and awareness with time.

The proposed framework is shown in Fig. 5. The framework covers two types of flood: fluvial and pluvial, and four areas of mitigation measures: flood mitigation structures, rules and policies, social awareness, and early warning systems.

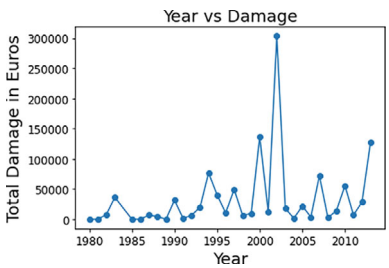


Fig. 3 Damage versus year

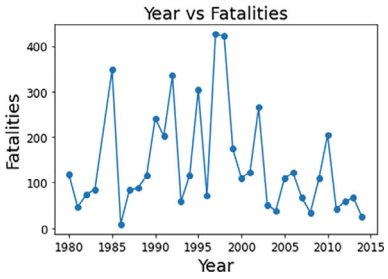


Fig. 4 Fatalities versus year

Firstly, flood mitigation structures are highly effective for both fluvial and pluvial floods. Similarly, in the case of fluvial floods, social awareness is equally effective. Although, for pluvial floods, it is found to be moderately effective. However, the development and adaptation of proper rules and policies are highly effective for pluvial floods. For fluvial floods, this is still relevant and effective although not as high as those mentioned before. Also, early warning systems are an effective measure against fluvial floods but it is found to be ineffective against pluvial floods. In addition to the relationship, examples of each of the mitigation measures have been included in Fig. 5 based on past case studies.

4 Discussion

The proposed framework is shown in Fig. 5. The framework focuses on the two major types of floods in the "European Past Floods" shown in Figs. 1 and 2. The study done previously is used to summarize the mitigation measures into four major categories, as shown in Fig. 5. The relationship between the type of flood and the mitigation measure is evaluated using a review of studies and reports and analysis of the dataset.

For fluvial floods, flood mitigation structures, such as dykes, embankments, etc., are the most effective solution. Still, these are not sufficient to neutralize the impacts. The trend analysis of the dataset has shown that although these structures reduce the risks, they are also not sufficient, as seen in the flood of 2002 caused by continuous heavy rainfall (Risk Management Solutions 2003). It is found that many people are still ignorant about the effects on them as they feel safe, and hence, social awareness is a must. In addition to the above two, early warning systems, including forecasting, need to be implemented, which can reduce the damage by a huge factor. Finally, the current trend has been toward policies by federal and local authorities for flood-prone areas, which has given rise to adaptive techniques that revise the policies as required.

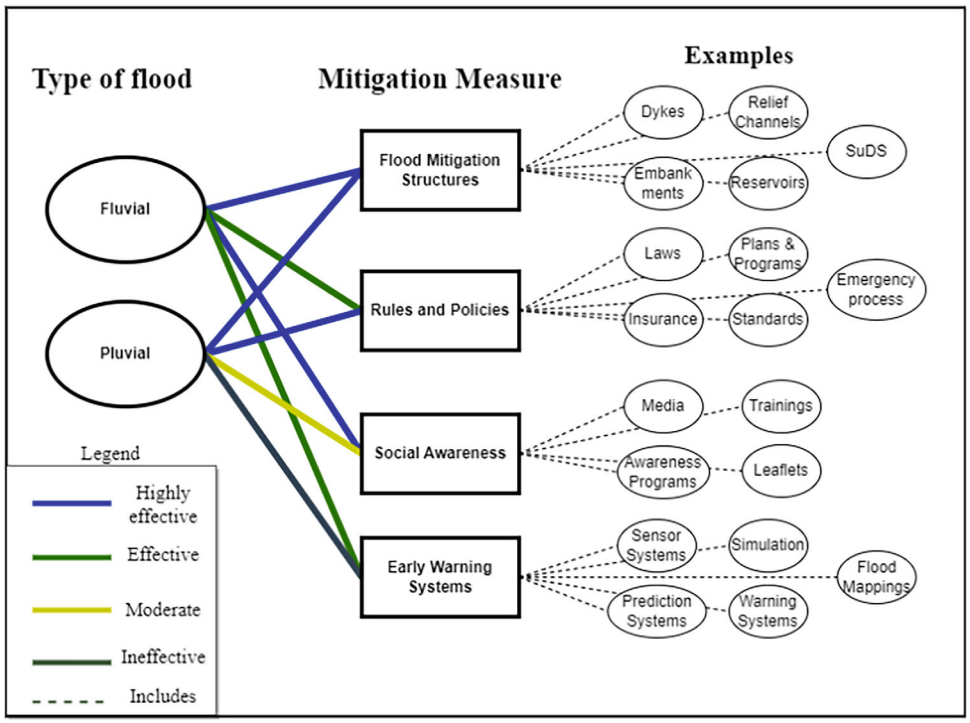


Fig. 5 Proposed framework for flood mitigation

In the case of pluvial floods, flood mitigation structures, including reservoirs, sub-surface SuDS, etc., are the immediate mode of mitigation. In addition, pluvial floods are mainly caused by improper urbanization and drainage and can be mitigated by implementing proper rules and policies from the associated authorities. Social awareness is an addition but plays a relatively small part in pluvial floods. Early warning systems have a significantly lower role in mitigating pluvial floods.

5 Conclusions

In conclusion, the analysis of the "European Past Floods" dataset underscores a significant prevalence of fluvial and pluvial floods. Fluvial floods have the highest severity and damage, followed by pluvial floods. Damage and fatalities have been decreasing every year in Europe but similar measures have not been implemented elsewhere yet. Hence, drawing from historical case studies from European countries, a categorization of mitigation measures into four distinct groups has been done. Additionally, the proposed general framework establishes a correlation between pluvial and fluvial floods and these four major mitigation categories, along with selected examples. The relationship has been quantified which facilitates the formulation of flood mitigation plans adaptable to diverse geographical contexts. Consequently, this reference framework serves as a tool for implementing mitigation strategies based on the specific flood risk profiles of different regions.

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Mapping Lightning Strikes Across Gujarat State for the Year 2022 and Development of Prediction Model

Pratyush Rao, Gautam Shah, Nimit Savant, Seema Lakhani, Pallavi Ghalsasi, and Alok Taori

Abstract

The world is witnessing rapidly changing climatic conditions. "Lightning" is considered as a natural disaster as it accounts for more than 40% of the deaths occurring due to weather-related disasters. To monitor lightning occurrences over India and help the Government build a robust disaster management system, the National Remote Sensing Centre (NRSC), ISRO, Hyderabad has established a network of long-range lightning detection sensors (LDS). The present study is focused on mapping lightning incidents in the state of Gujarat for the year 2022 and determining vulnerable locations. The extended objective was also to develop a prediction model that aims to help the Government implement protective policies in the vulnerable geographical regions. The mapping of lightning was done using QGIS software and the data has been analyzed with respect to various parameters like elevation, land coverage, and weather parameters. Further, a prediction model based on machine learning classification method called XGBoost has been developed. Our studies have shown that during monsoon season, most of the lightning strikes happen where the elevation is less than 30 m above sea level and post-monsoon the built area poses a serious concern. The vulnerability of strikes also increases when the temperatures are between 21 and 30 °C and wind speed is between 1 and 4 m/s. Our prediction model could predict 87% of records correctly with some limitations. Present research work can be further extended over larger geographical regions and longer time periods and represents a very novel and unique approach to study causative factors behind lightning incidents.

Keywords

Lightning · Lightning detection sensors · Vulnerable locations · Mapping · Elevation · Land coverage · Weather parameters · Prediction model

1 Introduction

Cloud-to-ground (CG) lightning happens when dielectric breakdown takes place in the air followed by electrostatic discharge through which the charged atmospheric regions temporarily equalize themselves and create a giant spark (Rakov and Uman 2003). Lightning is a known worldwide disaster as per the World Meteorological Organization (WMO) and it is noted that over India majority of weather-related deaths occur due to lightning (Taori et al. 2023). To monitor lightning occurrences over India, the National Remote Sensing Centre (NRSC), ISRO has established a network of long-range lightning detection sensors (LDS) under the National Information System for Climate and Environment Studies (NICES) program (Taori et al. 2023). In the present article, we have mapped lightning incidents in the state of Gujarat for the year 2022 and have analyzed their occurrences with respect to various parameters. We have also developed a prediction model that aims to foresee these fatal events.

2 Materials and Methods

The wide network of LDS installed by NRSC, ISRO, Hyderabad provided the data for the entire state of Gujarat. Lightning was correlated with weather dependent factors

P. Rao · G. Shah · N. Savant · S. Lakhani · P. Ghalsasi (✉)
School of Engineering and Technology, Navrachana University, Vadodara, Gujarat, India
e-mail: pallavig@nuv.ac.in

A. Taori
National Remote Sensing Center (NRSC), Indian Space Research Organization (ISRO), Hyderabad, India

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and the data pertaining to these factors was carefully selected and obtained from reputable repositories (NOAA National severe storms laboratory. http://www.nssl.noaa.gov, National Remote Sensing Center, NRSC. https://bhuvan-app1.nrsc.gov.in/lightning, Open-Meteo Homepage. https://open-meteo.com, National Weather Service Homepage. http://www.weather.gov, Food and Agriculture Organization of the United Nations Homepage. http://www.Fao.org, Copernicus Climate Data Store Homepage. http://www.cds.climate.copernicus.eu, DIVA-GIS Homepage. http://www.Diva-Gis.org, ArcGIS Homepage. http://www.livingatlas.arcgis.com). Lightning data was mapped on the state of Gujarat using QGIS software. Gujarat state district shape file was used as a base map and was overlaid by lightning data containing the geographical coordinates.

In Gujarat, cloud-to-ground lightning strikes have been a rare phenomenon. The dataset engineered to use for this prediction model consists of date, coordinates of a region, minimum and maximum temperature on a given date, minimum and maximum apparent temperature on the said date, wind speed, total rain received, total number of hours it precipitated for, shortwave radiation, and count of lightning strikes. The prediction approach known as a classification model (with bins defined as 0—no strikes, 1—more than 0 strikes) with which intensity of lightning strikes received in the region is predicted instead of the exact number of lightning strikes. In order to develop a model to be more sensitive toward detecting the outliers, majority of records that have zero lightning strikes were deleted.

3 Results

3.1 Mapping of Lightning Data

In order to understand the possible factors responsible for lightning, the data related to lightning was mapped with land coverage and simulated weather data. The GRIB/raster files for each factor (elevation, land coverage) were compared to the monthly aggregated level incidents, whereas for wind speed/direction and temperature the lightning data was compared on the maximum lightning day.

It is observed that February, May, November, and December received almost no lightning strikes, whereas during June–August almost all regions in the state received lightning strikes. The month of September received maximum lightning strikes likely due to convective activity. The most vulnerable locations shifted from northeast to southwest (January–April 2022), from southwest to southeast and northeast (May–June 2022), southeast locations (July–August 2022) and shifted from northeast to northwest. Finally, during September to December, the vulnerable locations remained in southeast.

It is found that except for the months of July–September, medium-to-highest elevation regions (30–1065 m above mean sea level) receive maximum lightning strikes. During these monsoon months maximum lightning strikes happen in medium-to-lowest elevation (<30 m above mean sea level). Comparison of the data to the land coverage map of Gujarat shows that during monsoon season, regions with proximity to water bodies and forest received more strikes than the urban spread, whereas the focus has also been the built area from September till November. Figure 1 shows aggregated mapped data for the months of August and September 2022.

It was observed that the wind speed was low around 1–4 m/s in the regions that attracted maximum lightning strikes. Strikes were also observed to happen in the regions when winds curl with speed mostly low (0–2 m/s). For almost all of the observed instances with lightning strikes have a temperature between 21 and 30 °C.

3.2 Prediction Model

The dataset included around 630 k records, out of which only 33 k were related to cloud-to-ground lightning strikes. So, 500 k zero records were deleted for this model to be developed without overfitting on the dataset. The model was trained on the dataset using the attributes mentioned in the introduction and a tree-based algorithm, XGBoost, (Géron 2019) was used which did not require excessive scaling. Figure 2 is a confusion matrix obtained wherein the y-axis shows actual bins of the lightning strikes and the x-axis gives the values predicted by the model. The matrix implies correctly predicted instances across the diagonal. The model gave a precision predicting 0 as 87% and 1 as 86%. The recall score for 0 is 86%, indicating that out of all the 0 s 86 percent of them have been classified correctly, and the recall for 1 is 87%.

4 Discussion

Observed lightning strikes from low-altitude regions during monsoon may be related to the formation of multilayer clouds. The contribution of built areas to lightning during October needs to be investigated more in terms of population study, urbanization, pollution, etc. Deceleration of wind speed was also seen to be responsible for lightning.

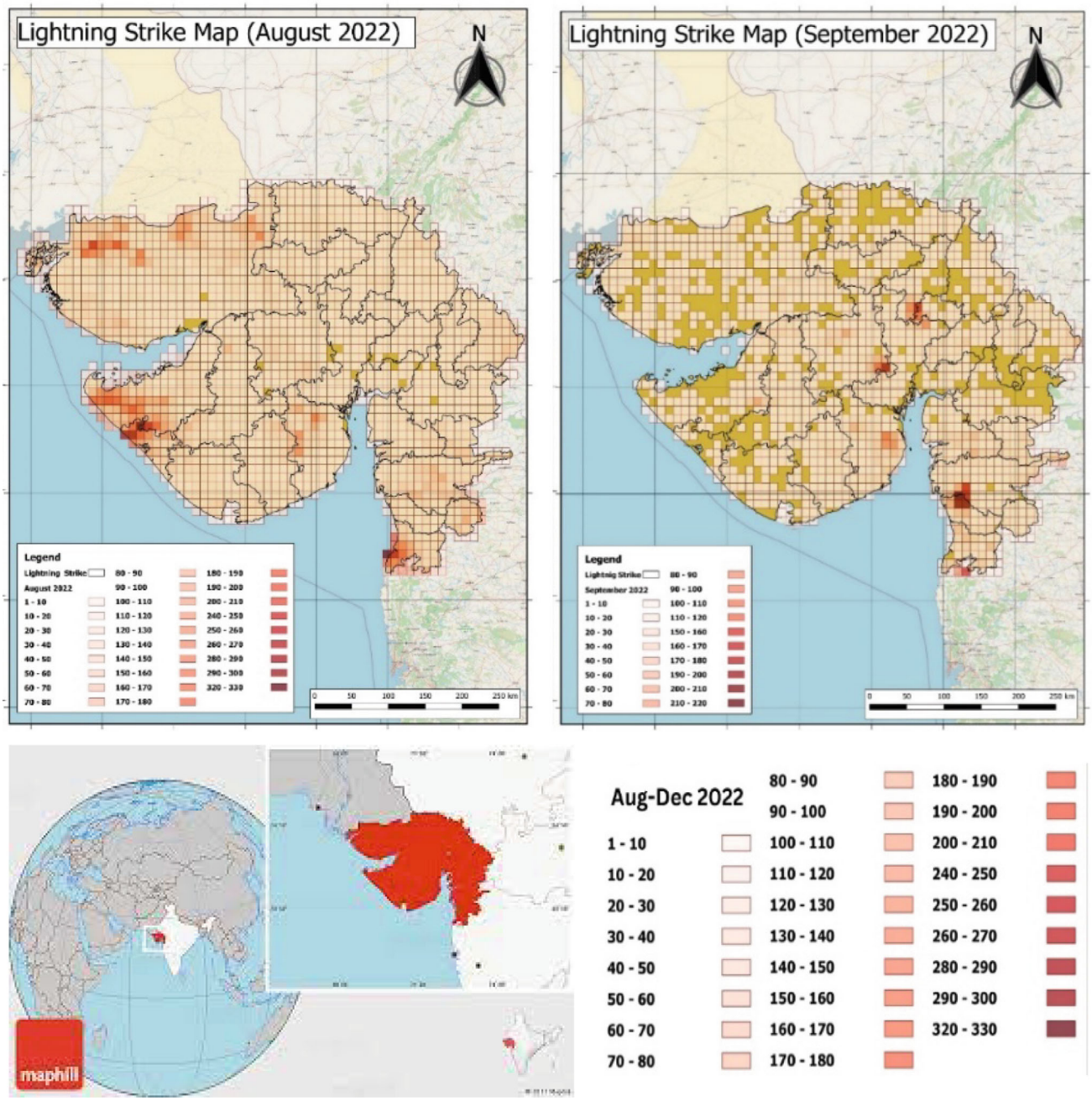


Fig. 1 Lightning data aggregated for August and September 2022 months, mapped against the district map of Gujarat state. Inset of state map on global map taken from www.maphill.com

The prediction model successfully predicted 87% of the records correctly. There is a 17.1% chance of a false alarm, and a 12.98% chance that it will be predicted to be low but there will be severe lightning strikes. The probability in the latter half is known as a Type 2 error and must be absolutely avoided. The model posed a number of limitations based on dataset sources through different APIs, simulated dataset instead of actual dataset, limited time duration for sampling, and deletion of zero records.

5 Conclusions

This work enabled the authors to comment on how climatic and demographic factors affect the frequency and distribution of lightning strikes and the vulnerable locations for lightning across the state of Gujarat. The mapping is being extended for a longer time period and the prediction model is being refined by the authors.

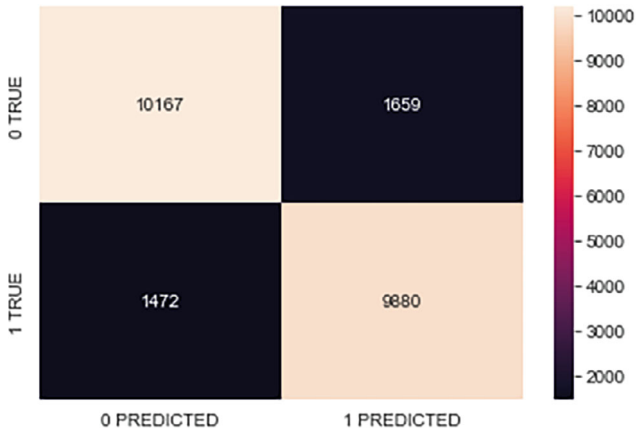


Fig. 2 Confusion matrix

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Soil Radioactivity Levels and Ionizing Radiation Hazard Occurrence in the Crati Basin, Calabria (Southern Italy)

Ilaria Guagliardi, Tommaso Caloiero, Nicola Ricca, and Ernesto Infusino

Abstract

The natural materials, as rocks, soil, vegetation and groundwater, contain radioisotopes which are subjected to the process of the radioactive decay that creates terrestrial radiation. It consists of Ionizing Radiation (IR) or Non-Ionizing Radiation (NIR). NIR is a form of radiation with less energy than ionizing radiation. The process does not involve the removal of electrons from atoms or molecules of materials. Conversely, IR is released when atoms and molecules lose electrons, affecting air, water and living tissue. IR can move invisible and access to human tissues altering the cells of human body and causing hazards such as skin or tissue damage. This study aims to assess the natural radioactivity levels in soil samples from the Crati basin, the largest basin in the Calabria region (southern Italy) and to calculate ionizing radiation hazard occurrence which can cause cell damages in the local inhabitants. The study area is lithologically formed by plutonic and metamorphic crystalline rocks of the Sila Massif, by crystalline and sedimentary rocks of the Coastal Chain and by carbonate and siliciclastic sedimentary rocks of the Pollino Massif. The climate of the area is largely influenced by its geography and its location in the middle of the Mediterranean region. A sensitive detector, including a Geiger–Muller tube with an external NaI (Tl) probe, was used for the survey. Results evidenced that the mean equivalent dose rate for natural sources of radiation in sampled soils is 90.38 μSv/h, with a maximum value of 195 μSv/h and a minimum of 55 μSv/h. The average radiation levels in the soil samples were higher than the global average dose rate values reported by UNSCEAR. However, the difference was not statistically significant enough to pose a fatal cancer risk to the population in the study area. The soil radioactivity levels in the Crati basin can be referred to the lithological types occurring in the area, which contain primary minerals responsible of the radionuclide's activity.

Keywords

Natural radioactivity · Soil · Dose rate · Calabria

1 Introduction

Radiation is a natural occurrence in the environment, and various surveys have been conducted to collect and validate environmental radioactivity data from natural sources. There are two main categories of natural sources of ionizing radiation: cosmic rays from space interacting with the Earth's atmosphere, and radioactive materials produced during the formation of the Earth, which are still present in the Earth's crust.

The terrestrial contribution mainly consists of radionuclides from the uranium and thorium decay chains, as well as radioactive potassium.

Uranium is commonly found in association with rocks containing light elements (Basham and Kemp 1993), and its content increases with magmatic fractionation (Wedepohl 1978a). Granitic and rhyolitic rocks generally contain between 2 and 15 parts per million (ppm) of uranium. and silicic alkaline rocks often have higher uranium contents (up to 26 ppm U) (Basham and Kemp 1993; Wedepohl 1978a). Some granites can be more uraniferous (Wedepohl 1978b).

Thorium, another radioactive element, is typically associated with silicic alkaline igneous rocks and generally has

I. Guagliardi (✉) · T. Caloiero · N. Ricca · E. Infusino
National Research Council of Italy, Institute for Agriculture and Forestry Systems in the Mediterranean, Rende, CS, Italy
e-mail: ilaria.guagliardi@isafom.cnr.it

E. Infusino
Lab of Genesis of pollutants in the water cycle, Department of Environmental Engineering, University of Calabria, Rende, CS, Italy

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an average abundance in the Earth's crust in the range of 6–10 ppm (Basham and Kemp 1993; Wedepohl 1978a). Basalts and mafic intrusive rocks typically contain between 0.1 and 4 ppm and ultramafic rocks may have even less thorium (Wedepohl 1978a).

Potassium is abundant in the Earth's crust, with an average crustal concentration of about 2.5% (Alloway 2013), and it has three isotopes, one of which, ^{40}K, is radioactive. It is enriched in alkaline silicic rocks and is less concentrated in silica-poor ultramafic rock types.

These natural radionuclides can migrate through various pathways in the environment, including air, water, rock, soil and the food chain. They can enter the human body through ingestion and inhalation, leading to both internal and external exposure.

The objective of this study is to investigate the levels of radionuclide activity concentrations in soil samples from the Crati basin, the largest basin in the Calabria region of southern Italy. The study aims to assess the potential ionizing radiation hazard, which could cause cellular damage in the local population.

2 Materials and Methods

The Crati basin is situated in the northwestern sector of the Calabria region and is the largest basin in the area in terms of both its size and the presence of artificial lakes (Gaglioti et al. 2019). It has a perimeter of approximately 320 km and covers an area of 2447.7 km^2. The main river in this basin is 95 km long; it originates from the Sila Massif and empties into the Ionian Sea. The average and maximum elevations of the basin are 597 m above sea level and 2258 m above sea level, respectively (Fig. 1). The Crati basin experiences significant climatic variation due to its location in the Mediterranean region and its mountainous terrain, which gives it a subtropical Mediterranean climate.

Geologically, the Crati basin is a graben surrounded by three morpho-structural highs: the plutonic and metamorphic crystalline rocks of the Sila Massif to the east, the crystalline and sedimentary rocks of the Coastal Chain to the west and south and the carbonate and siliciclastic sedimentary rocks of the Pollino group to the north.

The soil samples were individuated in 145 points to determine the natural radioactivity concentration (Fig. 1).

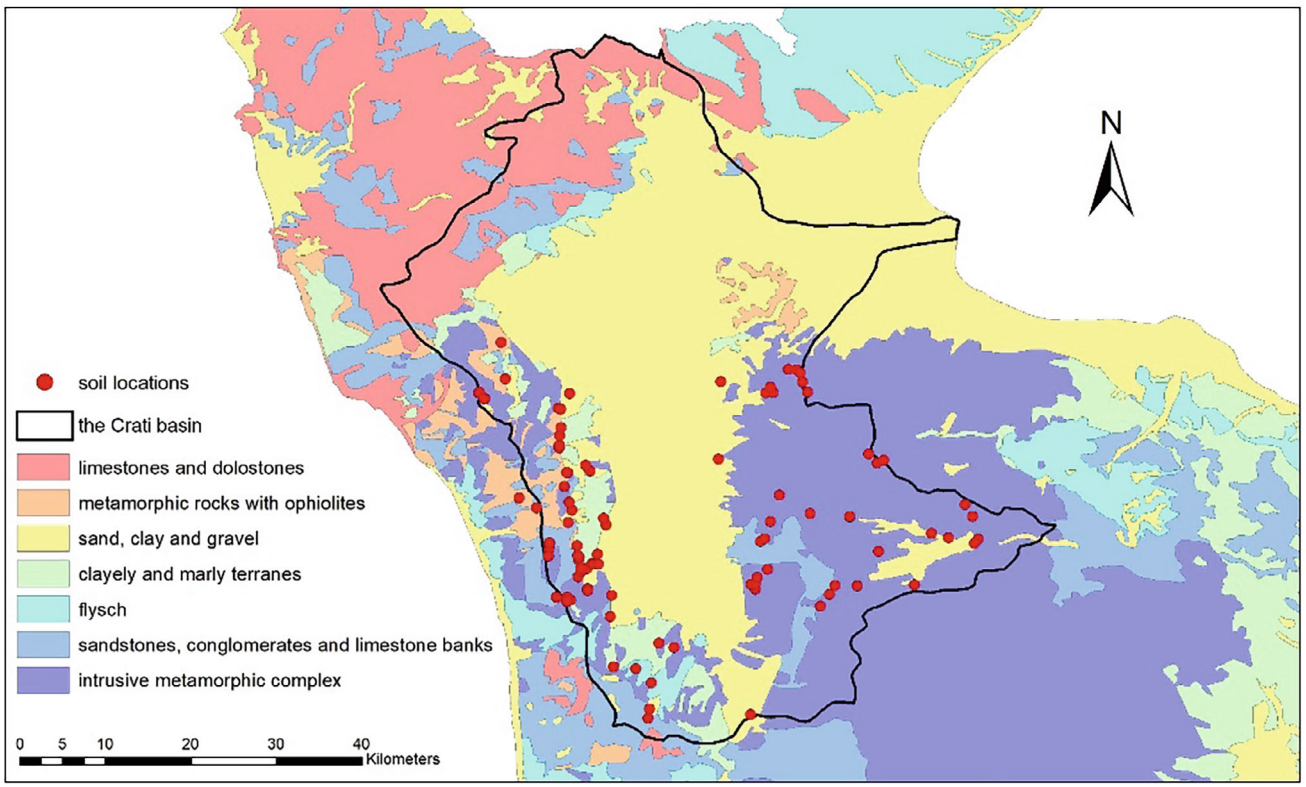


Fig. 1 Lithological map of the study area with the indications of soil sample's locations

The radiological characterizations of the soils were performed using a high sensitivity detector up within a Geiger–Muller tube and with an external probe NaI (Tl).

The rate of accumulation of radioactivity is expressed as dose rate or dose accumulated per unit time e.g. in units of micro-Sieverts per hour (μSv/h), which is a direct measurement from sources external to the body.

3 Results and Discussion

Results indicate that that the soil dose rate ranges between a minimum value of 55 μSv/h and a maximum value of 195 μSv/h (Table 1 and Fig. 2).

A strong control on radioactivity is kept by the local geology of the study area, closely linked to variations in the petrological characteristics of crystalline source rocks, and by the pedogenetic features of sampled soils. Some lithotypes of plutonic and metamorphic crystalline origin of the Sila Massif and of the Coastal Chain and Pollino group were included in the sampling procedure. The rocks in the Sila Massif with high silica content have elevated uranium levels, resulting in high radiation levels. In contrast, sedimentary rocks in the Coastal Chain, like basal conglomerate, sand, sandstone, calcarenite and clay, as well as the carbonate and siliciclastic sedimentary rocks of the Pollino group, have lower radiation levels.

Table 1 Main descriptive statistics of the dose rate in 145 sampling points

Statistics	Soil dose rate (μSv/h)
Minimum	55
Maximum	195
Mean	90.38
Median	81.5
St. Dev.	26.18
Skewness	1.53
Kurtosis	3.11

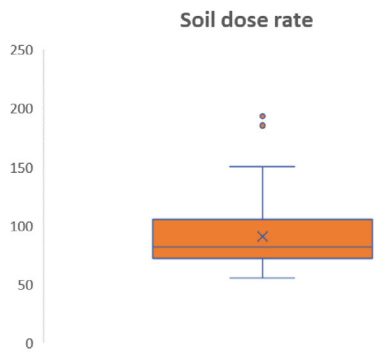


Fig. 2 Boxplot of soil dose rate

The survey included various soil types. The complex distribution patterns of radioactivity data showcase the profound influence of pedogenetic features on radioactivity levels in different soil groups. Whilst quantitative radioactivity data did not strictly correlate with soil types, it is evident that the main pedogenetic features have a clear control on radioactivity. For instance, igneous-metamorphic outcropping rocks or relatively young soils, like Fluvisols, Leptosols and Cambisols, with an abundant skeletal fraction exhibited the highest mean activity of radionuclides. Conversely, lower values were recorded in older soils, such as Luvisols and Arenosols, formed on conglomerates and sands. This emphasizes the need to consider the specific soil types and their developmental stages when evaluating radioactivity levels.

It is widely recognized that radiation doses lower than 100 μSv have not been linked to a statistically significant increase in cancer risk (Electric Power Research Institute 2009). A health hazard evaluation indicates that the population in the study area does not face significant radiological impact. Anyway, it's crucial for the scientific community to remain vigilant about these issues. Despite the existence of a threshold below which low-level radiation causes no harm, prolonged exposure can still lead to health complications.

4 Conclusions

Potassium, uranium and thorium account for much of the external background radiation dose from radionuclides to which humans are exposed. Their properties determine the fate of the radionuclides in soil transport or surface disposal environments. Understanding their behaviour is crucial for defining source terms and evaluating doses. Because the doses result from interaction of humans with radionuclides contained in soil, a knowledge of the behaviour of naturally occurring radionuclides in this media was investigated in this study. The study evaluated background exposure levels in the Crati basin in the Calabria region. The highest radioactivity values were found in locations with soil types mainly originating from igneous-metamorphic rocks and/or in relatively young soils. In contrast, the lowest values were observed in older soils on conglomerates and sands. These equivalent dose rates do not present a serious radioactive health hazard to the population living in the study area.

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Effect of Zeolite and Vermiculite on the Physical Properties of Fluvisol

Mariana Hristova, Ana Katsarova, Nikolai Dinev, and Milena Kercheva

Abstract

The study aimed to compare the effect of zeolite and vermiculite input on the hydrological properties of Fluvisol soil after the greenhouse experience with lettuce cultivation. The effect of zeolite and vermiculite addition was evaluated at 1, 5 and 10% concentrations. Undisturbed soil samples were taken in metal rings with a volume of 100 cm^3 from the vessels with the studied variants of vegetation experience with lettuce to determine the bulk density, total porosity and water retention to negative pressure − 3 3 kPa. The water retention capacity of the soil samples of the variants was carried out according to procedures close to those described in ISO 11274:1998. The effect of zeolite in the variant with imported 10% zeolite is positive, as there is the most significant increase in Absorbable Water Capacity (AWC) by 1.2% vol. An important factor in introducing vermiculite, a swelling mineral, is the change in drainage pores, which can lead to waterlogging with excessive watering. The content of drainage pores (> 30 μm) in the control version is 18.9%. In variants with imported zeolite, the change in this volume is from − 2.4 to + 5.3%, whilst in vermiculite, it is negative in all variants—from − 1.0% in the variant with 1% vermiculite to about − 4.3% in the variants with dose 5 and 10%. The studied variants of zeolite and vermiculite addition in vascular experience showed that a positive effect on soil physical properties has the option with the addition of 10% zeolite, which increases the digestible water capacity and does not negatively affect the drainage properties of the soil.

Keywords

Hydrological properties · Bulk density · Absorbable water capacity · Drainage pores · Water retention

1 Introduction

Natural and synthetic zeolites and vermiculites have numerous uses, including soil improvers (Mumpton 1999; Polat et al. 2004; Panuccino et al. 2009; Ippolito et al. 2011; Lai et al. 2017; Rodríguez-Fuentes and Rivero González 2018). Of note is the contribution of Bulgarian scientists in developing substrates to enhance soil fertility with the use of zeolites and vermiculites, which are internationally recognized (Stoilov et al. 1979, Petrov et al. 1982; Mumpton 1999; Rodríguez-Fuentes and Rivero González 2018), which have also been used for experiments in space greenhouses (Ivanova et al. 1993, 1995; Kostov Sapunova 2009).

Vermiculite is a mineral of the Hidroslude group with a layered structure (hydrated magnesium–aluminium silicate), and zeolite is an alkaline aluminium silicate with a microporous structure. Both minerals are known for their high hygroscopicity. Their different structure determines the different way of water retention and release. In vermiculite, the three-layer crystal lattice expands (swells) when hydrated and shrinks when dehydrated. Zeolite is a mineral that contains water in its crystal lattice, but as Bish (2018) notes, it is not liquid water.

The results of previous investigations on the effect of different fractions of zeolite on the corresponding fractions of light soil (carbonate chernozem, medium sandy loam) show that the introduction of 10 and 20% zeolite into this soil does not change the assimilating water capacity independently of the amount of zeolite slicing (Dilkova et al. 1982). The larger-sized (from 0.5 to 5 mm) fractions of zeolite are distinguished by a greater drainage-aeration capacity and a small digestible water capacity compared to the smaller-sized (< 0.5 mm) frac-

M. Hristova (✉) · A. Katsarova · N. Dinev · M. Kercheva
Agricultural Academy, Institute of Soil Science, Agrotechnology and Plant Protection "Nikola Poushkarov", Sofia, Bulgaria

A. Katsarova
University of Forestry, Sofia, Bulgaria

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tion (Dilkova et al. 1982). The data obtained by the authors show that the investigated fractions of zeolite have a significant content (17.3–18.5% vol.) of micropores (< 0.2 μm). This resulted in an increase of the non-absorbable water capacity in the investigated mixtures by about 1–1.5%vol (Dilkova et al. 1982).

The study aimed to compare the effect of zeolite and vermiculite input on the hydrological properties of Fluvisol after a pot experiment with lettuce cultivation.

2 Material and Methods

Physical Characteristics

The particle-size distribution of the untreated Fluvisol was determined on soil < 2 mm in size according to ISO 11277, and the texture class was determined according to FAO (2006) and according to Kaczynski (1958). The specific density of the soil was determined pycnometrically in water (ISO 11508:1998).

The effect of zeolite and vermiculite addition at concentrations of 1, 5 and 10% was evaluated on data on bulk density, water retention at different matrix potential (basic hydrophysical characteristic) and total and differential soil porosity in vascular trial.

Undisturbed soil samples were taken in metal rings of 100 cm^3 volume from the vessels with the studied variants of vegetation experience with lettuce for the determination of bulk density (ISO 11272:1998), total porosity and water retention to negative pressure − 33 kPa. The water retention capacity of the soil samples of the variants was carried out by procedures close to those described in ISO 11274:1998. Pre-soil samples were wetted by a capillary route at a potential of − 0.25 kPa on a sand bath for over 20 days. The water supply of the wetted samples at pressures − 1, − 5, − 10 and − 33 kPa (pF 1.0, 1.7, 2.0 and 2.5) is carried out by a capillarimeter with a hanging water column (Shot filters G5 with pore diameters of 1.0–1.6 μm). Equilibrium at each potential is achieved in 5–7 days.

Moisture retention at matrix potential pF 4.2 (− 1500 kPa) was determined on crushed soil samples of < 2 mm understanding with a cellophane membrane Richards press. Moisture retention at matrix potential pF 5.6 was determined at controlled 75% relative humidity in desiccators containing saturated NaCl solution.

The total porosity (Pt) is calculated from measured bulk density and specific soil density data. The effective radius (r) of the pores that retain water when negative pressure is applied (P) is calculated by the formula of Jurin:

$$P = \frac{2\gamma_{H_2O}}{r}$$

where γ_{H_2O} is the surface tension of water (0.0729 J m^{-2}), and P is in Pa.

The volume of pores occupied by air (AP) at a given matrix water potential (P) is calculated as the difference between the total porosity and the measured volumetric humidity (θ) at this potential.

3 Results and Discussion

The particle-size distribution and texture class according to FAO (2006) and according to Kaczynski (1958) are presented in Table 1.

The specific density of the soil was determined in control—2.72 $g.cm^{-3}$ and in a variant with added 1% vermiculite 2.71 $g.cm^{-3}$. The lighter mechanical composition of the soil explains the relatively high values. The bulk density of the soil in the studied vascular experience variants was, on average, 1.14 $g.cm^{-3}$, and the total soil porosity was 58.2% (Table 2). No unambiguous conclusion about changes in these properties due to the added minerals can be drawn.

The course of the curves is identical, and no significant difference is observed between the variants, except for the variant with the addition of 10% zeolite. In this variant, the water retention at potential − 33 kPa, which is usually assumed to be allowed field moisture, is higher than the control by 2.3% (Tables 3 and 4).

4 Conclusions

The studied variants of zeolite and vermiculite addition in vascular experience showed that a positive effect on soil physical properties has the option with the addition of 10% zeolite, which increases the digestible water capacity and does not negatively affect the drainage properties of the soil.

Table 1 Particle-size distribution and texture class of the soil under study

FAO (2006)				Kaczynski (1958)	
Sand	Silt	Clay	Textural	Physical clay	Textural
2–0.063 mm	0.063–0.002 mm	< 0.002 mm	Class	< 0.010 mm	Class
35.6	44.7	19.7	Loam	42.2	Medium sandy loam

Table 2 Bulk density, specific density and total soil porosity by variants

Variant	Humidity at sampling, %	Spec. density g.cm^{-3}	Bulk density g.cm^{-3}	Total porosity, %v/v
3.1. Control	23.0	2.719	1.13	58.5
3.2. 1% eolite	24.2	2.719	1.17	57.0
3.3. 5% zeolite	24.2	2.719	1.05	61.5
3.4. 10% zeolite	22.1	2.719	1.13	58.3
B.5. 1% vermiculite	21.6	2.709	1.13	58.4
B.6. 5% vermiculite	22.8	2.709	1.18	56.3
B.7. 10% vermiculite	22.2	2.709	1.16	57.3
Average ± st.deviation	22.9 ± 1.0		1.14 ± 0.05	58.2 ± 1.7

Table 3 Pores occupied by water at different matrix potentials of the soil in variants

Variant	Water retention W, %w/w						
	− 0.25 kPa	− 1 kPa	− 5 kPa	− 10 kPa	− 33 kPa (FC)	− 1500 kPa (WP)	Wh (75%)
Control	48.9	47.6	35.1	31.2	26.7	10.4	3.1
1% zeolite	46.4	45.2	34.6	31.0	27.4	10.5	3.1
5% zeolite	48.2	46.6	35.3	31.4	24.7	11.0	3.2
10% zeolite	50.9	48.3	36.5	32.8	29.0	11.5	3.5
1% vermiculite	49.7	47.8	35.9	31.8	25.7	10.9	3.0
5% vermiculite	46.1	44.8	35.2	31.1	26.9	10.0	3.1
10% vermiculite	49.5	48.5	36.8	31.8	25.9	10.3	3.5

Table 4 Pore volume distribution of different effective diameters in the studied variants

Variant	Pore size distribution, %v/v				
	d > 300 μm	d > 60 μm	d > 30 μm	d > 10 μm	0.2–10 μm (AWC)
Control	3.3	4.8	18.9	23.3	16.3
1% zeolite	2.7	4.1	16.5	20.7	16.9
5% zeolite	11.1	12.8	24.6	28.7	13.7
10% zeolite	0.7	3.6	17.0	21.2	17.5
1% vermiculite	2.3	4.5	17.9	22.5	14.8
5% vermiculite	1.7	3.3	14.6	19.5	16.9
10% vermiculite	0.0	1.2	14.7	20.5	15.6

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The Need for the Assessment of Air Quality in Shkodra City

Aurora Dibra and Arjana Striniqi

Abstract

Shkodra is an urban area with about 120,000 inhabitants. During year 2020–2023, it conducted monitoring of air quality in Shkodra city in 11 zones, respectively, with 256 monitoring points. The main gases and pollutants that change the air quality are ozone O_3, nitrogen dioxide NO_2, sulfur dioxide SO_2, particulate matter PM_{10}, particulate matter $PM_{2.5}$, or fine particles, carbon oxide CO, carbon dioxide CO_2, etc. These pollutants have a big impact on human health and the natural environment. The pollutants analyzed and assessed in our preliminary study are particulate matter PM_{10}, particulate matter $PM_{2.5}$, nitrogen dioxide NO_2, and carbon dioxide CO_2. The monitoring zones and monitoring points are sites inside the city, some are located near the center of the city, in the main roads, and in the inner part of the city (about 50 m far from the main roads). A sensor-based device called an "Aero-qual" Series 500 was used to measure pollutants. The device to be used for monitoring is held and operated freely in the hand, positioning it at a height of 1.5 m above ground level. The instrument was calibrated before measurements. Monitoring was performed in days and nights with normal climatic conditions, dry air and wind speeds less than 5 m/s. Monitoring was done at least 75% of the time set during the day in the intervals from 06.00 to 22.00 and the other part during night in the intervals from 22.00 to 06.00. Monitoring was performed from 5 to 7 hours, in one certain time frame of day and night. The most problematic parameters are carbon dioxide CO_2 and nitrogen dioxide NO_2, their presence relates to traffic on the main roads of the city. The other zones which are far from the main roads also have some values higher than the norms but are lower than the center of the city. PM_{10} and $PM_{2.5}$ have values within the norms of EU standards for most of the monitored zones. The other parameters carbon oxide CO, carbon dioxide CO_2, and ozone O_3 were lower than the norms in all monitored zones. Monitoring of air pollution in Shkodra city shows a very high concentration of these pollutants in street canyons and high values near the roads and in open space. The influence of the air pollution was evidenced especially at crossroads with narrow streets. In urban background and schools' concentrations were under mean annual limit value. The most elevated pollutant concentrations were found at the south part of the city. The aim of the preliminary study was the monitoring of air quality and the assessment of the air pollution in Shkodra city. We also gave some recommendations for the local authorities and government bodies.

Keywords

Air quality · Air pollution · Urban green spaces · Monitoring platform · EU standards

1 Introduction

Currently, Albania ranks fifth (WHO 2022) in the world in terms of air pollutant levels from different sectors and mainly for air quality in urban areas. As a result, the number of individuals who register to be cured of respiratory diseases and stress has doubled in the last decade (WHO 2022). This situation is mainly addressed to the aggravation of traffic in urban areas, (Zhang and Batterman 2013) where if we add to this fact the traditional problems of relatively old cars which emit greater amounts of pollutant gases also combined with the quality of the fuel that has been traded for years in the Republic of Albania. In recent years,

A. Dibra (✉) · A. Striniqi
University of Shkodra "Luigj Gurakuqi", Shkodër, Albania
e-mail: aurora.dibra@unishk.edu.al

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Table 1 Albanian air quality standards for some pollutants

Criteria pollutant	Averaging time AAM-annual arithmetic mean	Primary standards	Secondary standards
Sulfur dioxide SO_2	AAM	60 μg/m^3	35 μg/m^3
Carbon dioxide CO_2	AAM	80 μg/m^3	30 μg/m^3
Nitrogen dioxide NO_2	AAM	60 μg/m^3	60 μ ug/m^3
Ozone O_3	AAM	None	65 μg/m^3
	1 hour av.	235 μg/m^3	235 μg/m^3
	8 hour av.	120 μg/m^3	120 μg/m^3
Particulate matter (PM_{10})	AAM	60 μg/m^3	60 μg/m^3
Particulate matter ($PM_{2.5}$)	AAM	15 μg/m^3	15 Mg/m^3

several legal initiatives have been taken regarding the quality of ambient air and the fuel tax system. VKM nr. 594, dated 10.09.2014, Albania, adopted the National Quality Plan for the Air Quality and Law no. 162/2014, dated 04.12.2014 "On the protection of ambient air quality." This law constitutes the framework for the protection of air quality and is based on Directives 2008/50/EC and 2004/107/EC. The law comes into force in December 2017. It also opened the legal basis for the approval of DCM no. 352, dated 29.4.2015 "On the assessment of ambient air quality and requirements for certain related pollutants." The new rules and requirements for air quality monitoring and assessment will create a significant step forward in the quality of work that has been done so far with regard to air quality monitoring. These rules are applied by all EU member states provide a sound basis for drafting a report on air quality assessment in the EU range. All datas are saved in a digital and we can get information for the air quality for Albanian Cities, also for Shkodra City (Green Lungs Platform 2022) (Table 1).

2 Materials and Methods

The selection of sites for air monitoring is done based on their diversity of conditions. We have done measurements of seven air quality parameters in 11 zones (69 different locations of zone A the red color) Fig. 1, 24 for the Zone B (86 different locations of zone B the blue color), and 25 for the zone C (92 different locations of zone C the yellow color) for estimating air quality of Shkodra city. The sites inside the city are in the center of the city, in the main exit road of the city, and in the inner part of the city (about 50 m far from the main roads). A sensor-based device called an "Aero-qual" Series 500 was used to measure pollutants. The device to be used for monitoring is held and operated freely in the hand, positioning it at a height of 1.5 m above ground level. The instrument was calibrated before measurements. Monitoring was performed in days and nights with normal climatic conditions, dry air and wind speeds less than 5 m/s. Monitoring was done at least 75% of the time set during the day in the intervals from 06.00 to 22.00 and the other part during night in the intervals from 22.00 to 06.00. Monitoring was performed from 5 to 7 hours, in one certain time frame of day and night. Results are presented for 4 parameters in the GIS-maps for all the monitoring points. In the legend of the map are presented the national and EU-standards for each parameter.

3 Results

The graphics maps show that the most polluted zones are urban areas which are near the center of the city and near the industrial zone of Shkodra. In the center of the city all parameters exceed EU and Albanian standards. In the crossroads the main factor of pollution is the traffic. The maximum values are mainly during the day for PM_{10} and carbon dioxide CO_2. The increased number of cars on the roads and the lack of traffic -lights is causing this source of pollution. The level of nitrogen dioxide NO_2 as shown in the map is problematic in the entrance of the city. Here are located the roads also for the border with Montenegro, the bridge in the Buna River is plenty of traffic during the summer days and in the industrial area. Three points in the center of the city have maximum values of NO_2. The other zones with the polygons blue and yellow which are far from the main roads also have some values higher than the norms but are lower than the center of the city. The most problematic parameters are CO_2 and NO_2, their presence

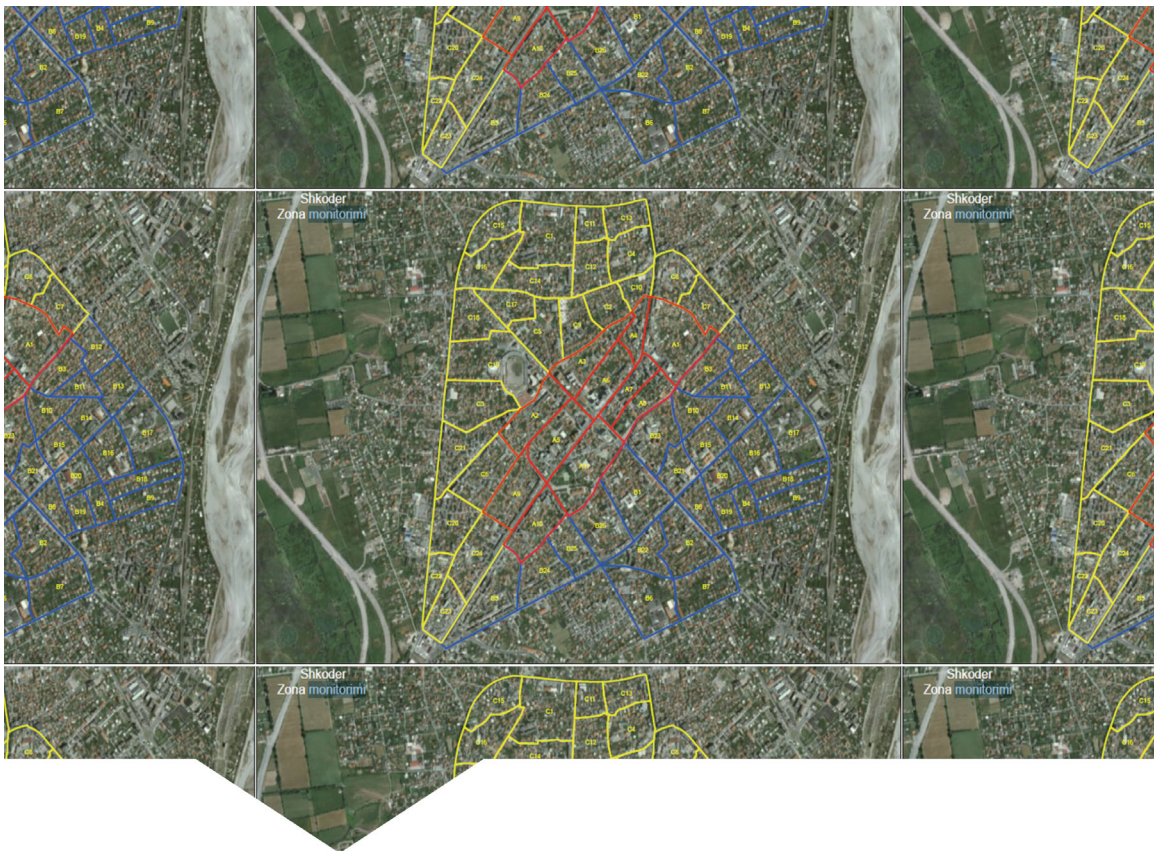


Fig. 1 Map of the monitoring zones Shkoder

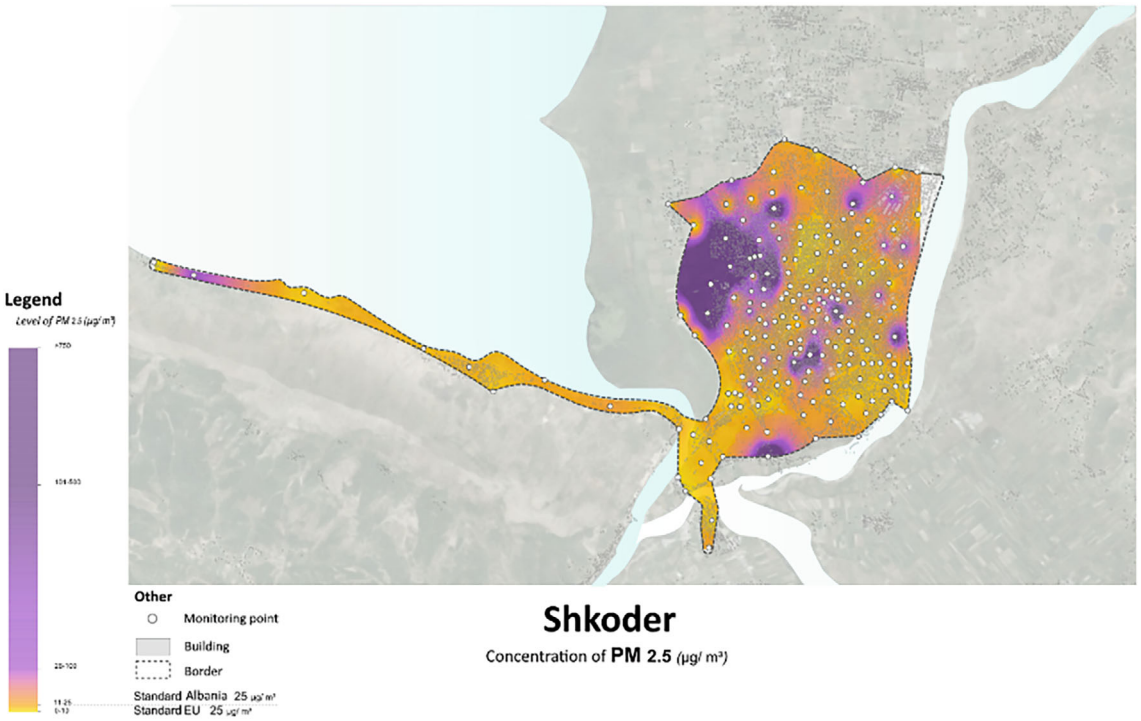


Fig. 2 The concentration of $PM_{2.5}$ ($\mu g/m^3$)

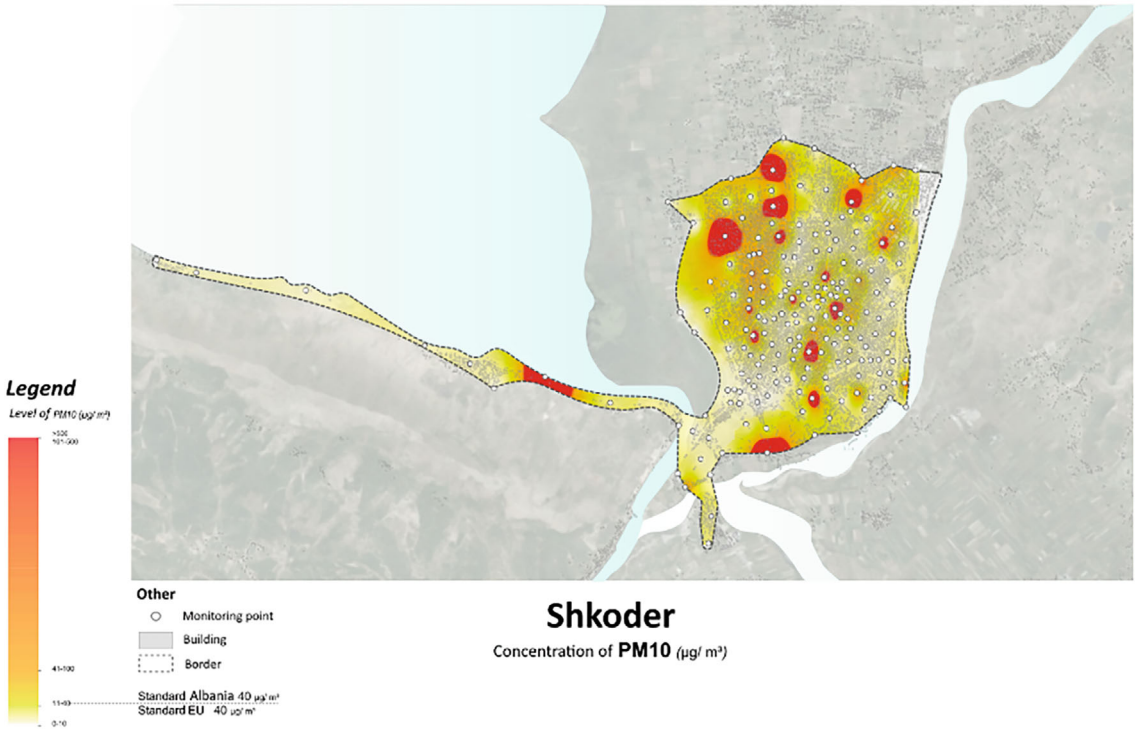


Fig. 3 The concentration of PM_{10} ($\mu g/m^3$)

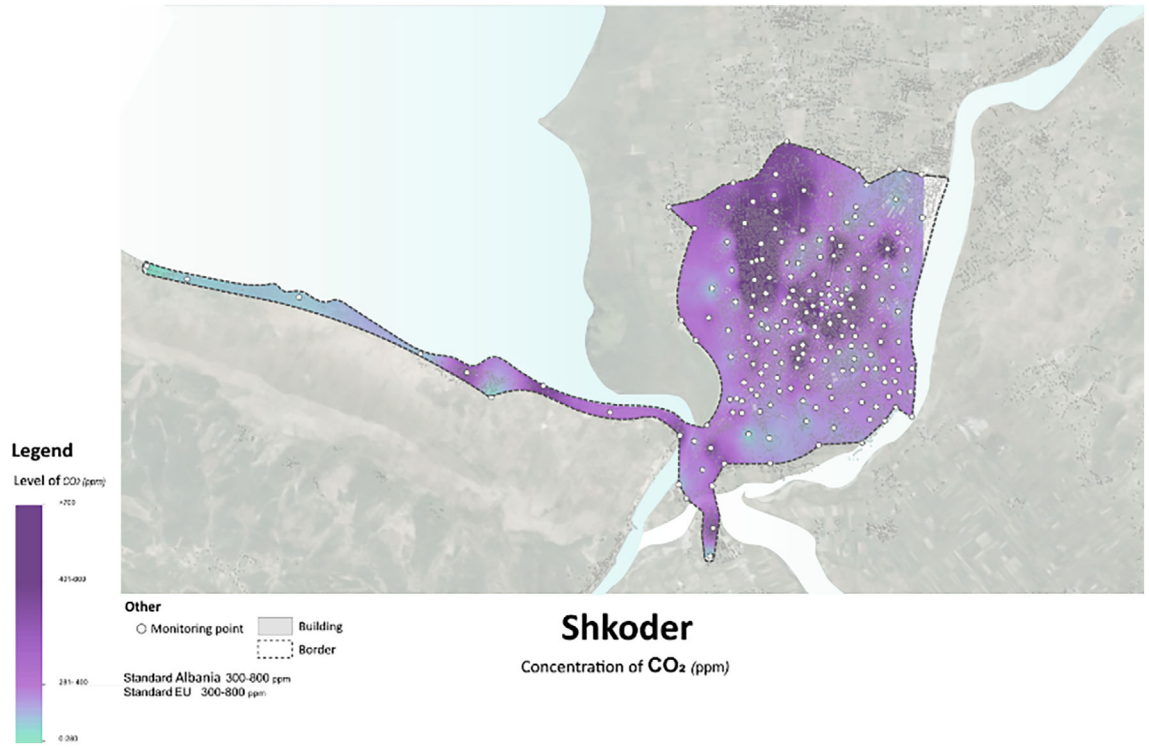


Fig. 4 The concentration of CO_2 (ppm)

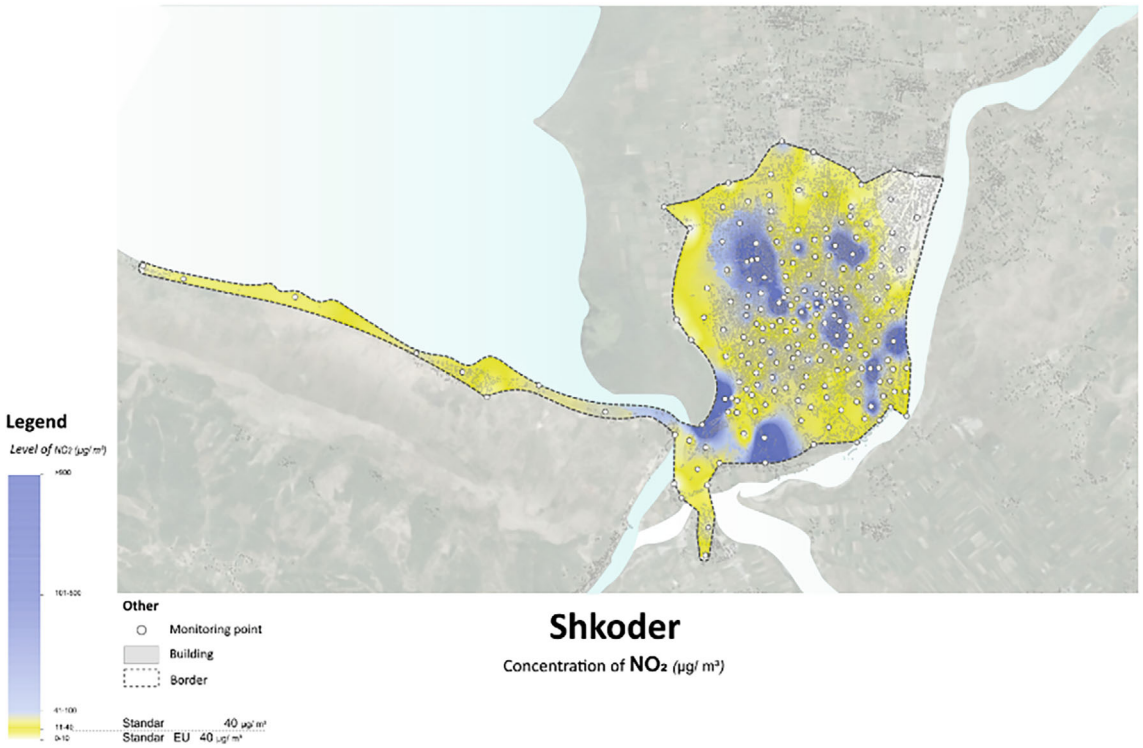


Fig. 5 The concentration of NO_2 ($\mu g/m^3$)

relates to traffic on the main roads of the city (Figs. 2, 3, 4, and 5).

The PM_{10} and $PM_{2.5}$ have their values within the norms of EU standards for in 93% of monitored points. The other parameters carbon oxide CO, sulfur dioxide SO_2, and ozone O_3 were lower than the Albanian and EU-standard norms in all monitored zones.

4 Discussion

Air pollutants like CO_2 and NO_2 are the main problem of pollution in Shkodra city. They are problematic at the crossroads, for that the traffic plan must be urgently revised in the center of Shkodra. Setting traffic lights is urgent in Shkodra Municipality and more attention should be paid for the sanitation of the main roads to eliminate particulate matter PM_{10}. The most elevated pollutant concentrations were found at the south part of the city. Ambient (outdoor) air pollution in both cities and rural areas was estimated to cause 4.2 million premature deaths worldwide per year in 2019 (WHO 2022). This mortality is due to exposure to fine particulate matter, which causes cardiovascular and respiratory disease, and cancers. Albanian authorities responsible for city management and health problems should consider a priority the limitation of pollution from air pollutants. Mathematical models and practical algorithms are needed to be undertaken concerning monitoring of the air quality in a large city as Shkodra (Lancia et al. 2018).

5 Conclusions

Monitoring of air pollution in Shkodra city shows a very high concentration of carbon dioxide CO_2 and nitrogen dioxide NO_2 in street canyons and high values near the roads and in open space. The influence of the air pollution was evidenced especially at crossroad with narrow streets. In urban background and schools' concentrations were under mean annual limit value. Street canyons are the most polluted areas due to small windiness and small volume, which pollutants use for dispersion. The particulate matter PM $_{10}$ and particulate matter PM $_{2.5}$ have the values within the norms of EU standards for in 93% of monitored zones. The other parameters carbon oxide CO, sulfur dioxide SO_2, and ozone O_3 were lower than the Albanian and EU standard norms in all monitored zones. The most elevated

pollutant concentrations were found at the south part of the city, which was also the most populated and urbanized area. In the last 10 years, another factor for the air pollution is the decrease of green area surface from 1.6-meter square per inhabitant to less than 0.5 meter square per inhabitant. The control of the urbanization and the sustainable mobility in the city is an urgent need in Shkodra in order to have a good air quality and good health for all the communities living in the area.

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Risk Reduction by Urban Evacuation: State of the Art on Road Networks Models

Giuseppe Musolino

Abstract

Risk reduction by urban evacuation was systematically studied in the literature since early 2000s. In particular, it received a great impulse after the 9/11 attack and the Katrina hurricane. Today new frontiers opened by the next-generation of Transportation System Models (TSMs) request further developments of research. The publication dealt with the state of art about recent publications on road network modelling for emergency management, with a focus on the link cost functions. The link cost function is the brick for building the so-called 'disutility updating model' that allows to obtaining the costs (or disutility) on road network forecasted/experienced by users (e.g. evacuees) during an urban evacuation.

- The results of the work concern a state of the art on road networks for risk reduction by urban evacuation, based on a bibliometric analysis of relevant literature.
- The findings allowed to identify the main trends, gaps and future directions in the examined research field. Some modelling advancements in terms of specification, calibration and validation of next-generation of network models are made possible due to the massive adoption of e-ICTs.
- The conclusions of the work concern the challenges that need to be addressed for the development of network models able to incorporate the potentialities of e-ICTs for risk reduction by urban evacuation.

Keywords

Risk reduction · Urban evacuation · Road network modelling · Cost functions · Disutility updating model · State of the art

1 Introduction

The problem of risk reduction in urban evacuation was largely studied in literature (see Kindinger 2004; Goldblatt 2004; Russo and Vitetta 2006; Russo and Vitetta 2007, amongst the others). The risk may be considered as the product of three probabilities, or components: *hazard*, or probability of the occurrence of an event (i.e. hurricane, terrorist attack), *vulnerability*, or probability that a system (i.e. building, bridge, …) will resist to an event and *exposure* of people and goods to the event. If we consider an urban area, the exposure of people and goods may be reduced by means of *evacuation* measures, which allow people and goods to be rescued from the area where a calamitous event is supposed to produce its effects.

The ex-ante assessment of evacuation measures inside an urban area may be supported by Transportation System Models (TSMs) framework (see Cascetta 2009; Russo and Rindone 2010a; Russo and Chilà 2009, and references included). TSMs are composed by a network model, by a travel demand model and by an assignment model. The building of TSMs was traditionally executed by means of direct surveys in order to obtain the characteristics of the network elements: nodes and links; and to obtain the (revealed or stated) behaviour of transport users on the network. Today, new frontiers are provided by emergent Information and Communication Technologies (e-ICTs) in obtaining detailed information about the network characteristics in a 'dynamic' context.

The paper deals with the network modelling finalized to the assessment and forecasting of transport users' costs (or disutilities) travelling along urban road networks, thanks to

G. Musolino (✉)
Dipartimento di ingegneria dell'Informazione, delle Infrastrutture e dell'Energia Sostenibile (DIIES), Università Mediterranea di Reggio Calabria, Reggio Calabria, Italy
e-mail: giuseppe.musolino@unirc.it

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the potentials given by the e-ICTs. The link cost function is the brick for building the so-called 'disutility updating model' that allows to obtaining the costs (or disutility) on road network forecasted/experienced by users (e.g. evacuees) during an urban evacuation.

2 Transport Network Model and Learning Process

TSMs framework is composed by three sub-models; the travel demand model, the network model and the assignment model. The *travel demand* model estimates transport user's choices according to the performances of transport infrastructure and services. The *network model* estimates the cost of transport users connected to the use of transport infrastructures and services. The *assignment model* estimates the performances of the network and the flows of transport users travelling on the network that are the result of the interaction between the transport user's choices and the infrastructures and services performances.

As far as concerns the network model, there are different classifications in the literature. The network could be congested or not-congested; in the former case, the performances of the network depend on the flows; in the latter case, there is no dependency of the performances from the flows. According to the criterion of spatial and temporal representation of the network elements, such as links and nodes, the network may be static if the performances of nodes and links are assumed to be constant over a reference time period; whilst may be dynamic if the performances of nodes and links are supposed to be variable inside a reference time period (within-day) or from a time period to another time period (day-to-day). According to the criterion of aggregation of cost functions, the (link) cost functions may be macroscopic, such as the speed-flow diagram; or microscopic, such as the stimulus-response or car-following model (see Marcianò et al. 2011; Vitetta et al. 2009) and references included).

The general formulation of a congested static network model is composed by the following two equations:

- path costs versus link costs consistency equation

$$\mathbf{g} = \Delta^{\mathrm{T}} c(\mathbf{f}) \tag{1}$$

- path flows versus link flows consistency equation:

$$\mathbf{f} = \boldsymbol{\Delta}\mathbf{h} \tag{2}$$

where
g, path costs vector;
Δ, link-path incidence matrix;
c(), link cost functions vector;
f, link flows vector;
h, path flows vector.

The specification of a dynamic network model, according to both a within-day and a day-to-day pattern, requires an extension of the static Eqs. (1) and (2).

The modification of users' knowledge about the network performances may be described by means of the so-called *learning process* that explains how transport users (e.g. evacuees) forecast today the costs (or disutilities) of the transport network (e.g. during an evacuation) from previous experience of the network (e.g. in ordinary conditions) and/or from forecasts coming from e-ICTs.

In broad terms, the learning process of individual users may be simulated with the (dis)utility updating model that allows to obtaining the forecasted/computed costs in a period t. In the case of path costs, the forecasted (or computed) path costs at time t may be expressed as an updating function of experienced path costs at time t-1 and the forecasted (or computed) path costs at time t-1 (Cantarella et al. 2020).

The potentials of emerging ICTs could be taken into account by introducing the concept of learning process that explains how users (evacuees) forecast the costs (or disutilities) of the transport network in emergency conditions from previous experience of the network and/or from information provided by emerging ICTs (e.g. internet of things, big data, artificial intelligence.

3 Emerging ICTs

New, or emerging, forms of Information and Communication Technologies (ICTs) have been developed in the last decade. They quickly spread in many areas of economy and society (e.g. manufacturing, mobility, social media, ….), influencing the behaviour of people at individual and collective way. Some applications are proposed in the field of city logistics (Comi and Russo 2022).

The different emerging technologies present in the market may be classified into four groups (see Atzori et al. 2017; Carlan et al. 2020; Russo and Rindone 2010b; Russo and Rindone 2024, and the references included):

- Internet of Things (IoTs) is a '*framework that leverages on the availability of heterogeneous devices and interconnection solutions, as well as augmented physical objects providing a shared information base on global scale, to*

support the design of applications involving at the same virtual level both people and representations of objects' (Atzori et al. 2017);

- Big Data (BD) provides richer information than traditional data, both in terms of volume and variety, collected and processed within a tolerable elapsed time, in order to allow a more detailed representation of traffic phenomena.
- Artificial Intelligence (AI) aims to improving the prediction and decision-making on transport operations, as well as to automatic repetitive (though sensitive) manual transactions;
- BlockChain (BC), or 'distributed ledger' is a '*technology for keeping a chronologically ordered list of transactions (a ledger) on multiple, independent stakeholders (called nodes). Updates of the list should be identical on each of the nodes and each node checks the validity of the transactions before updating its list*' (Carlan et al. 2020).

4 Conclusions and Further Research

The paper presents a state of the art on road networks models, which is part of an ongoing research project composed of different research lines (Musolino 2024; Russo and Rindone 2024). In particular, the paper focuses on modelling the inter-periodic dynamics of the transportation network during an evacuation. The consolidated static network models require an extension in order to capture the two following elements. The first element concerns the modifications of the transportation network during an evacuation in terms of both topology (e.g. link closure, contraflow) and capacity of the links and of the network. The second element concerns the potentialities of emerging ICTs in providing valuable information according to both within-day and day-to-day patterns. The concept of learning process has been introduced to take into account the perception of path costs (disutilities) in ordinary and emergency conditions by the transport users.

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Risk Reduction by Urban Evacuation: A Literature Review of Training Actions

Corrado Rindone and Francesco Russo

Abstract

Disastrous events are producing relevant damage at global level. This underlines the necessity to increase the level of preparedness of communities for increasing the capability of responding to emergency events. This implies an increased knowledge of risk, its components, and relative actions for their reduction. By focusing on the exposure risk component, the main action is the evacuation procedure, aimed at reducing the amount of people present in a system in emergency conditions. The objective of the research is to investigate the main solutions for increasing the level of preparedness of people, risk managers, and decision-makers. In particular, the paper proposes a synthetic literature review about the training activities. Literature mainly reports methodological solutions for supporting public decision-makers in performing real emergencies. For instance, US organizations introduced and experimented two main classes of training activities: discussion-based activities including seminars, workshops, and simulation modeling of evacuation conditions; operation-based activities, to simulate, in an operational context, real evacuation procedures to be implemented in an emergency real situation. This review focuses on scientific research about real experimentations of evacuation conditions. The specific study contexts are European Union and United States. Despite the scientific and practical efforts at international level, more insights are needed to increase the capacity of community and risk managers to face real emergency events in a correct way. The proposed literature's review offers an overview of real experimentations of evacuation procedures. The proposed work is useful for: researchers interested in individuating literature's gaps for producing scientific advancements on urban evacuation planning; risk managers and public decision-makers that would increase its capability to implement the emergency planning process.

Keywords

Risk assessment · Evacuation planning · Training activities · Real experimentations

1 Introduction

Disastrous events are producing relevant damage at global level. By focusing on the disasters caused by natural hazards, the growth of total damages increases by about 350% in the last forty years (from 1980 to 2020) (World Bank 2023).

The 9/11 Commission Report, realized after the attacks to the twin towers, underlined that "neither full nor partial evacuation drills were held" (US Commission 2004).

At urban level, the Sustainable Development Goals (SDGs) 11 regards safety, resiliency, and sustainability of cities (United Nation 2015). Actions aimed at disaster risk reduction contribute to limit the impacts of a dangerous events. United Nations adopt specific strategies for disaster reduction with a systematic effort for analyzing and managing risks, and their components: occurrence, related to the probability that an emergency event occurs; vulnerability, related to the probability that the system resist to the disastrous effects; exposure, related to the quantity of people and property (land and environment) potentially affected by the damages. Risk management is a cycle of the following activities (United Nations 2023): *mitigation,* working on prevention of emergency events (e.g., planning); *preparedness*, working on the capability of manager and people of responding to the effects (e.g., exercising, training); *response*, aiming at control, limit, and reduce event's conse-

C. Rindone (✉) · F. Russo
DIIES, Università degli Studi Mediterranea di Reggio Calabria, Reggio Calabria, Italy
e-mail: corrado.rindone@unirc.it

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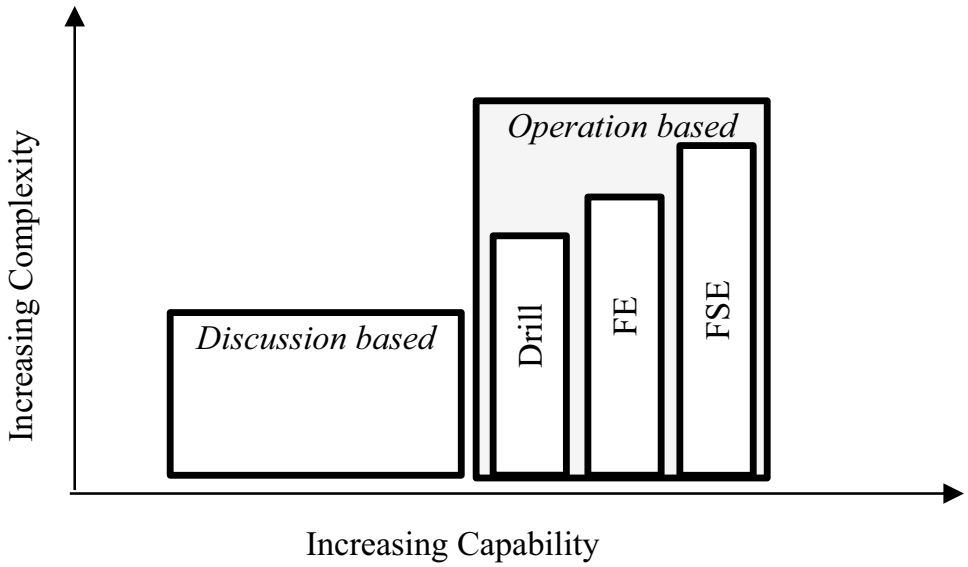


Fig. 1 Exercises in relation to complexity and capability (FE: Functional Exercises; FSE: Full-Scale Exercises)

quences (e.g., emergency planning); *recovery,* including activities for restoring after the event. The research focuses on exposure risk component and activities for increasing the level of preparedness of people, risk managers, and decision-makers. These activities regard a single building or a portion of an urban area.

In Italy, under the research project SICURO (safety of users in road evacuation), two exercises in a town in the south of Italy have been organized. The aim was to experiment with an urban evacuation, for limiting impacts of an imminent dangerous event. A reduction about 20% of evacuation times has measured as difference between the two exercises (Russo et al. 2012). Literature classifies training activities in relation to an increasing level of complexity and capability developed by people and managers (US Federal Emergency Management Agency 2020) (Fig. 1):

- Discussion-based activities including seminars, workshops, and simulation modeling of evacuation conditions;
- Operation-based activities, to simulate, in an operational context, real evacuation procedures to be implemented in an emergency real situation; this class comprehends.
  - Drills, for testing a single function within a single entity (e.g., a civil protection unit conducts a decontamination drill);
  - Functional Exercises (FEs), for validating procedures of coordination, command, and control between various multi-agency (e.g., urban emergency centers, safety office of a public administration);
  - Full-Scale Exercises (FSEs), for testing procedures that involve more organizations, disciplines, territorial levels (e.g., hospitals, urban emergency centers, fire fighters, emergency services).

This paper focuses on the operation-based activities developed in an urban context, for testing evacuation procedures and then people mobility in emergency conditions. The specific objective of this paper is to propose a literature review about this class of exercises, aimed at increasing risk's knowledge about disaster reduction.

After this introduction, the paper is organized in two sections that report method and results of a literature review on training and learning actions implemented at urban level.

2 Method for Evacuation Study

Training activities increase the level of preparedness comprehending simulation of an emergency situation. This paper focuses on exercises that require an increasing level of complexity from the discussion based to the operation based. Each class exercise has to be designed, implemented, and evaluated. In this context, it is necessary to develop a modeling framework where Transport System Models (TSMs) in terms of demand (Chilà 2012); supply (Musolino 2021), and their interactions (Marcianò et al. 2010) monitoring and evaluation methods supported by ICT converge in a Decision Support System (Vitetta et al. 2009; Di Gangi et al. 2023). It is necessary to increase the knowledge about transport system in evacuation conditions because this contributes for increasing efficiency of the emergency operations (Vitetta 2022). With this aim, a systematic review has been performed for investigating the literature contributions about the research's topic. Table 1 describes including and excluding criteria adopted for systematic review.

Table 1 Including and excluding criteria for literature review

Including criteria	Excluding criteria
English language	Single building
Urban area	Discussion based
Evacuation procedures	Conference review, short survey, note, letter, erratum
Original studies, review articles, case reports, case series	

Table 2 Selection criterion in the Scopus database

Selection criterion	Selected papers
"Evacuation" AND "training"	1883
"Evacuation" AND "exercises"	643
"Evacuation" AND "simulation" AND "exercises"	120
"Urban" AND "evacuation" AND ("full-scale exercises" OR "functional exercises" OR "drill")	34
In-depth analysis (exercises in urban area)	26

3 Literature Results

The search terms used to pick papers from the Scopus database are displayed in Table 2. Note that the number of papers related to "evacuation and training" is high (about 1900 papers). However, the number is considerably reduced when the word exercise is used (about 650 papers). The number is further reduced by selecting the word "urban." In fact, a large part of the papers indexed on Scopus refer to the exercises carried out in the hospital setting. Instead, the goal of this paper is to analyze the evacuation exercises carried out in urban areas. For this reason, the word "urban area" was used among the selection criteria, resulting in 34 papers. From an in-depth reading and analysis of these papers, a further selection was obtained, identifying only 26 papers concerning the topic analyzed. By respecting a geographical point of view, the great part of exercises is realized in China (5 papers), in United States (4 papers) and Japan (3 papers). A limited number of papers refers to exercises realized in Europe (1 paper). The remaining paper concern other continents (e.g., India or Latin America).

4 Discussions and Conclusions

According to the including and excluding criteria, there is a limited quantity of research about evacuation exercises realized in an urban area. One of the main problems is to quantify the benefits produced by exercises implementation. A very limited quantity of papers concerns operation-based exercises realized in European Countries. As far as the simulation modeling is concerned, only a limited part of the selected papers used Transport System Models (TSMs). The results obtained underline the necessity to produce further insight on the research's topic, to support decision-makers and managers involved in emergency planning and relative testing activities.

Future developments of this paper concern the quantification of the exercises' contribution for increasing the capability of people and personnel involved in emergency situations. It is possible to adopt emerging technologies for supporting the exercises implementations.

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Risk Reduction by Urban Evacuation: A Review of Mobility Solutions for Users with Special Needs

Corrado Rindone and Benedetto Barabino

Abstract

Recent events (e.g., pandemic situation produced by COVID-19) underline the necessity to adopt flexible form of urban transport planning. It is necessary to increase the knowledge about transport systems in emergency conditions, for supporting the identification of tailored solutions aimed at risk reduction, for events with delayed effects in the times (e.g., explosion of a tank for dangerous good transport). By focusing on the exposure risk component, the main action is the planning of the evacuation procedures for reducing the number of people present in a dangerous area. This implies a segmentation of people according to their specific needs in evacuation conditions. This paper reviews the existing literature by identifying mobility solutions for people without personal transportation potential affected by effects higher than autonomous travelers. Transit options could be a feasible solution for supporting evacuation of special needs users (e.g., senior citizens, people with disabilities and other medical conditions, children). However, this implies a great effort to adapt the fixed characteristics of collective transport services (stops, routes, capacity) to flexible spatiotemporal users' needs. Despite the scientific and practical efforts, the urban evacuation requires more insights regarding this issue. It is necessary to evaluate the contribution of mobility solutions for transit-dependent populations on different issues (e.g., transport emergency personnel and equipment to an incident site; during recovery phases, after the emergency has passed). The proposed review provides an overview of transit solutions adapted for evacuation conditions with a specific reference to special needs users. The proposed work helps support risk managers and public decision-makers involved in the emergency planning process.

Keywords

Risk assessment · Evacuation planning · Special needs users · Collective transport · Decision-support system · Transport system models · Road safety

1 Introduction

Recent events (e.g., pandemic situation produced by COVID-19) underlined the necessity to study the transportation system in ordinary and extraordinary conditions. This implies an increased risk's knowledge and their components (occurrence, vulnerability, and exposure). By considering the evolution of an urban system during an emergency situation, this paper focuses on the specific class of events for which there is a significative temporal interval on which people present in the system could be evacuated, assuming the constant transport infrastructure asset (Russo and Chilà 2014). For these specific cases, before the event's occurrence, the decision-makers can activate an emergency transportation planning process for defining a set of evacuation procedures, with the aim to reduce the exposure risk component. A planned evacuation procedure enables people to move from the area affected by potential negative effects to the safe places as quickly as possible. Some authors specified the transport network design problems for evacuation conditions (Vitetta 2022; Marcianò et al. 2011; Musolino and Vitetta 2011). However, the literature underlines the necessity to produce more insights about planning considering different levels of autonomy in movements. Some categories can reach the safe areas with an own means of transport (e.g., a car);

C. Rindone (✉)
Università degli Studi Mediterranea di Reggio Calabria, Reggio Calabria, Italy
e-mail: corrado.rindone@unirc.it

B. Barabino
Università degli Studi di Brescia, Brescia, Italy

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others cannot reach the area in an autonomy way (carless users). A good evacuation plan should define correct procedures for all categories of evacuees. For instance, in 2005, Hurricane Katrina showed the lack in evacuation planning by concerning the collective transport (Renne and Mayorga 2022). This regards especially the evacuation of people with special needs that have a low level of autonomy in mobility (e.g., vulnerable users, seniors, children, people with disabilities, and people without an own vehicle). In this context, it is necessary to increase the knowledge about transport systems in evacuation conditions, for supporting the identification of tailored mobility solutions aimed at risk reduction, for events with delayed effects in the times (e.g., explosion of a tank for dangerous good transport). The quantitative support tools for designing these solutions comprehend: a set of demand models for classifying and estimating the quantity of evacuees according to their specific needs and the level of autonomy in mobility in emergency conditions; a set of supply design models for quantifying infrastructures, vehicles, and services needed for implementing evacuation procedures (Musolino 2021); spatial Decision-Support Systems for management transport system in emergency conditions (Di Gangi et al. 2023). The objective of this paper is to propose a concise review of mobility solutions for supporting evacuation planning for users with special needs. The increased knowledge of the mobility needs support decision-makers to design transport system in evacuation condition.

After this introduction, the paper has two sections. Section 2 reports a review of mobility solutions identifying users with special needs and methodologies for design tailored transport services to be implemented during an evacuation procedure. Section 3 discusses the obtained results with conclusive remarks.

2 Evacuation Planning for Special Needs Users

Evacuation planning implies high uncertainty, conflicting objectives, and spatial and temporal constraints (Niyomubyeyi et al. 2019). These issues are more restrictive for the users with special needs (Sect. 2.1) and then, a set of tailored mobility solutions must be designed for this users' category (Sect. 2.2).

2.1 Users with Special Needs

Evacuation planning determines the categories and relative quantity of evacuees to move from the dangerous places to the safe areas. The plan individuates when, where, on which transportation mode and by which path each evacuee should travel from the origin to the assigned destination (Saadatseresht et al. 2009). Nevertheless, people segmentation is pivotal in transit owing to the crucial differences in passenger demands. Segmentation could be done by a priori (or profiling) or a posteriori (or post hoc) approaches (Wedel and Kamakura 2000). By a priori segmentation, studies need to learn more about the motivations and demographics of passengers to understand their specific needs. For instance, according to Russo and Chilà (2014), people present in an affected area to be evacuee comprehend the following categories: residents within the area; non-residents that play their daily activities in the area (e.g., employees and students); non-residents that sometime play their activities in the area (e.g., shopping activities); people with special needs or weak users. By post hoc segmentation, studies should discover segments more oriented toward specific needs. Some clustering procedures and models should adopt to identify segments within the data. Moreover, demand models for ordinary conditions have to be adapted for evacuation conditions (Russo and Chila 2021) with dynamic approaches (Russo and Chilà 2010).

2.2 Design of Mobility Solutions

Expedition of evacuees' movements contributes to reduce the exposure risk component. For this reason, starting from the estimated travel demand of users with special needs (see Sect. 2.1), a set of tailored solutions have to be identified, building on the classical bus network design problem (Ceder and Wilson 1986), adapted for the evacuation conditions (Kabir et al. 2023). More in detail, the problem requires a specification for the users with special mobility needs: objectives functions, e.g., maximizing the number of people transported from dangerous to safe areas; control variables, e.g., vehicle capacity, vehicle routes, vehicle equipment, location of collection points (similar to the bus stops), and relative time spent; constraints formulation belonging to different classes: technical (e.g., temporal interval available for concluding evacuation procedures, available transport infrastructures, available financial resources), behavioral (e.g., weak users characteristics), normative (e.g., evacuation rules), and congruency. The problem can be addressed adopting: a "what if" approach, by supposing a set of solutions on the supply system and simulating iteratively their effects measured with performance indicators (e.g., efficiency, effectiveness, quality); a "what to" approach by formulating the problem as a constrained mathematical optimization. The output of the problem are the mobility solutions for evacuating people with special needs. The solutions can be classified, considering the configuration of:

- the material transport infrastructures, including physical components of the transit systems that remain operative

and accessible after any storm or emergency event; sometime, these infrastructures constitute the unique alternative for carless users;
- the non-material infrastructures, including,
- training and exercises for experimenting evacuation procedures with the aim of increasing preparedness of community and emergency managers;
- Information and Communication Technologies (ICTs) for enabling the bidirectional exchanges between weak users and emergency managers and monitoring the correct advancement of evacuation procedures (Musolino 2021);
- the motorized (e.g., ambulances, school bus) and non-motorized (e.g., wheelchair) vehicles with (or without) equipment on board, for responding to the specific mobility needs of each category of weak users;
- transport services organization including the definition of transit characteristics in terms of stops, lines, routes, and timetables;
- governance including role and responsibility of the entities involved in each phase of the emergency cycle (prevention, preparedness, response, and recovery) acting alone on a collaborative way (e.g., transit agencies for satisfying mobility needs of weak users) (Urbina and Wolshon 2003).

3 Discussion and Conclusive Remarks

Evacuation planning contributes to risk reduction, working on the exposure component. The specific mobility needs of the different categories of users play a relevant role in the emergency planning. The effectiveness of an evacuation procedure depends on the optimal use of the available material, non-material, and equipment resources. The mobility solutions for vulnerable people regard different components of the transport system in the evacuation conditions. Often, transit systems are the unique modality for people who cannot evacuate with personal vehicles. This category includes people with various disabilities related to different factors (e.g., age, low-income, restriction in a hospital). Transportation needs associated with each of these groups may differ, but few plans address these specific needs. Literature underlines the role of the transit networks design, to determine the success, or failure, of an evacuation. An example of a procedure used in New Orleans to help those with special needs when hurricanes are approaching is the "City-Assisted Evacuation" method (Schrilla 2019). Then, an evacuation plan has to include indications about technical characteristics of transport infrastructures, equipment, and services for satisfying special needs of vulnerable people.

Future research developments regard the possibility of integrating emerging ICT tools and TSM for supporting decision-making processes about evacuation procedures.

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Risk Reduction by Urban Evacuation: State of the Art on Traffic Assignment Models

Giuseppe Musolino

Abstract

Systematic studies about risk reduction by urban evacuation started in early 2000's, mainly after the 9/11 attack and the Katrina hurricane. Today, new frontiers opened by the next-generation of Transportation System Models (TSMs) request further developments of research. One of the research lines concerns the development of traffic assignment models able to estimate the performances and flows that arise from the interaction between the users' choices (e.g., evacuees) and the performance of transport infrastructures and services in emergency conditions. The work deals with the state of art about publications on traffic assignment models to support risk reduction by urban evacuation. The existing traffic assignment models are classified according to the theoretical background, the static or dynamic nature, the equilibrium or network loading approach. The results of the work concern a state of the art on traffic assignment models for risk reduction by urban evacuation. The current approaches of traffic assignment models in risk reduction by urban evacuation are analyzed and compared. The findings allow to pinpoint the main trends, gaps, and future directions in the examined research field. The main modeling advancements concerning the dynamics of traffic assignment models are made possible due to the massive adoption of e-ICTs. The conclusions of the work concern the challenges that need to be addressed for the development of traffic assignment models in support of the assessment of risk reduction by urban evacuation.

Keywords

Risk reduction · Urban evacuation · Traffic assignment models · State of the art

1 Introduction

Risk is commonly considered as the product of three probabilities: the probability that an event occurs, or *occurrence*; the probability that a system will resist to the event, or *vulnerability*; and the probability that people and goods will be rescued before a calamitous event will produce its effects, or *exposure*.

The exposure of people and goods in an urban area may be reduced by means of urban evacuation (Russo and Vitetta 2007), by adopting measures that involve the transport network, in terms of infrastructures and services, and the travel demand, or people (and goods) that need to be evacuated.

The effects of these measures could be forecasted by means of Transport System Models (TSMs) that simulate an urban transportation system where the travelers and the road network mutually interact ((Ortuzar and Willumsen 2001; Cascetta 2009; Cantarella et al. 2020), and reference included).

New frontiers are opened today by the next-generation TSMs that allow to benefit from the data provided by e-ICTs. One research line concerns the development of traffic assignment models able to estimate the performances and flows that arise from the interaction between the users' choices (e.g., evacuees) and the performance of transport infrastructures and services in emergency conditions.

G. Musolino (✉)
Dipartimento di ingegneria dell'Informazione, delle Infrastrutture e dell'Energia Sostenibile (DIIES), Università Mediterranea di Reggio Calabria, Reggio Calabria, Italy
e-mail: giuseppe.musolino@unirc.it

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2 Risk and Traffic Assignment Models

The calculation of exposure, and then, the evaluation of the risk level associated to a given emergency scenario for a given level of occurrence and vulnerability (Russo and Rindone 2010; Russo and Chilà 2009) starts from the outputs provided by a TSMs framework.

TSMs simulate a transport system where the transport network and the travel demand interact. The sub-models inside the TSMs are the transport network model, the travel demand model, and the assignment model.

The transport network model receives as inputs the characteristics of the transport infrastructures and services with may be available also from e-ICTs tools (if present) and provides as outputs the transport costs, or disutilities, of travelers on the network. The transport network model is composed by a graph, with links and nodes, and by cost functions, such as the link speed-flow diagram or the car-following model (see (Marcianò et al. 2011)). The travel demand model receives as inputs the socio-economic characteristics of the urban area and data (e.g., space-time trajectories of travelers) from e-ICTs tools (if present). The travel demand model estimates the demand flows as the results of multiple choices of travelers, conditioned by the performances of the transport infrastructure and services and on the own users' characteristics. The most common travel demand model is the multi-step model that simulates the sequential process of travelers' choices, such as choice to make a trip, the choice of destination and of the departure time of the trip, the choice of mode and of the path to reach the destination.

The traffic assignment model receives as inputs the transport costs of travelers on the network, estimated the network model, and the demand flows between each origin-destination couple, estimated with the travel demand model. The model provides as outputs the (congested) costs and the flows of travelers on links and nodes of the transport network.

The most consolidated traffic assignment models present in literature relies on the topological-behavioral paradigm. The model is called "topological" because the transport roads and intersections, as in the case of urban area, are schematized with a network composed of links, nodes, and cost functions; and it is called "behavioral" because the trip choices of travelers are simulated according to a modeling framework that relies on random utility theory (Ben-Akiva and Lerman 1994).

Traffic assignment models may be classified according to different criteria (see (Cascetta 2009; Cantarella et al. 2020), and the references included).

An important criterion of literature is based upon the capacity of the traffic assignment model to capture the "static" or "dynamic" conditions of the transport system inside a reference time period.

Static models assume that travel demand flows, path choices, and the transport network are consistent in a reference time, in other words the transport system is in stationary conditions. They allow to obtain acceptable results when it is reasonable to assume constant levels of demand flows and constant performances of the transport infrastructures, in terms of links' capacity, or they have low oscillation around average values, inside a reference time period.

Static models can be subdivided into

- Free-flowing models, such as network loading, if there is the assumption that the link travel times are not dependent from the traffic flows;
- Equilibrium models, where the consistency among the path and link flows and the corresponding path and link costs is ensured. The above consistency is formulated in with different mathematical formulations: fixed-point formulations, variational inequalities, and optimization models.

Traffic assignment models based on equilibrium are classified in "User Equilibrium-UE" and "System Optimum-SO" models.

The UE equilibrium assumes that trip choices of travelers are undertaken in order to minimize their individual costs, according to the first principle of Wardrop (Cascetta 2009; Cantarella et al. 2020). The SO equilibrium assumes that trip choices of travelers are undertaken in order to let the minimum total cost for all travelers be achieved, according to the second principle of Wardrop (Cascetta 2009; Cantarella et al. 2020). In the case of SO equilibrium, some travelers choose alternatives of non-minimum cost. Traffic assignment models based on UE and SO equilibrium rely on different assumptions about the behavior of travelers. UE-based model simulates individual behavior of travelers aimed to minimize their individual cost, while SO-based model simulates a cooperative behavior of travelers aimed to minimize the total cost of all travelers on the transport network.

Dynamic traffic assignment models remove stationary conditions and the evolution of the transport system may be represented inside a reference time, as in the case of emergency conditions. This class of models is necessary when relevant changes in the capacity of the network and in the levels of the demand flows are present, like during evacuation conditions.

Dynamic traffic assignment models may belong to two categories, in relation to the treatment of the "dynamics":

- "Within-day" traffic assignment models simulate the dynamics of the network and of the travelers' choices inside a reference time period (e.g., morning peak hour)
- "Day-to-day" traffic assignment models simulate the dynamics of the network and of the travelers' choices between similar reference time periods (e.g., morning peak hours of different days).

3 Final Remarks

The paper presents a state of the art on traffic assignment models, both static and dynamic. There is a wide range of modeling approaches offered by the scientific literature, mainly developed in the context of ordinary conditions of the urban transport system.

The massive adoption of e-ICTs could make possible some developments of the dynamic mechanisms of the traffic assignment models, both on the network and on travel demand side. Some applications are proposed in the field of city logistics (Comi and Russo 2022).

Among the e-ICTs, it is possible to identify the internet-of-things and the big-data as the ones with the greatest impact on the traffic assignment models. The internet-of-things enables the real-time vehicle-to-vehicle and the vehicle-to-infrastructure communications; therefore, it allows to have the knowledge of the transport system at the time when the travelers make their trip choices. The big-data provides an exhaustive and detailed representation of historical patterns of costs of the network and of the trip choices of the travelers.

The theoretical approaches that are the backbone of the current traffic assignment models (UE vs. SO equilibrium, day-to-day vs. within-day) presents severe limitations in the context of an urban evacuation, where transport network conditions could rapidly change and users modify their behavior due the emergency conditions. Two main elements make challenging the use of existing models. The first is the poor and discontinuous information about the conditions of the road network during an evacuation; and the second concerns the difficulties to forecast the effects of an approaching calamitous event on the road network.

The paper is part of an ongoing research project composed of different research lines (Russo and Rindone 2024). In order to overcome the above limitations of the existing models, the research will progress along two main lines concerning the development of an updating utility model on the supply side and of an updating choice models on the demand side.

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Contribution to the Study of Flooding in Algiers: A Correlation with Precipitation Data and Urbanization

Farah Gaouaou and Mehdia Asma Keraghel

Abstract

Global precipitation patterns have been altered by recent climate change, resulting in various natural hazards such as flash floods. These floods are exacerbated by intensive land use and urbanization resulting from human activities. This study analyzes the spatio-temporal evolution of flooding in the department of Algiers using daily rainfall data, obtained from the Agence Nationale des Ressources en Eau (ANRH). It also examines the changes in urbanization within the department, highlighting shifts in land use distribution between 1984 and 2022 using supervised classification techniques. Annual cumulative rainfall was calculated based on daily precipitation data from 1971 to 2018 at three meteorological stations in Algiers. These rainfall data were then compared with the Civil Protection flood records. The rainfall pattern in Algiers shows an upward trend in average cumulative rainfall from 1990 to 2010, peaking at nearly 1058 millimeters per year in 2002. Since 2010, precipitation levels have remained relatively stable, hovering around 1100 mm per year, indicating a period of stability with consistent annual rainfall. However, since 2018, the average rainfall has decreased significantly. This explains the increased frequency of flood events in the 2000s and the subsequent periods of drought with water shortages since 2018. These flash flood events are also associated with rapid population growth and unregulated land use in Algiers since the late 1990s. Our results show that urbanization in Algiers has increased by about 24.34% during this period, covering an area of 185.21 km^2. These findings can be valuable for civil protection agencies and relevant authorities in developing new land use plans and implementing future flood risk prevention strategies by closely monitoring the climate to mitigate extreme events in Algiers.

Keywords

Algiers · Climate change · Flash floods · Precipitation data · Spatiotemporal evolution · Urbanization

1 Introduction

Natural disasters have always occurred, causing widespread human, economic, and environmental damage. In Algeria, floods are the second major risk affecting the country after earthquakes. The most devastating floods in the country are associated with intense rainfall events (Bourenane and Bouhadad 2019). These events are exacerbated by the socio-economic growth of the Algiers department. This has led to a dense urbanization of its territory and to a significant urban migration, which sometimes occupies unbuildable areas (Redjem et al. 2020). The frequency and intensity of floods in Algiers have increased significantly over the last decade and are expected to increase in the coming years under the influence of climate change (Egis 2012). The main objective of the present study is to investigate the spatio-temporal evolution of flooding in Algiers, focusing on the evolution of two causal factors: urbanization and precipitation.

2 Materials and Methods

The flood records of the General Directorate of Civil Protection were used to study the spatio-temporal evolution of flooding in Algiers. This database systematically records key information on floods in the region from February 1946 to October 2021.

F. Gaouaou
National Higher School of Marine Sciences and Coastal Management, Algiers, Algeria

M. A. Keraghel (✉)
Marine and coastal ecosystems laboratory, National Higher School of Marine Sciences and Coastal Management, Algiers, Algeria
e-mail: asma.keraghel@enssmal.edu.dz

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Table 1 Geographical location of the meteorological stations

Stations	Code	Longitude	Latitude	Altitude
Birmandreis	20,509	3.04891	36.74186	140
Baraki	21,421	3.0915	36.68669	20
El Hamiz	20,602	3.35059	36.60534	130

A supervised pixel-by-pixel classification was performed to study the temporal evolution of the urbanization of Algiers. The classification was performed using the maximum likelihood algorithm on five Landsat satellites images (30 m spatial resolution) of level 2 from the years 1984, 1992, 2003, 2012, and 2022. These images were downloaded from the USGS (United States Geological Survey) website.

The precipitation study was based on the methodological guide of Amiot (Amiot 2021) to describe the current local climatic context and its past evolution, using appropriate climate indicators. Daily precipitation data were obtained from the Agence Nationale des Ressources en Eau (ANRH) for three meteorological stations. These data cover a period of more than 50 years: El Hamiz station (1905–2020), Birmandreis station (1951–2018), and Baraki station (1971–2020). The selected stations are located in El Hamiz, far from urbanization near the El Hamiz dam, Birmandreis in the middle of urban areas, and Baraki near the industrial zone and agricultural lands, close to the El Harrach River. Table 1 shows the locations of these stations, which ensure a good representation of the different geographical areas of Algiers.

3 Results

According to Fig. 1, which shows the annual number of floods from 1946 to 2021, the number of floods has increased exponentially since the early 2000s, especially since 2006. It has gone from an average of two (02) floods per year (1946–2000) to ten (10) floods per year (2000–2021), increasing by a factor of five.

Figure 2 shows the spatial and temporal evolution of urbanization in the department of Algiers over the last fifty years. Algiers shows an almost linear increase in urbanization from the eighties to 2011, with a rate of 2.92 km^2/year (0.38% growth per year). Afterward, this rate increased significantly to 9.68 km^2/year (1.27%). This growth is particularly pronounced in the central and western regions. In the eastern region, the increase is mainly located around the older established settlements.

Figure 3 shows the annual rainfall anomalies. Pettitt's statistical test shows that before 1972, wet years were more frequent and more pronounced, with a maximum of +650 mm (in blue) compared to the climatological normal, except for the station of Birmandreis. A drier period characterizes the rest of the time series (orange).

4 Discussion

The significant increase in the number of floods since 2006 is the result of a combination of anthropogenic and climate-related factors. The classification results show an explosion of urbanization in Algiers over the last 50 years, with an increase from 18.89% in 1984 to 29.2% in 2011, reaching 43.23% in 2022. This urbanization has resulted in soil impermeability that exposes the region to a high risk of flooding. The Department of Algiers faces persistent challenges related to its sanitation system and its resilience to flooding. Rapid urbanization and climate change have exacerbated these problems, highlighting the urgent need to invest in modern, sustainable infrastructure to strengthen the city's resilience to extreme climate events (Quenault et al. 2011).

Urbanization in Algiers is a multifactorial phenomenon that is caused by: (1). The important industrialization and the economic growth of the city, which encourage the migration of rural populations to urban areas: Algiers has four

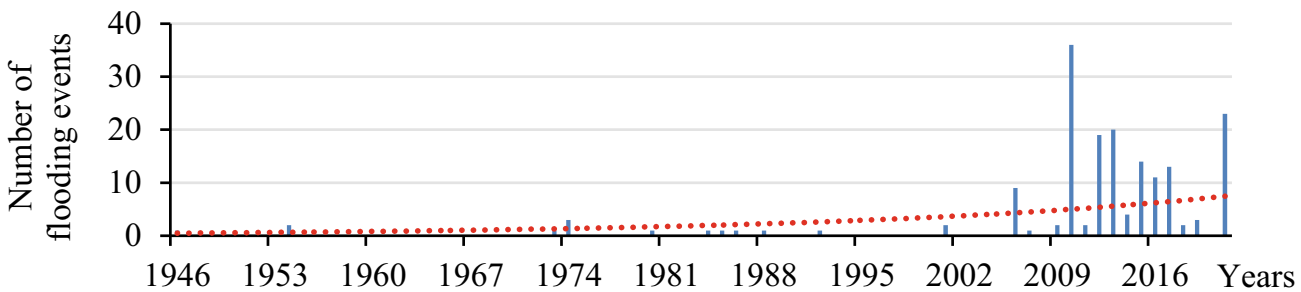


Fig. 1 Annual change in the number of floods in Algiers between 1946 and 2021; The red line corresponds to the exponential increase in the number of floods

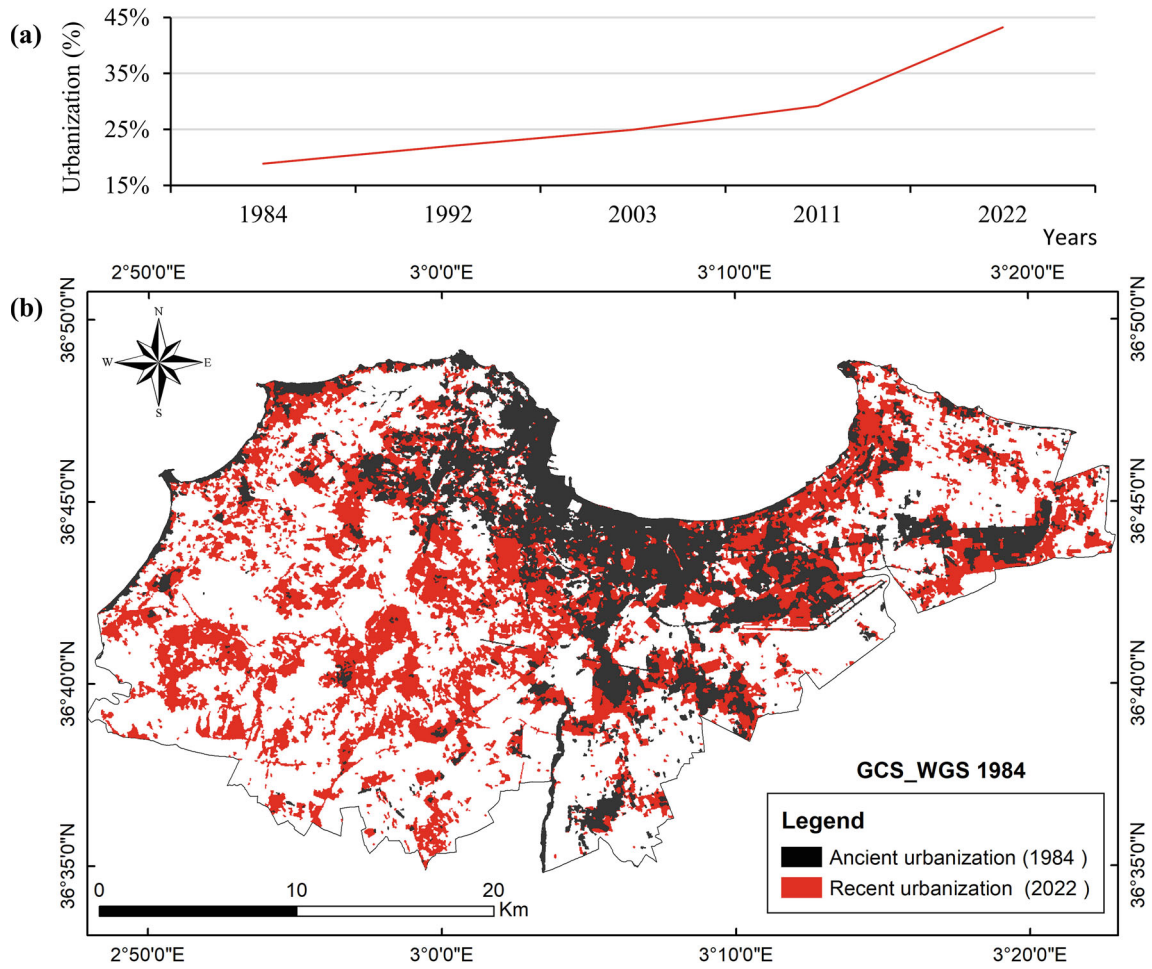


Fig. 2 **a** The evolution of urbanization in Algiers between 1984 and 2022, **b** Map of urbanization trends from 1984 to 2022. The green dots correspond to the meteorological stations of, from left to right, Birmandreis, Beraki, and El Hamiz

industrial zones (Rouiba-Reghaia, El Harach, Sidi Moussa, and Oued Samar) and more than 26 industrial parks. As the economic and political center of Algeria, Algiers also boasts a complex and diversified infrastructure to support its various activities; (2) Population growth (from 2.66 million inhabitants in 2000–3.29 million in 2020 (Meklati 2009)), characterized by a significant change in the distribution of the population within the territory of Algiers. Between 1998 and 2008, the suburbs were characterized by a strong population growth (migration to outlying municipalities). The highest relative growth rates, exceeding 250%, are in the western suburbs of the hypercenter, due to the availability of more land for housing and the proximity of major roads (launch of government-funded housing projects since 2001); (3) Conflicts and crises, such as the civil war of the 1990s, natural disasters, famine, drought, etc., which forced people to leave their land and seek refuge in urban areas.

The results of the precipitation study show that before 1972, wet years were more frequent and more pronounced. The period between 1975 and 2003 is characterized by dry years. However, from 2003 to 2017, a marked return to wet years was observed, contributing to the floods recorded during this period. In the last decade, a further change in trend has been observed, with a return to drier conditions. In addition, since 1975, a cyclical variation between dry and wet periods has been observed, although the duration and intensity of each phase can vary. This variability can be influenced by several factors, such as the North Atlantic Oscillation (NAO) (Nouaceur et al. 2013).

5 Conclusions

The number of floods in Algiers has increased fivefold since 2006. This increase is mainly due to the huge expansion of urbanization in Algiers since the 2000s, as well as to intense rainfall favored by a wetter period from 2003 to 2017. However, statistical breakpoint tests indicate an overall drier

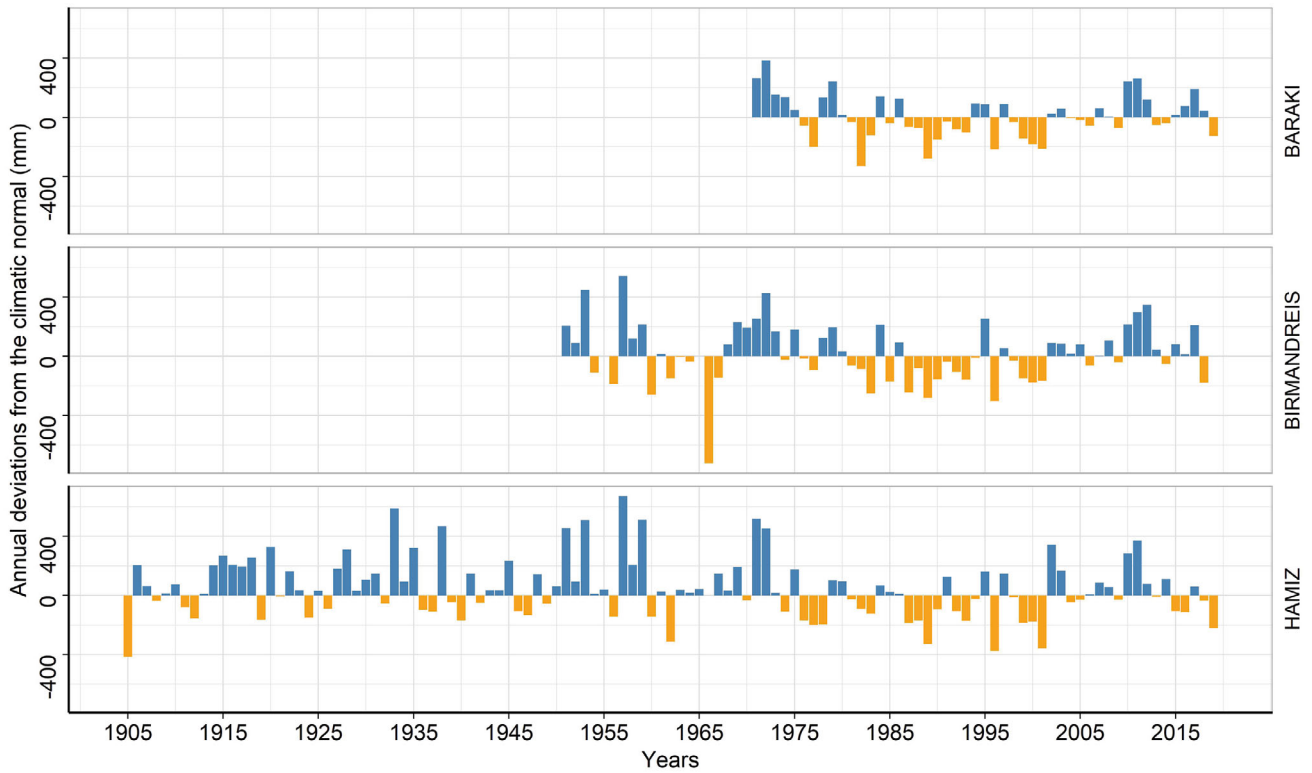


Fig. 3 Annual rainfall anomalies for the three meteorological stations

period since 1972, suggesting that urbanization, and thus soil impermeability, is the main driver of the increasing trend of flooding in Algiers.

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Risk Reduction by Urban Evacuation: State of the Art of Traffic-Free Areas Around the Schools

Francesco Russo and Domenica Savia Pellicanò

Abstract

The problem of the evacuating schools in the risk situation is topical as the emergency management is associated with the management of students having different degrees of autonomy. In addition to the emergency plan, evacuation drills, and constant staff training, it is important to have free and safe areas around the schools where students can be gathered to protect their safety. The paper focuses on the topic of the evacuation of schools and, in particular, on the importance of the presence of free areas around the schools which can serve as a buffer for evacuation in the risk conditions. Two scientific areas have been investigated: the first related to study cases of traffic-free areas around the schools; the second related to the evacuation of schools. From the survey emerges that any paper is in the intersection of the two areas, studying the traffic-free areas around the schools in relation to the risk of evacuation. The traffic-free areas guarantee daily high safety from road accidents for all pupils and relatives accompanying them and for older students, and a reduction of the environmental impact from CO_2 and fine particulate matter. In this sense, they are one of the best tools for pursuing the goals of Agenda 2030. It emerges the absence of studies that deal with the sizing of free traffic areas around schools both for the evacuation and for the reduction of air pollutant emissions and hence the necessity of research in this intersection area leaving from the results obtained in the two research lines.

Keywords

Risk reduction · Sustainability · Urban evacuation · Schools · Emergency · Traffic-free zones

F. Russo (✉) · D. S. Pellicanò
University of Reggio Calabria, Reggio Calabria, Italy
e-mail: francesco.russo@unirc.it

1 Introduction

Areas around the schools should be green and safe; the environment outside the school also contributes to promote learning and plays a key role both in developing student behavior toward cities and in pursuing international sustainability goals for the cities of which the schools are part. Congested, CO_2 and fine particulate matter (e.g., PM2.5 and PM10), noisy environments with physical dangers represent a reality that clashes with the concept of education and goes against the sustainability goals.

The sustainable development of the areas around schools is an important component for the urban sustainability considering that a high rate of citizens attends schools, considering students, teachers, parents, suppliers, and others. Then, the schools have to be green (noise and air pollution), safety (car accident and risk), and they have not to be a source of economic loss (consumption, time wasters, etc.). These elements constitute the pillars of sustainability as declined into 17 goals of 2030 Agenda (United Nations 2015).

The goal 4, education, aims to *Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all;* the target *4.7* is *By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development…*; the target 4.a is *Build and upgrade education facilities that are child, disability, and gender sensitive and provide safe, non-violent, inclusive, and effective learning environments for all.*

The "green" concept is linked to the goals 9 and 11. The goal 9 aims to *Build resilient infrastructure, promote sustainable industrialization, and foster innovation;* the indicator related to the study is 9.4.1 *CO_2 emission per unit of value added.* The goal 11 is *Make cities and human settlements inclusive, safe, resilient, and sustainable;* the specific measurable indicator is *11.6.2 Annual mean levels of fine particulate matter* (e.g., *PM2.5 and PM10) in cities (population weighted).*

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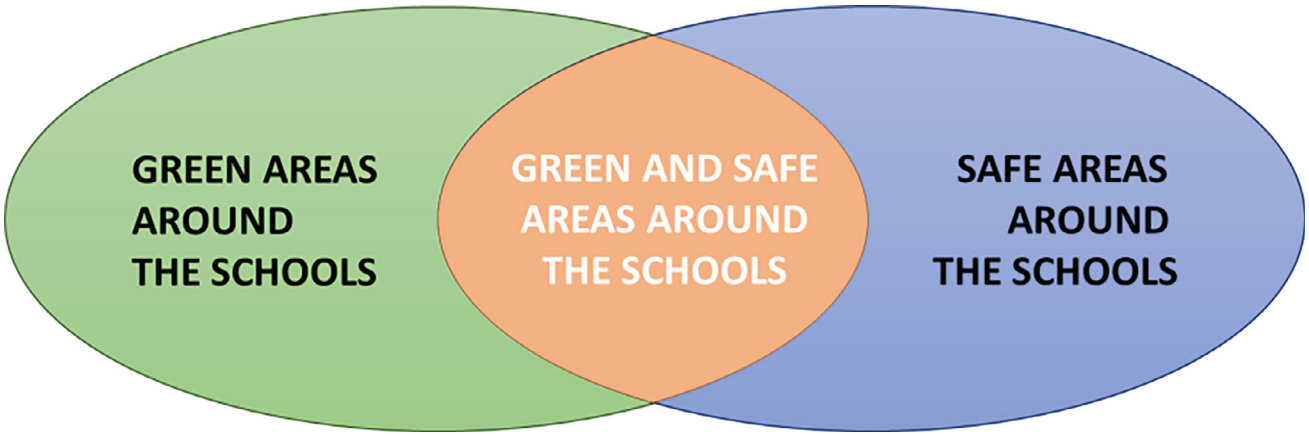


Fig. 1 Macro-categories of studies related to areas around the schools

The "safety" concept is linked to goals 3 and 13. The goal 3 aims to *Ensure healthy lives and promote well-being for all at all ages.* The related indicators are *3.6.1 Death rate due to road traffic injuries* and *3.9.1 Mortality rate attributed to household and ambient air pollution.* The goal 13 is *Take urgent action to combat climate change and its impacts*; the related indicator is *13.1.3 Proportion of local governments that adopt and implement local disaster risk reduction strategies in line with national disaster risk reduction strategies.*

The economic concept can be linked to goal 7 *Ensure access to affordable, reliable, sustainable, and modern energy for all* and goal *8 Promote sustained, inclusive, and sustainable economic growth, full and productive employment and decent work for all.*

The paper proposes a state of art grouping the studies in tree macro-categories (Fig. 1), considering the extremely limited literature in the three fields. The first group includes researches that deal with sizing green areas around schools to reduce the environmental impacts deriving from the mobility congestion around these buildings (Sect. 2). The second group concerns the studies that deal with designing the areas around the schools in order to mitigate the risk of disasters by providing safe accumulation areas (Sect. 3). The third group includes the studies which envisage the creation of green areas around the schools which also perform a safety function in the presence of natural disasters (Sect. 4). The paper aims to underline the lack of studies in the literature review related to areas around the schools with dual function (third group).

2 Green Areas around the Schools: A State of the Art

In the scientific literature, several studies focused on the congestion around schools to identify the levels of air pollution and investigate the effects of the environment on student health (Rawat and Kumar 2023; An et al. 2021; Osborne et al. 2021).

An et al. (2021) summarized the findings presented in the literature studies and suggested directions on the development of research to mitigate risk; the shape of the streets and the layout of the buildings have to be considered in urban planning. The new school buildings should be away from main streets. Spaces around existing schools should be reorganized with trees and hedges to limit the air pollution. Moreover, low-pollution school programs should be planned. Dadvand et al. (2015) demonstrated that the creation of green spaces around schools not only affects sustainability, but produces an improvement in the cognitive development of students.

Several projects deal with the planning of green areas around the schools. The Caminia project aims to realize child friendly cities considering strategies, tools, and actions in which the participation of interested parties is central (Emilia Romagna Region: Camina 2019). The design of safe home school paths is included in the project (Emilia Romagna Region 2002). Other policies are addressed to limit road accidents and to develop sustainable mobility from an environmental and social point of view (Emilia Romagna Region 2004). The Life Monza project involves the design of Low Emission Zones for the reduction of environmental impacts in the city of Monza (Italy); the construction of two safer pedestrian crossings is envisaged, both to slow down traffic flows and to safeguard the crossing to reach the schools (Pessina 2000).

3 Safe Areas around the Schools: A State of the Art

Evacuation paths and accumulation areas in case of catastrophic events such as earthquakes were analyzed by several authors, some of which have focused their attention on school buildings. Di Gangi (2013) proposed a methodology to iden-

tify the escape routes from buildings with specific reference to schools. This approach was useful in evaluations in the absence of advanced simulation tools. Di Gangi and Velonà (2009) specified and calibrated a system of models capable of simulating the pedestrian outflow correlated to the evacuation of a building with specific application to a school building. The use of specific simulation models can reproduce user behavior and can be used as support in the evacuation plans. Xiao et al. (2017) simulated school children's evacuation behaviors and interaction with the physical environment in earthquake emergencies. Grant et al. (2007) presented a methodology for prioritization of seismic intervention in school buildings in Italy, identifying the highest risk buildings based on increasing detail filters. Priorities and timing were assigned based on the vulnerability, seismic hazard, and occupation of the buildings. Borzi et al. (2013), starting to previous study, proposed a methodology for the definition of a scheme for prioritizing interventions of school buildings that carries out an analysis in successive phases with an increasing level of detail. Only buildings with seismic risk above a certain threshold pass to the next stage, so that the number of analyzed buildings decreases with each stage.

Other studies and projects implemented communication systems and platforms to mitigate earthquake vulnerability in school buildings (2021).

4 Green and Safe Areas around the Schools: A State of the Art

In scientific literature, there is a marked lack of studies dealing with areas around schools that are functional both to reduce emissions and to mitigate the risk in the event of an earthquake. The only studies present are shown below.

Russo et al. (2021) proposed a research that is guideline for sustainable mobility in an urban context in order to guarantee safe and green conditions around schools while satisfying the other sustainability components. This work was developed starting from the regional programs *Scuola Sicura* and *Green and Safety School (*2021*)*. Both programs were developed by Calabria Region (Italy) in the 2016–2019 years. The aim was to give a new and never developed field to increase safety and security and to realize the green around the school achieving the sustainability components.

Iiritano et al. (2022) presented the technical-administrative process for realizing of the LTZ near the schools. Starting from the plan document, the implementation program and the list of financeable interventions constitute the initial phase of the process. The interventions concerned the establishment of LTZ, in which the entrances to the schools were located. The implementation included also financial implementation, as an executing phase (call, agreements, etc.). The projects were scored and ranked.

5 Conclusions

Areas around schools and university departments should be green and safe, as addressed in sustainable urban mobility plan (Campisi et al. 2023). The environment outside the school helps to promote learning and plays a key role both in developing student behavior toward cities and in pursuing international sustainability goals. In the previous paragraphs, the few available examples of the implementation of traffic-free areas around schools to reduce risk and emissions have been recalled. The paper intends to underline how in the scientific field there is a significant gap in the researches that have dealt with the areas around schools as places with the double function of reducing emissions and reducing vulnerability in the event of an earthquake, despite the fact that these areas have a fundamental role. Based on the study carried out, technic and administrative urban planning measures are necessary and a collaboration link between local stakeholders and communities in the development of the safe areas should be realized.

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Exploration and Extraction of Uranium in Saudi Arabia

Salah Ud-Din Khan, Ashfaq Ahmad, Rawaiz Khan, and Nils Haneklaus

Abstract

Nuclear energy contributed low greenhouse gas emission to the environment which makes it possible to meet the future nuclear goals of the Kingdom of Saudi Arabia (KSA). Since, KSA has ambitious plan to build nuclear power plants, thus creating a requirement of uranium. Therefore, in this study, the uranium ores exploration is discussed primarily from phosphate rocks and from desalination concentrate. Since, phosphate rock is considered as promising secondary source of uranium due to its huge reserves and the relatively high uranium concentrations. Possible presence of uranium in phosphate rock of various regions in KSA is discussed. Further, sea water contains the largest amount of uranium known to man today (up to 4.5 billion tons) which is more than 1000 times higher than the amount of terrestrial uranium and could support human energy needs for at least another 1000 years. Therefore, the research is extended to explore the content of uranium from desalinate concentrate as higher uranium concentrate is present in concentrated brine solution. Finally, the use of inexpensive biowaste active carbon from date pit saw dust (from Qasim region of KSA) is deemed to be used for uranium extraction. Best available technologies for uranium recovery are reviewed and their recovery efficiencies are used to estimate the total amount of uranium that could theoretically be recovered today.

Keywords

Natural uranium · Phosphate rock · Biowaste · Uranium recovery

1 Introduction

Seawater desalination is of great importance for Saudi Arabia's freshwater supply, as it accounts for 61 percent of domestic water consumption. The disposal of brine concentrate from seawater desalination accounts for a significant portion of the total project cost and varies depending on the amount of concentrate and the specific discharge and waste treatment methods. (Sethi et al. 2006; Reclamation, U.B.o. and S.N. Laboratories 2003). Therefore, the disposal of rejected brine from desalination is of great concern and can cause pollution of seawater and land (Alnajdi et al. 2020). Alternatively, desalination rejected brine could be used as one of the possible potential sources for unconventional uranium recovery. The idea of uranium recovery from brine concentrate is favorable for several reasons: (a) The presence of more uranium in brine concentrate than in seawater enhances uranium adsorption, (b) the brine concentrate is free of suspended elements due to physical filtration from membranes, enabling stronger uranium to adsorbent surface interaction as the absorption surfaces are not blocked by other ions, and (c) recovery of radiotoxic uranium that would otherwise be dumped into the sea or on land where it can become

S. U.-D. Khan (✉)
Sustainable Energy Technologies Center, College of Engineering, King Saud University, Riyadh, Saudi Arabia
e-mail: drskhan@ksu.edu.sa

K.A.CARE Energy Research and Innovation Center, King Saud University, Riyadh, Saudi Arabia

A. Ahmad
Department of Chemistry, College of Science, King Saud University Riyadh, Riyadh, Saudi Arabia

R. Khan
Engineer Abdullah Bugshan Research Chair for Dental and Oral Rehabilitation, College of Dentistry, King Saud University, Riyadh, Saudi Arabia

N. Haneklaus
Td-Lab Sustainable Mineral Resources, Universität für Weiterbildung Krems, Krems an der Donau, Austria

Institute of Chemical Technology, TU Bergakademie Freiberg, Freiberg, Germany

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a pollutant (Wongsawaeng et al. 2021). Phosphate rock is considered as promising secondary source of uranium due to its huge reserves and the relatively high uranium concentrations. Phosphate rock is the fourth most mined material on earth and the Kingdom of Saudi Arabia has relevant phosphate mining operations as well (Cheira 2015). During wet phosphoric acid processing of phosphate rock, the majority (>80%) of the uranium dissolves into wet process phosphoric acid (WPPA), an intermediate product in fertilizer production, from where it could be recovered. Tetravalent uranium ions are more easily co-precipitated or trapped with calcium sulfate than hexavalent uranium ions. This is the reason why the majority of uranium flows into solution (approximately 80–90% in the Kingdom of Saudi Arabia) and the rest precipitates into the phosphogypsum waste stream (Becker 1989). Large quantities of phosphate rock are industrially processed to make WPPA an intermediary in the manufacturing of fertilizer (Gupta and Singh 2003). A large proportion of the rock is of sedimentary origin and contains significant concentration of uranium (Cioroianu et al. 2001). The phosphoric acid produced from these rocks is found to contain uranium in the range of 50–300 mg/L (Ragheb and Khasawneh 2010). The world's largest phosphate rock resources are concentrated in a single band that spans all of North Africa and extends across Jordan and to the north-west of Saudi Arabia (Al-Eshaikh et al. 2016). The Saudi Arabian phosphate resources are believed to be well over 7000 million tons and are located in numerous sites throughout the north of the Kingdom of Saudi Arabia (Morshedy et al. 2021). Ma'aden and SABIC of the Kingdom initiated the processing and extraction of phosphate rock in 2012. The project based in Ras-Alkher generates three million tons of di-ammonium phosphate fertilizer, 400,000 tons of ammonia and 200,000 tons of phosphoric acid per year (Faisal et al. 2020).

2 Extraction of Uranium

Saudi Arabia is abundant in minerals, has some of the world's largest phosphate reserves, and is investing in large-scale phosphate projects including Ma'aden's large-scale phosphate complex and Phosphate. In addition, since a subsequent volume of potable water comes from desalination which accounts for 60% of the total produced water. It produces an enormous amount of rejected brine concentrate during desalination process. Therefore, phosphoric acid and desalination concentrate both are promising sources for the extraction of uranium to meet future needs of the Kingdom's renewable energy program. Moreover, the Kingdom of Saudi Arabia is the second largest date palm producers in the world closely following Egypt. The waste from date palm trees can be converted to a valuable product (activated carbon) which may be further used as an adsorbent for the removal of uranium (Fig. 1).

3 Adsorption and Activated Carbon

To extract and recover uranium from aqueous solutions, various adsorbents have already been investigated (Naushad et al. 2019; Li et al. 2015; Sun et al. 2015). These adsorbents, which come in a variety of shapes and sizes, have demonstrated high adsorption efficiency toward uranium species (). Activated carbon (AC) is a highly porous carbonaceous substance that is usually created through the thermal treatment of various natural components (such as biomass residuals, coal, and char) in the presence of chemical activators and limited/no-air access (Kyaw et al. 2021). Every year, Saudi Arabia produces more than 15% of the world dates from roughly 25 million date palm trees of various varieties (Basheer et al. 2021). This result in a significant volume of waste materials made up of date palm trunks, fronds, and leaves many tons larger than the produced fruits. These wastes are often treated in one of two ways: they are placed in existing landfills, or they are inappropriately burned in open dumpsites, potentially causing harmful health effects and ecosystem imbalance. Conversely, the palm waste conversion to a higher value product such as the activated carbon would be an essential component of long-term growth. Recently, many studies were conducted on the production of activated carbon using date palm precursors for a variety of applications (Rambabu et al. 2021; Abdus-Salam et al. 2021; Dalhat et al. 2021; El-Maadawy 2019).

4 Results and Discussion

Saudi Arabia, along with China, the United States, Russia, and Morocco, is one of the world's leading phosphate exporters. According to a recent financial times report, the Kingdom intends to increase capacity by 50% to produce nine million tons of phosphate fertilizers per year. Figure 2 compares the data from US geological surveys reports (Jan 2021–2022) for leading phosphate rock-producing countries (Fig. 2a) and global distribution of phosphate rock reserves by country in 2022.

There is a significant content of uranium in phosphate rocks. According to reports by WNA, besides 6.19 million metric tons (MT) of known recoverable uranium resources, an additional of 9–22 million MT may be recovered from global phosphate rocks reserves. (WNA, "Uranium from Phosphates," 2015). The Kingdom has a large agricultural industry and is mining phosphate rock in the north of the country that shows uranium concentrations in excess of

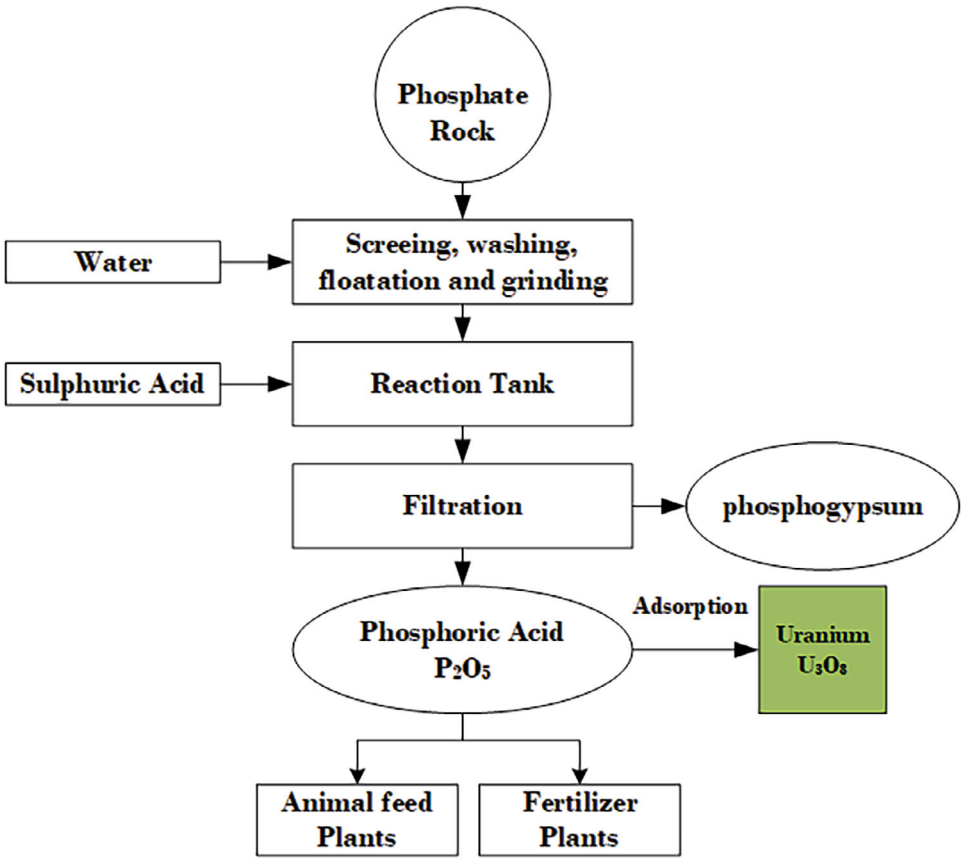


Fig. 1 Phosphoric acid production process from phosphate rock

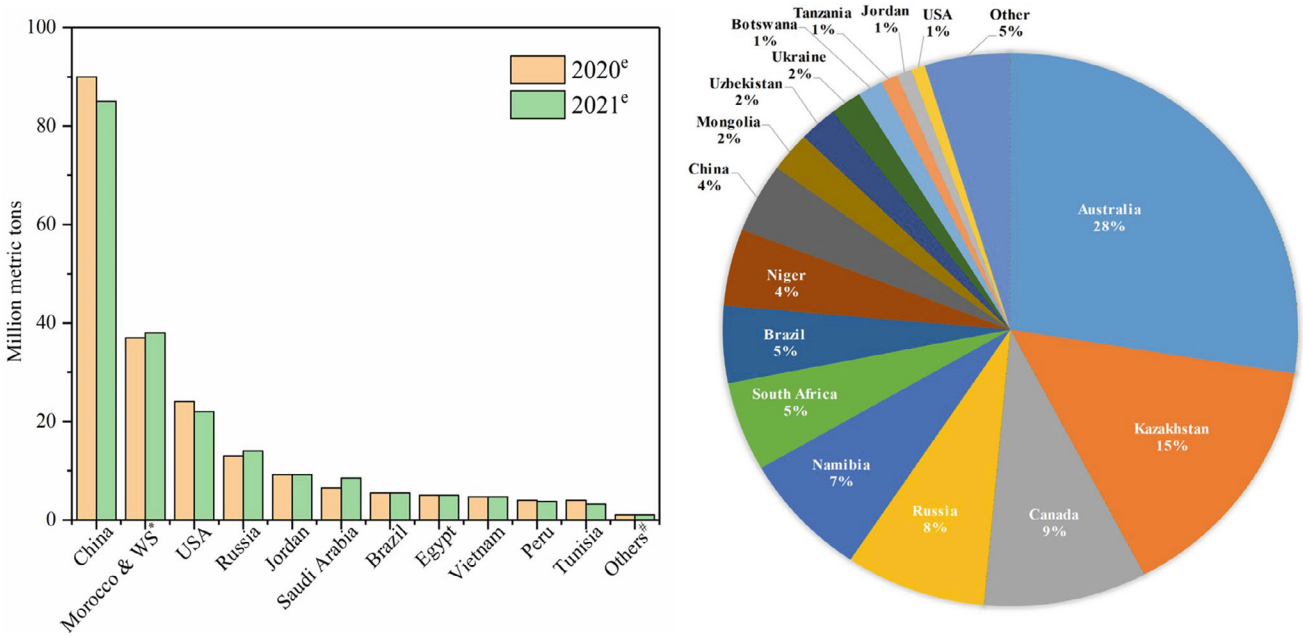


Fig. 2 **a** Leading phosphate rock-producing countries with estimated production for the year for 2020–2021, (e: Estimated, *: Western Sahara, #: countries making a contribution of more than one million tons each to global production. **b** Global distribution of phosphate rock reserves by country 2022 (U.S. Geological Survey)

90 ppm. Increasing uranium recovery from phosphates in the Kingdom of Saudi Arabia can thus be considered promising and we will use a low-cost approach utilizing biowaste from palm date production that may provide a sustainable route to cover large shares of the future uranium needs of the Kingdom of Saudi Arabia increasing the energy independence of the Kingdom.

5 Conclusions

The study concluded that the Kingdom of Saudi Arabia have huge phosphate rocks which can be used to extract uranium by using adsorption process. The amount of extracted uranium can help to support the Kingdom's plan of developing nuclear power plants. Most optimized method is discussed with major parametric analysis. Phosphate rock production is expected to get increase in the KSA as the amount of unconventional uranium that can theoretically be recovered with technologies are available today. Also, recovering uranium from phosphate rocks reduces the environmental effects caused due to the toxicity of these heavy metals. The study also suggests to consider phosphate rock as potential uranium source which can help the Kingdom to reduce its dependency on the import of uranium.

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Assessment of Soil Lead Contamination Near Cottage Industries in a Low-and Middle-Income Township

Thokozani Patrick Mbonane

Abstract

Cottage industries contribute to soil contamination by lead (Pb) a heavy metal. In low- and middle-income townships contaminated soil poses a risk to children that play in the environment. The objectives of the study were to measure soil lead levels and estimate health risks associated with soil lead exposure among children. The study was conducted in Katlehong Township situated within the City of Ekurhuleni. Soil samples were collected within formal and informal settlements. Soil lead contamination was measured using the portable X-ray fluorescence spectrometer. 30 out of 35 samples were higher than 600 parts per million (mg/kg). The average soil Pb mean in the formal settlements was 157.01 mg/kg for formal settlements, while in the informal settlements, it was 338.96 mg/kg. Soil samples collected near lead-emitting cottage industries (such as automobile and spray-painting workshops) were higher (soil Pb = 644 mg/kg) than non-lead-emitting cottage businesses (soil Pb = 527 mg/kg). The health index showed that the health risk exceeded the maximum acceptable level. The study highlights the importance of protecting children's environment, especially where they play and grow. There is a need for a proactive approach by local authorities to enforce zoning and public health by-laws against polluters.

Keywords

Soil lead levels · Lead contamination · XRF · Cottage industries · Environmental exposure · Low-and middle-income township · Environmental health

T. P. Mbonane (✉)
Department of Environmental Health, Faculty of Health Sciences, University of Johannesburg, Johannesburg, South Africa
e-mail: tmbonane@uj.ac.za

1 Introduction

Cottage industries are characterised as informal business or household-based work within residential areas. According to Charmes (Charmes 2012), in 2015–2010, it was estimated that the informal economy contributed to 66% of the work opportunities in Africa. Cottage industries assume a huge and noticeable part in many developing countries with few job opportunities, where they may be the sole source of income for a lot of families (Tasneem and Rouf 2014), (Goel and Chowgule 2019). Some cottage industries make use of extremely poisonous metals such as mercury, arsenic, cadmium and lead, which are associated with a variety of negative health effects (Teare et al. 2015; Mathee et al. 2020). Lead use in the cottage industry has been linked to lead exposure in the wider population, especially vulnerable populations (Haman et al. 2015; Naicker et al. 2013; Mathee et al. 2005).

Lead can be found in pewter, brass, vintage, handcrafted, imported or improperly glazed ceramic plates and ceramics (Pantic et al. 2018; Welton et al. 2018). An acidic element in these components could work along with the glaze and promote the release of lead (Pantic et al. 2018; Yin et al. 2020). Mining and related industries, such as smelting, generate waste materials that can pollute the surrounding environment and pose a risk to neighbouring residents long after the facilities have closed (Allan-Blitz et al. 2022; Bruno et al. 2020; Bansah et al. 2016; Emmanuel et al. 2018). The acid is extremely corrosive and dissolves lead as well as lead particulate matter (Flora et al. 2012). Another example of cottage industry activity is E-waste recycling, which is often done inside house complexes, and is a major source of exposure to lead and other toxins across the world, but especially in Asia and Africa (Pascale et al. 2016).

Lead is commonly used in both formal and informal industries in South Africa, with children being the most vulnerable to lead exposure (Mathee 2014; WHO 2015).

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Lead released from the cottage industries has a significant effect on the health of the environment as well as the quality of life of the people who live in those areas (Kordas et al. 2018). The environment can get contaminated with lead oxides which could cause adverse health effects on the people who are exposed. Rapid urbanisation and industrialization, as well as inadequate environmental health policies and legislation, are major reasons why people living in areas near cottage industries are highly affected by lead (Teare et al. 2015; Mathee et al. 2020).

There are currently no known environmental management and health actions addressing the environmental contamination due to lead levels. Therefore, the study aimed to (i) describe common cottage industries in Katlehong Township and (ii) determine and describe the soil lead concentration near cottage industries in Katlehong Township.

1.1 Study Design and Setting

A descriptive cross-sectional study was conducted from August to September 2021. The study was conducted in Katlehong township, City of Ekurhuleni located in Gauteng Province, South Africa. Katlehong township with a total area of 55.36 km2 and is divided into 52 sub-sections. In 2011, Katlegon township was estimated to have a population of 467,890 residents.

1.2 Sampling Procedure

The 38 soil samples were collected in front of the cottage industries (within a distance between 5–10 m). Some owners refused and those samples were not included in this study. A stainless-steel spatula was used to scoop soil from various cottage industries, and it was poured into a 50 ml plastic bottle container for each sample. The following procedure (conforming to USA's standards) was followed to collect soil samples:

- The 28 ml bottle was labelled with a sampling number and the location it was taken from.
- A clean spatula was used to collect soil within a 1-foot diameter circle into the bottle until it was full, and the bottle was then sealed.
- To avoid cross-contamination, the spoon was cleaned with wipes until the soil was not visible anymore. Discard wipes used in a trash bag.
- Samples were collected and dried overnight at 90 °C in a laboratory oven to determine lead concentration. These samples were placed on a portable X-ray fluorescence (XRF) spectrometer analyzer (Thermo Scientific Niton XRF Analyzer—XLT 800 SERIES) which was used to analyse the dry samples for lead in soil.

1.3 Health Risk Assessment for Soil Lead

This study sought to quantify the human health risk due to soil lead exposure in children based on three major pathways (inhalation, ingestion and dermal), according to US Environmental Protection Agency (USEPA) guidelines. The study's health risks (HR) focused on carcinogenic risk (CR) and non-carcinogenic risk (NCR). The equations used are below:

$$\mathrm{LDI_{ing}} = \frac{\mathrm{Pb\ x\ IngR\ x\ EF\ x\ ED}}{\mathrm{BW\ x\ AT}}, \tag{1}$$

$$\mathrm{LDI_{inh}} = \frac{\mathrm{Pb\ x\ InhR\ x\ EF\ x\ ED\ x\ FSPO\ x\ PLAF\ x\ PM10}}{\mathrm{BW\ x\ AT\ x\ PET}}, \tag{2}$$

$$\mathrm{LDI_{dem}} = \frac{\mathrm{Pb\ x\ CF\ x\ EF\ x\ ED\ x\ SA\ x\ AF\ x\ ABS}}{\mathrm{BW\ x\ AT}}, \tag{3}$$

$$\mathrm{HQ} = \frac{\mathrm{inh, ing, derm}}{\mathrm{RfD}}, \tag{4}$$

$$\mathrm{LCR} = \mathrm{LDI\ (inhalation, ingestion, dermal)\ x\ CSF}. \tag{5}$$

Table 1 below shows the abbreviations of the equations used, while Table 2 describes the reference used.

The HQ was determined using formula 4, while the lifespan cancer risk was established using formula 5. The last non-carcinogenic risk (NCR) was determined using the following formula 6. The sum of the hazard quotient (inhalation + ingestion + dermal). Where ≤1 implies no potential non-carcinogenic effects, and > 1implies potential carcinogenic effects.

$$\mathrm{NCR} = \sum \mathrm{HQ} = \mathrm{HQ_{inh}} + \mathrm{HQ_{ing}} + \mathrm{HQ_{derm}} \tag{6}$$

1.4 Data Analysis

The data collected was checked for errors and cleaned using Microsoft Excel version 2019. After that, it was entered into the IBM Statistical Package for the Social Sciences (SPSS) version 2021. The descriptive data (geometric means with standard deviation [SD], medians and ranges) was presented in figures and tables. Pearson Chi-squared and t-tests were used to determine the statistical difference between a group of settlements and industries.

Table 1 Description of statistical difference in the type of industries

Parameter abbreviation	Description	Value	Unit
AF	Dermal adherence factor	0.2	Mg/(cm^2 × d)
ABS	Dermal absorption factor	0.001	–
LDI	Average lead daily intakes via 3 exposure pathways	–	–
IRg	Soil intake frequency of children for one day	200	Mg/d
IRh	Breathing rate of children for one day	7.5	m^3/d
CF	Conversion factor	1 × 10–6	Kg/mg
CFS	Cancer factor slopes		
CR	Carcinogenic risk		
EF	Exposure frequency for one year	350	d/y
ED	Average exposure duration	6	y
BW	Average body weight	15	Kg
AT	Average time (non-carcinogenic)	ED × 365	d
	Average time (carcinogenic)	70 × 365	
FSPO	Proportion of particulate matter from soil in the air	0.15	–
Pb	Measurement concentration of soil heavy metal i	–	Mg/kg
PLAF	Inhaled retention rate of particulate matter from soil	0.75	–
PM_{10}	Amount of inhalable particles	0.15	Mg/m
SA	Exposed surface area of skin	1600	cm^2
HQ	Hazard quotient		
NCR	Non-carcinogenic risk		
R*f*D	Reference doses for lead concentration		Mg/(kg × d)

Table 2 Lead metal risk reference dose cancer slope factor

Metal	R*f*D$_{inh}$	R*f*D$_{derm}$	R*f*D$_{ing}$	CFS$_{inh}$	CFS$_{derm}$	CFS$_{ing}$
Lead (Pb)	1.4×10^{-3}	1.4×10^{-3}	3.6×10^{-3}	4.2×10^{-2}	4.2×10^{-2}	8.5×10^{-2}

1.5 Ethical Consideration

The study obtained approval from the University of Johannesburg, the Research Ethics Committee (REC-1077-2021) and the Ekurhuleni Research Committee (NHRD: GP_202106_061).

2 Results

2.1 Description of Cottage Industries in the Study

In our study, we found different cottage industries in Katlehong Township. These industries include hair salons, motor repair shops, panel beaters, upholstery shops and spaza shops. There were more cottage industries from the formal settlement compared to the informal settlement with 30 (79%) and 8 (21%), respectively. The results show that there were 27 and 11 non-lead-emitting cottage industries. The Pearson chi-square did any statistical difference ($p = 0.02$) between the type of cottage (non-lead-emitting vs. lead-emitting) when compared to two different settlements (formal vs. informal), as shown in Table 3.

The Pearson correlation analysis showed a positive significant relationship ($r = 0.45$; $p \leq 0.01$) between lead cottage industries and informal settlements as well as between formal settlements and non-lead cottage industries ($r = 0.89$; $p = 0.03$). While it showed a negative significant relationship ($r = -1.23$; $p = 0.02$) between lead cottage industries and formal settlements. As shown in Table 4.

2.2 Soil Lead Concentration

The geometric mean of soil lead concentration was 317.75 mg/kg with a standard deviation (SD) of 280,772. While median was 181.39 mg/kg and soil lead concentrations ranged from 48 to 628 mg/kg. Table 5 shows that the informal settlement (447.67 mg/kg, SD = 279.85) had higher soil lead levels mean compared to the formal settlement (300.30 mg/kg, SD = 279.85). Despite, the highest lead concentration being found in the formal settlement (691 mg/kg). The t-test did show the statistical mean

Table 3 Description of statistical difference in the type of industries

Cottage	Formal settlement n (%)	Informal settlement n (%)	Total N (%)	P-value*
Non-lead cottage	8 (27%)	0	8 (23%)	0.02**
Lead cottage	22 (73%)	8 (100%)	30 (77%)	
Total	30 (100%)	8 (100%)	38 (100%)	

* P-value was determined using Pearson Chi-squared, ** Statistical difference set a 0.05

Table 4 Correlation matrix between type and area of cottage

	Non-lead cottage	Lead cottage	Formal settlement	Informal settlement
Non-lead cottage	1			
Lead cottage	0.23 (0.60)[a]	1		
Formal settlement	0.89 (0.03*)	−1.23 (0.02)	1	
Informal settlement	0.63 (0.43)	0.45 (≤0.01*)	0.77 (0.11)	1

* P-value was determined using Pearson Chi-squared, ** Statistical difference set a 0.05

Table 5 Description of statistical difference in the type of industries

Variable	Geometric mean (SD)	Lowest concentration	High concentration	P-value*
Area				
Formal	287.77 (279.85)	48	628	0.03
Informal	447.67 (300.30)	101	691	
Cottage				
Non-lead cottage	98.83 (110.391)	48	628	0.01**
Lead cottage	449.10 (271.11)	55	691	

* P-value was determined using *t-test*, ** Statistical difference set a 0.05

Table 6 Lead average daily intake, hazard quotient, non-carcinogen effects and carcinogenic effects

Metal	LDI_{ing}	LDI_{inh}	LDI_{derm}	HQ_{inh}	HQ_{ing}	HQ_{derm}	NCR	LCR
Pb	4.8×10^{4}	4.6×10^{3}	3.1×10^{2}	6.2×10^{1}	9.8×10^{4}	2.2×10^{1}	2.8×10^{2}	3.4×10^{3}

difference in the lead concentration between formal and formal settlement. The distribution according to industries shows that soil samples near lead-emitting industries had higher lead concentrations. The geometric mean in the soil samples from non-lead-emitting cottage industries was very low at 98.83 mg/kg (SD = 110.391). While near cottage industries emitting lead it was high 449.10 mg/kg (SD = 271.11). There was a statistical difference between the mean of lead and non-lead-emitting industries with a p-value of 0.01.

2.3 Health Risk Effects

Table 6 shows the average daily intake for lead. Soil lead exposure has the potential to cause carcinogenic and non-carcinogen effects among children, while ingestion and inhalation were the most common pathways for potential human lead exposure among children.

3 Discussion

Cottage industries are extensively dispersed across the country, following the dispersion of the population and hence concentrating in bigger cities (Yesilonis et al. 2008). Most cottage industries are primarily found in the informal economy, operating from basic and improvised locations with an average of three employees (Meagher, 2013). Yet, in this study, the majority of cottage industries were found in the formal settlement (30 vs. 5) which are not associated with impoverished living conditions and low standard of living (Nkonki-Mandleni et al. 2021). This could be attributed to the existence duration of the formal settlement area where residents are well established in the area. While those in the informal settlement have recently settled in their area the majority of people in the informal settlement work in the nearby industrial areas.

Informal settlements and near lead-emitting cottage industries were predicted to have higher soil lead concentra-

tions. These areas have seen a growth in cottage industries that could emit lead contamination to the environment such as panel beating and spraying of automobiles in the streets, and metal scrap recycling, which includes melting of steel and copper (Mugudamani et al. 2022). In this study, the informal area (settlements) had a high soil lead concentration of 447.67 mg/kg (SD = 300.30) compared to the formal area of 287.77 mg/kg (SD = 279.85). The highest soil lead levels were found in a steel welding workshop at 691 ppm, according to the findings. These results indicated that there is a problem with the lead levels produced in this cottage industry since they were over the permissible limit of 600 ppm. In the informal settlements, the samples were collected from glass recycling areas, scrap yards and metal recycling yards. According to the results, the highest levels of lead were recorded at 628 ppm at a metal recycling workshop. The results indicated that cottage industries in both the formal and informal industries contributed to soil lead contamination.

Previous studies have found that high soil lead concentrations have the potential to lead to non-carcinogenic and carcinogenic effects among South African children who are exposed to lead. This study found that children were at a greater risk for both carcinogenic and non-carcinogenic effects. Hence, a call for more research as well as environmental health management actions to address the sources of lead exposure in our township to protect children against potential health effects.

There are currently no legislation and policies that seek to address the impact of cottage industries emit lead on human health in South Africa. Furthermore, the is a lack of policies that sorted to address the lead-contaminated soil. Such policies exist in rich countries such as the USA. The US Environmental Protection Agency has developed and implemented policies regulating lead in soil (Lupolt et al. 2022). However, in South Africa, the government banned leaded petrol and implemented regulations governing the lead in paint (Mathee 2014). Therefore, this study might set a basis for environmental management and health government departments to understand the importance of ensuring a safe environment for young children by conducting environmental contamination surveys. The limitation of the study is that it was conducted in a small township of the City of Ekurhuleni and a few samples were collected. Therefore, it might not describe the extent of soil lead contamination. Future studies should be conducted to develop and explore interventions to address soil lead contamination and its health impact in townships and other similar areas.

4 Conclusions

This study aims to bring awareness to the communities in Katlehong townships of the effects of soil lead concentration, although most of the levels are not high above the limit of 600 mg/kg, they still affect human health adversely and no treatment is better than prevention.

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Consequence Reduction for Business from Natural Disasters Using Depreciation Approach

Marin Galabov, Plamena Zlateva, Ekaterina Bogomilova, and Dimiter Velev

Abstract

Nowadays, natural disasters, due to available climate changes, increase their negative impact on tangible fixed assets of companies by damaging or destroying them. Therefore, in order to continue their production activities, companies need to repair existing assets or purchase new ones. The purpose of the paper is to propose a depreciation approach to be used to reduce these consequences for business from natural disasters. The main idea is to use the funds accumulated through depreciation expediently for the acquisition of new tangible fixed assets to replace the destroyed ones. It is assumed that the term 'depreciation' refers to an accounting method used to allocate the cost of a tangible fixed asset over its useful life. Various depreciation methods are considered: linear and nonlinear (declining and ascending). The essence of the proposed approach is to suggest suitable optimal method for depreciation of a given tangible fixed asset, taking into account its specific features, in order to accumulate as mush depreciation funds as possible during the first years. Thus, the asset destroyed from natural disasters can be replaced with new one as quickly as possible. To verify the approach, several examples are presented with specific tangible fixed assets showing the results of using various depreciation methods.

Keywords

Natural disaster · Disaster risk management · Consequence reduction · Business · Depreciation · Tangible fixed assets

1 Introduction

In recent years, the negative impact of natural disasters on business sustainability has been increasing due to available climate changes (European Environment Agency (EEA) 2021; Zolnikova et al. 2021). Especially, companies in the production sector are suffering significant negative consequences. Their tangible fixed assets are usually destroyed and production ceases as a result (e.g. supply disruption issues, selection of new suppliers, order allocation problems (Nazari-Shirkouhi et al. 2023)). This necessitates the purchase of new similar assets by the companies.

It is important to point out that depreciation is a successful opportunity to reduce the consequences for business from natural disasters. More specifically, the negative consequences which are related to the damage or destruction of the tangible fixed assets of the companies. It is known that depreciation enables companies to earn revenue from the assets they own by paying for them over a certain period (Ross et al. 2021).

In this research, it is assumed that the term 'depreciation' refers to an accounting method used to allocate the cost of a tangible fixed asset over its useful life. Depreciation is a value process. Depreciation of tangible fixed assets can also be regarded as a monetary assessment of their wear and use over the amortization periods. In particular, depreciation represents how much of an asset's value has been used. Depreciable value is the difference between the asset's carrying amount and its residual value (Bragg 2022).

The purpose of the paper is to propose a depreciation approach to be used to reduce these consequences for companies from natural disasters. The main idea is that funds accumulated through depreciation can be used in the acquisition of new tangible fixed assets to replace the destroyed ones.

M. Galabov · P. Zlateva (✉) · E. Bogomilova · D. Velev
University of National and World Economy, Sofia, Bulgaria
e-mail: plamzlateva@unwe.bg

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2 Essence of the Proposed Depreciation Approach to Reduce the Business Consequence from Natural Disasters

The essence of the proposed approach to reduce the business consequence from natural disasters is to suggest suitable optimal method for depreciation of a given tangible fixed asset, taking into account its specific significance for the company, in order to accumulate as mush depreciation funds as possible during the first years. Thus, the particular tangible fixed asset destroyed from natural disasters can be replaced with a new one as quickly as possible.

The main stages of the proposed depreciation approach are as follows:

1. Determination of the specific significance of the given tangible fixed asset for the company.

Business experts determine the specific significance degree of the given tangible fixed asset for the company (the benefit that the given tangible fixed asset can bring to the company) during the separate years of its estimated useful life (depreciation period).

2. Selection of depreciation method suitable for specific significance of the given tangible fixed asset for the company.

It is generally accepted in the specialized literature that 'the depreciation method is the way in which the amount of depreciation is determined during the separate accounting periods within the useful life of the depreciable asset.'

It is necessary to note that the following basic concepts are used when applying the depreciation methods: depreciation base, depreciation rate and depreciation quota.

The product of the depreciation base for the corresponding depreciation year and the depreciation rate for the same year sets the depreciation quota for the depreciation year. The depreciation rate for a given depreciation year is a percentage that is established according to certain rules. The depreciation quota is the part of the depreciable value that is intended to be included in the accounting records as a depreciation expense within the depreciation year. The depreciation year is a period of 12 months during which depreciation is charged on the given asset (Ross et al. 2021).

The methods of depreciation of tangible fixed assets are linear and nonlinear.

In the linear method, the depreciation is allocated proportionally to the periods that cover the estimated useful life of the depreciable tangible fixed asset. This method is generally applied when the company cannot determine the significance of the use of the given asset within its useful life.

In nonlinear methods, the amount of depreciation is different in the separate periods of the estimated useful life of the depreciable assets. Nonlinear methods can be descending or increasing.

Decreasing nonlinear depreciation methods are those in which each subsequent depreciation quota within the estimated useful life (depreciation period) of depreciable assets is less than the previous quota. These depreciation methods are applied when the company considers that the significance of the tangible fixed asset in the initial years is greater and then decreases. Such methods are the method of decreasing remainder, the method of evenly reduction, the method of decreasing sum of numbers and the method of unevenly reduction.

Increasing nonlinear depreciation methods are those in which each successive depreciation quota is greater than the previous one. These depreciation methods are applied when the company decides that the benefit that can bring the given asset in the initial years is less and then increases. Such methods are the method of evenly increase, the method of increasing sum of numbers and the method of unevenly increase.

3. Calculation of funds accumulated through depreciation in respect of the given tangible fixed asset.

A calculation is made of the funds that accumulate through depreciation associated with an asset during the separate years of its expected useful life (depreciation period) using the most appropriate method of depreciation, taking into account the significance of the tangible fixed asset to the company.

Various depreciation methods accumulate different funds. Accordingly, there are various possibilities for the participation of these accumulated funds in the replacement of the tangible fixed asset destroyed from the natural disasters, i.e. in reducing the company's negative consequences from natural disasters.

3 Applications of the Proposed Approach Using Various Depreciation Methods

3.1 Application of the Approach Using the Method of Decreasing Remainder

The method of decreasing remainder is characterized by the fact that the depreciation base is not constant, but decreasing. The depreciation base for a given depreciation year is the difference between the depreciation base and the depreciation quota for the previous depreciation year. The depreciation rate is the product of the linear depreciation rate and such a number that the product value is greater than 50, i.e. the rate must be greater than 50%.

Table 1 Application of the approach using the method of decreasing remainder

Depreciation year	Depreciation base (EUR)	Depreciation rate (%)	Depreciation quota (EUR)
First year	100,000	60	60,000
Second year	40,000	60	24,000
Third year	16,000	60	9600
Fourth year	6400	60	3840
Fifth year	2560	60	2560
			Total 100,000

Let us consider the following example: The depreciation base e 100,000 EUR (price of the machine—the tangible fixed asset). The amortization period is 5 years.

According to this method, the linear depreciation rate is first calculated: 100/5 = 20 or 20%. Then it is necessary to multiply this 20% by such a number that gives a percentage greater than 50%. Let the number be 3 and thus the depreciation rate becomes 60%. Here, the last depreciation quota is equal to the last depreciation base.

The particular application of the decreasing remainder method is shown in Table 1.

In this case, if a natural disaster occurs and destroys the machine (the tangible fixed asset) at the end of the first year of its operation, then the company will have 60,000 EUR accumulated funds through depreciation. These funds can be used for the acquisition of a new machine along with other funds of the company.

If the natural disaster occurs at the end of the second year, then these accumulated funds will be 60,000 + 24,000 = 84,000 EUR. Similarly, if the disaster occurs at the end of the third or fourth year of the machine's operation, the accumulated funds will be much more and the company will have a greater opportunity to purchase a suitable replacement machine.

3.2 Application of the Approach Using the Method of Increasing Sum of Numbers

The method of increasing sum of numbers is characterized by the fact that the depreciation rate (DR) increases each subsequent year. Here, the depreciation rate (*DR*) is calculated by dividing the depreciation year number by the sum of the numbers corresponding to the depreciation years using the following formula $DRi = i / (1 + 2 + \ldots + n)$, where n is the number of years for depreciation. The depreciation quota is not constant, but increasing. The depreciation base is constant.

Table 2 Application of the approach using the method of increasing sum of numbers

Depreciation year	Depreciation base (EUR)	Depreciation rate (%)	Depreciation quota (EUR)
First year	100,000	(1/15) x 100 = 6.67	6670
Second year	100,000	(2/15) x 100 = 13.33	13,330
Third year	100,000	(3/15) x 100 = 20	20,600
Fourth year	100,000	(4/15) x 100 = 26.67	26,670
Fifth year	100,000	(5/15) x 100 = 33.33	33,330
			Total 100,000

Let us consider the following example: The depreciation base e 100,000 EUR (price of the machine—the tangible fixed asset). The amortization period is 5 years.

The particular application of increasing sum of numbers is shown in Table 2.

In this case, if at the end of the first year a natural disaster occurs that destroys the machine (the tangible fixed asset), then the accumulated funds from the depreciation in the amount of 6670 EUR can be used in the acquisition of a new machine.

If the disaster occurs at the end of the second year then the accumulated funds will be 6670 + 13,330 = 20,000 EUR. The accumulated funds will be larger if the disaster occurs at the end of the third or fourth year, because to this 20,000 EUR will be added the accumulated 2000 EUR for the third year, as well as the 26,670 EUR for the fourth year (for amortization of four years).

4 Conclusions

A depreciation approach is proposed to reduce the consequences for business from natural disasters is proposed. The essence of the proposed approach is to suggest suitable optimal method for depreciation of a given tangible fixed asset, taking into account its specific features, in order to accumulate as mush depreciation funds as possible during the first years. Some applications of the proposed approach to reduce the business consequence from natural disasters using various depreciation methods are presented. Applications of the proposed approach to various businesses are planned.

Acknowledgments This research has been partially supported by National Science Fund of Bulgaria under the Grant № KP-06-H55/5 from 15.11.2021, titled 'Smart Risk Management for Business from Adverse Events and Natural Disasters'.

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Wildfires Impact in Water Quality: A Case Study from Portugal

Maria Costa, Noémia Santos, and Teresa Valente

Abstract

In the north of Portugal, hundreds of wildfires occur each year, putting at risk the existing water resources. This study aims to analyze the effects of forest fires on the quality of the water source that supplies a water treatment plant (WTP). In addition, the methods of remediation to deal with the disturbances resulting from fires are presented. The study was performed with the collaboration of the WTP—Castelo de Paiva (N Portugal), using historical data that allows to correlate water modifications with the occurrence of the fires in recent years. In addition, the physical-chemical parameters of the water were periodically controlled after a mega fire in August 2016. Soil and ashes were also analyzed in the lab. The results show the contribution of ashes to soil impermeability, inhibiting infiltration and leading to their entrainment into the watercourse that supplies WTP. This results in turbidity higher than 1000 NTU, which makes it difficult to apply conventional treatment processes. The episodes of precipitation higher than 10 mm/day began to occur about two months after the fire and gave rise to the first problems of very high turbidity in the catchment, leading to interruptions of the water supply systems. Six months after the fire (February 2017), turbidity values were still in the order of 1000 NTU. When turbidity increased, laboratory jar-tests were performed to adjust the rates of pre-oxidation reagents. Accompanying this, an increase in the dosage of calcium hydroxide and carbon dioxide was carried out, favoring the coagulation/flocculation stage. Due to the expected increase in the frequency and intensity of wildfires in a warming climate, this kind of interdisciplinary study is of great help for water treatment management.

Keywords

Water resources · Wildfires · Hydrochemistry · Turbidity · Remediation

1 Introduction

Surface runoff mobilizes ashes and residues produced during forest fires and deposits them in river catchments, deteriorating the surface water quality (Raoelison et al. 2023). Elevated suspended solids from storms following the wildfire can impact water treatment plants, threatening the attainment of drinking water standards for turbidity and increasing filtration and coagulation costs (Emelko et al. 2011; Murphy et al. 2015). Sediments can overwhelm these systems, requiring closure of water intake (Hohner et al. 2016), as happened with the present study case.

The subject of study is the mega fire that burned 2,190,992 ha between 8 and 17 of August 2016, affecting almost all of the hydrographic basin of Paiva River (N Portugal) and the water source that supplies the treatment plant of Castelo de Paiva.

The Paiva River, an affluent of Douro River, has about 71% of its basin area occupied by forest—a mixture of resinous and broadleaf forests where it is possible to find sections densely planted with eucalyptus (SNIAMB, https://sniamb.apambiente.pt/). There is a temperate climate with well-defined summer

M. Costa (✉)
Department of Geology in ECVA, University Trás-os-Montes Alto Douro, Vila Real, Portugal
e-mail: rosariomc@utad.pt

Department of Geosciences, GeoBioTec, University of Aveiro, Aveiro, Portugal

N. Santos
Águas do Douro e Paiva (AdDP), Porto, Portugal
e-mail: nsantos@adn.pt

T. Valente
Instituto de Ciências da Terra (ICT) – Polo da Universidade do Minho, Braga, Portugal
e-mail: teresav@dct.uminho@pt

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and winter, and in which the dry season occurs in summer (July to September).

The Castelo de Paiva WTP was designed to treat 30,000 m^3/day, which allows for a supply equivalent to the consumption of about 150,000 inhabitants/day and produces an average of 17,000 m^3/day. However, it has a high seasonal peak factor, with important fluctuations between the volumes produced in the winter and summer months.

This article reports the challenges of dealing with strong modifications in the water quality source and the collaborative efforts between local water managers and researchers to address knowledge gaps in the first critical months after the fire. Then, the main objectives of the present work were: (i) to describe the modifications and characterize the impact on the hydrochemical properties related to the fire; (ii) to develop strategies to implement in the WTP for responding to such modifications in future fire events.

2 Materials and Methods

Ashes and underlying burned soil were collected randomly three months after the fire and prepared for physical, chemical, and mineralogical analyses. After drying at 40 °C for 72 h, the samples were sieved through a 2 mm steel sieve. For mineralogy, the samples were analyzed by X-ray powder diffraction using CuKα radiation. The concentration of metals was determined by atomic absorption spectrometry after digestion with *aqua regia*. pH in water and KCl and electrical conductivity (EC) were analyzed in a suspension 1:2.5 following standard methods. Samples were also analyzed for organic matter (OM) by loss on ignition at 550 °C ± 50.

Historical physical-chemical data from the water intake in Paiva River at the WTP (2006–2015), and data obtained from June 2016 to May 2017 (3 months before the fire until 9 months after) were statistically analyzed. These samples were analyzed at the WTP laboratory by ion chromatography (major cations and anions) and Molecular Absorption Spectrometry (Al, Fe, Mn) after filtration with 0.45 μm cellulose membranes. Alkalinity was determined by volumetry, and total organic Carbon by direct combustion method—NPOC. Turbidity was measured by nephelometry. Determinations of pH, EC, and temperature were performed in the field.

Daily precipitation data registered after the fire at the closest weather station (Arouca 08H/01UG) (SNIRH https://snirh.apambiente.pt/) were plotted with turbidity to study the effects of rain events on water quality.

3 Results and Discussion

Major chemical composition of the ashes and the burned soil is presented in Fig. 1. The pH is in the near-neutral range for both types of material. EC is higher for ashes, as expected, but with a maximum of 157 μS/cm. In accordance, generally, the ashes show higher OM and typical ash elements such as Ca, Mg, and K. In addition, metals such as Zn, Cu, Pb, Cd, Ni, and Hg have higher concentrations in ash material. Such behavior indicates the transfer of these elements from the vegetation to the ashes (Abraham et al. 2017; Costa et al. 2014).

Water quality over the period 2006–2015 remains relatively constant. Paiva River has low mineralized water (21 μS/cm < EC < 78 μS/cm, median = 47 μS/cm), with slightly acidic to near neutral pH (6.3 < pH < 8.2, median = 7.1). Alkalinity is quite low (5 mg/L $CaCO_3$ < Alk. < 57 mg/L $CaCO_3$, median = 10 mg/L $CaCO_3$). The metal concentrations were all below the detection limit, except for Mn and Fe (maximum registered of 32 and 230 μg/L, respectively). Turbidity stands out due to its greater variability revealed in this period (0.29 < NTU < 396).

Monthly water quality results for a period of three months before the fire until nine months after, namely EC, alkalinity, total organic carbon, and pH, are presented in Fig. 2. In general, there is an increase in these parameters, following the fire, as reported in other studies (e.g., Abraham et al. 2017; Costa et al. 2014; Raoelison et al. 2023; Smith et al. 2011). Other parameters show small variations.

The episodes of daily precipitation higher than 10 mm/day began to occur about two months after the fire (in October 2016). They gave rise to the first problems of excess turbidity in the catchment (Fig. 3), leading to several periods of restrictions in the WTP, which were repeated in November with the continuation of precipitation. Six months after the fire (February 2017), there were again turbidity values in the order of 1000 NTU, thus imposing the need to close the water intake.

When turbidity increased, laboratory jar-tests were performed to adjust the rates of pre-oxidation reagents. Accompanying this, an increase in the dosage of calcium hydroxide and carbon dioxide was carried out to provide greater alkalinity to the water, favoring the coagulation/flocculation stage.

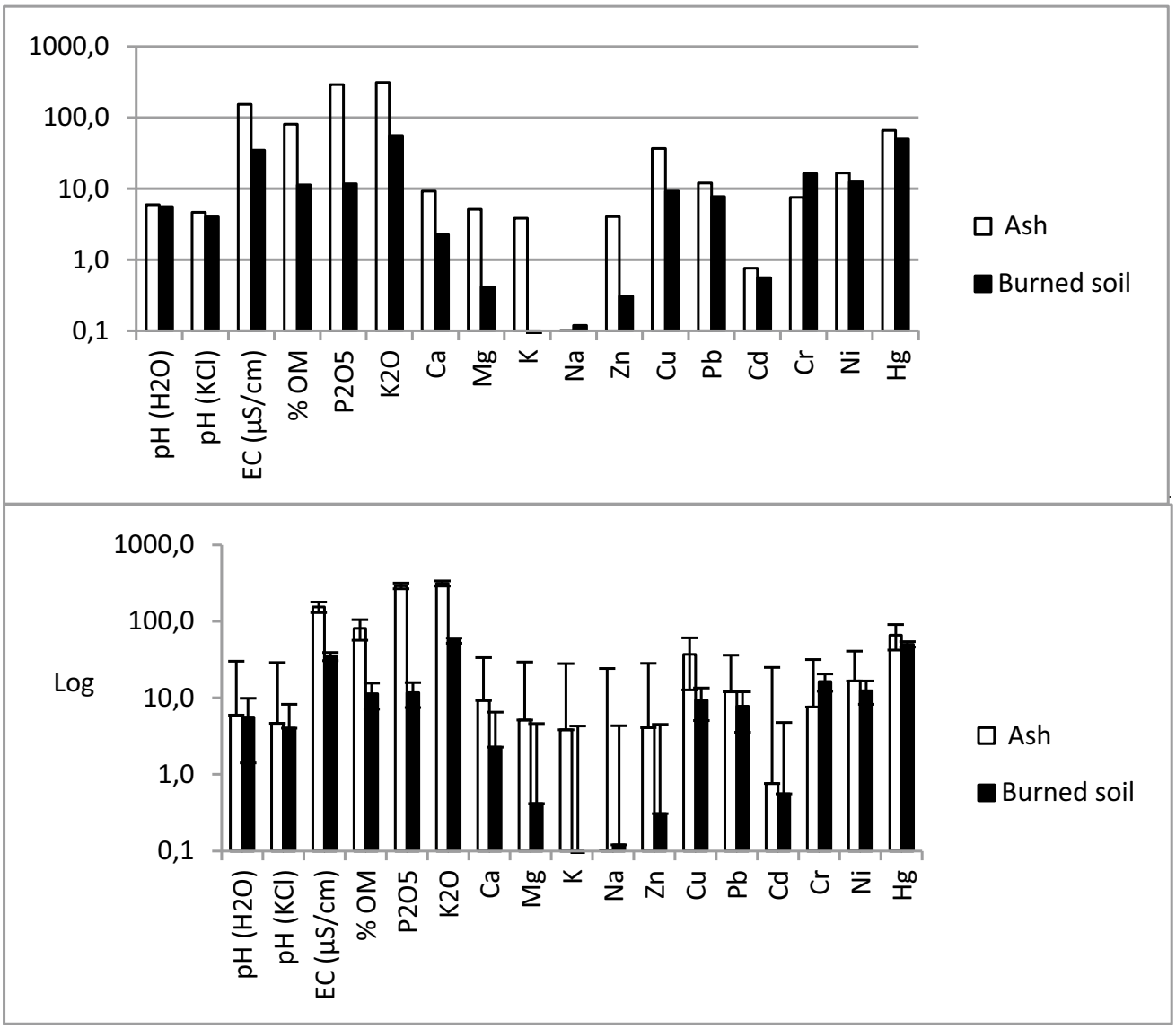


Fig. 1 Ash and burned soil properties. EC—electrical conductivity, OM—organic matter. Oxides and elements are expressed in mg/kg

4 Conclusions

Following rainfall, eroded soil and ash pose a considerable contamination risk to water bodies, including water supply reservoirs (Abraham et al. 2017; Smith et al. 2011). The results obtained in this study show that the ash generated by the fire made the soils impermeable (Moody et al. 2013), hindering precipitation infiltration and leading to ash runoff into watercourses (Wu et al. 2021). which caused an increase in water turbidity (reaching 1000 NTU) two months after the fire and again six months later, when heavy rains occurred. In these situations the water intake had to be shut off. Special remediation procedures were then implemented.

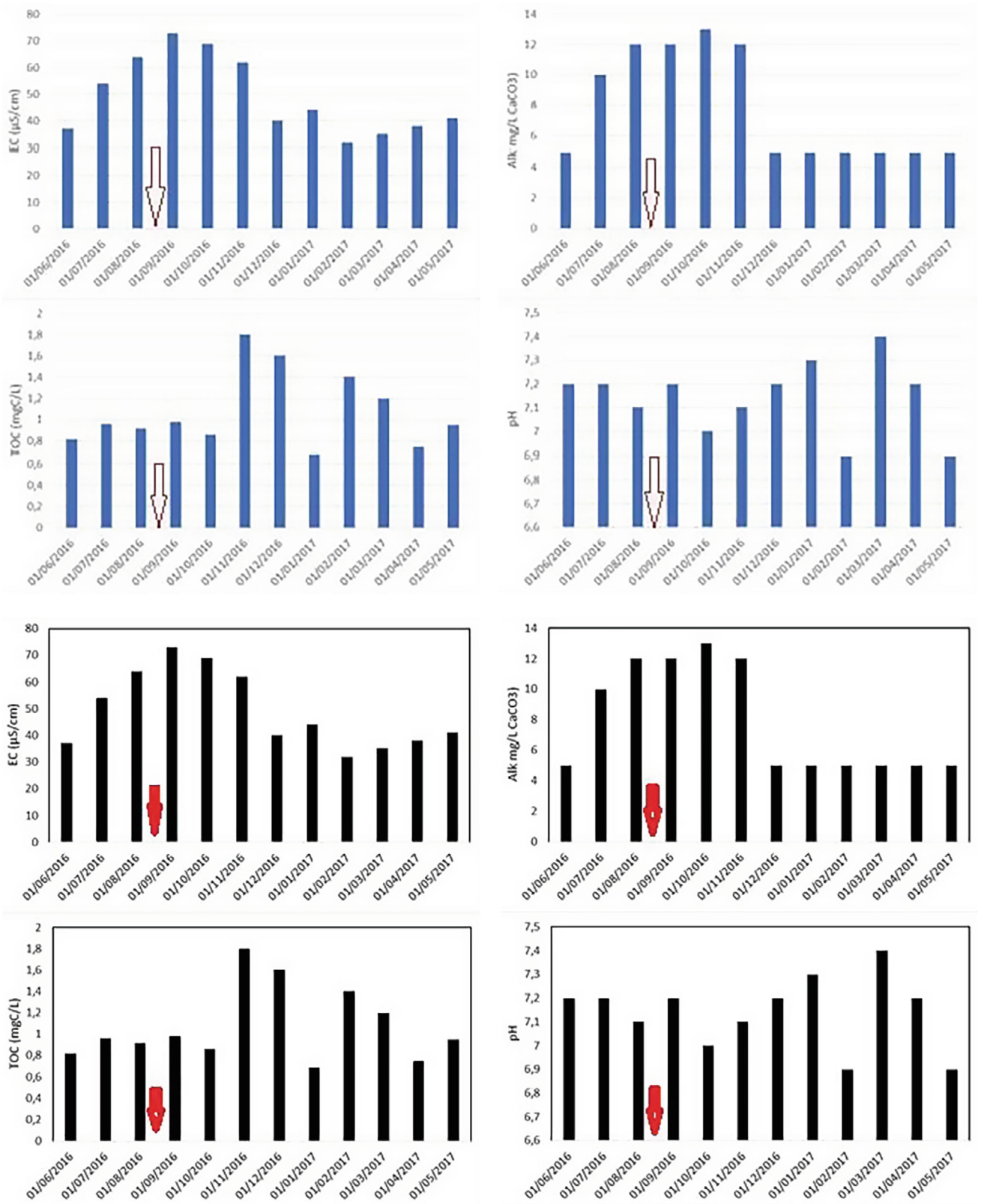


Fig. 2 Water electrical conductivity (EC), alkalinity (Alk), total organic carbon (TOC), and pH, from June 2016 to May 2017. The arrow marks the date of the fire

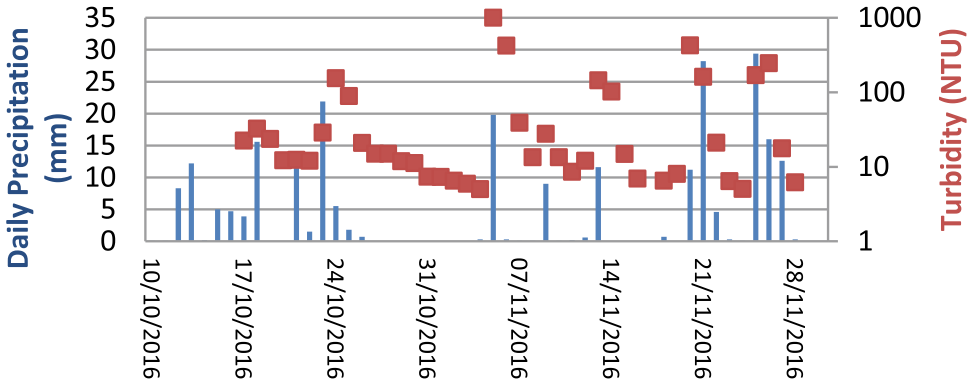


Fig. 3 Evolution of precipitation and turbidity between October and November 2016 (fire occurred between 8 and 17 of August 2016)

To increase the resilience of infrastructure in response to the challenges posed by climate change, particularly the impact of fires, which are one of the greatest risks in the Paiva river basin, the Company interlinked the Lever and Vale do Sousa subsystems, including the Castelo de Paiva WTP. This solution ensured the water supply to the population during problematic periods, with facility shutdown. Currently, the rehabilitation of the Castelo de Paiva WTP is in the project phase, aiming to provide it with greater robustness in responding to changes in water quality, and accommodating the changes observed in raw water quality through implementing new treatment processes.

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Assessing the Radionuclide Concentration and its Hazard Indices in Soil and Hina Leave Samples from Basra/Iraq

Israa Mohammed and Rasha Ahmed

Abstract

Context/Purpose: Basrah is an Iraqi city and it is one of the oldest cities in the world. It is known for its high-quality palm dates that are exported worldwide. Agriculture, including the cultivation of crops and cattle farming, plays a crucial role in providing livelihood opportunities for many inhabitants. Based on the significance of Basra governorate, this study aims to measure the radiation hazard indices and the concentration of naturally occurring radionuclides including ^{238}U, ^{232}Th, and ^{40}K in its soil, and ^{222}Rn concentration in hina leaves planted in the region. *Methods*: High-purity germanium detector has been used to assess ^{238}U, ^{232}Th, and ^{40}K concentrations in Basrah soil. Additionally, the radon concentration in both the soil and hina leaves has been measured using CR-39 detector. *Results*: The results show that the average value of ^{238}U, ^{232}Th, and ^{40}K concentration in Basra soil was found to be 39.5 ± 13.0, 19.9 ± 5.3, and 329.4 ± 116.8 Bq kg^{-1}, respectively. The average value of ^{222}Rn in hina plant was found to be 11.84 ± 1.37 Bq m^{-3}. *Interpretation*: The United Nations Scientific Committee on the Effects of Atomic Radiation (UNCEAR) revealed that the normal concentration of ^{238}U, ^{232}Th, and ^{40}K in soil is 35, 30, and 400 Bq kg^{-1}, respectively. The recommended levels of ^{222}Rn in soil and plants should range from 200 to 600 Bq m^{-3} as suggested by the International Commission on Radiological Protection (ICRP). In this work, the results show that the radionuclide concentration in hina leaves and soil was below the recommended limits. *Conclusion*: The radionuclide concentration and the radiation hazard indices were found to fall well within the safe limits. These low levels could be attributed to the geological composition of the soil, environmental factors, geological characteristics, the type of crops grown, and the farming practices employed.

Keywords

Hina · Uranium · HPGe · CR-39 · Radon

1 Introduction

Radioactivity in soil and plants is an essential consideration for environmental controlling and evaluating potential risks to human health. When the concentration of radioactive materials exceeds the recommended limits, this may pose a radiation hazard to human health. Accordingly, many scientists have conducted studies to measure the concentrations of radioactive nuclei in the environment, which include the soil, plants, air, and water (Taher Hussien et al. 2023; Ahmed 2022).

Basra is an Iraqi governorate, it contains wide areas of agricultural lands. Due to the significance of the area, Basra was selected for environmental pollution assessment. The main objective of this study is to evaluate the concentration of the most abundant naturally occurring radionuclides ^{238}U and ^{232}Th, and ^{40}K in Basra soil. Additionally, the study aims to measure the radon concentrations in hina plant (*Lawsonia inermis*), as they are among the most common agricultural trees in Basra, and their leaves are widely used as hair color and in tattoos.

I. Mohammed
Training and Workshop Center, University of Technology-Iraq, Baghdad, Iraq

R. Ahmed (✉)
Department of Physiology and Medical Physics, College of Medicine, Al-Nahrain University, Baghdad, Iraq
e-mail: rasha_ryadh@nahrainuniv.edu.iq

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2 Materials and Methods

2.1 The Study Area and Sample Preparation

Basra Governorate is located in southernmost Iraq, bordering Kuwait to the south, Turkey to the north, Jordan, Syria, and Saudi Arabia to the west, and Iran to the east. The geographical coordinates of Basra are at a latitude of 30.4960° N and a longitude of 47.8176° E.

A total of 18 (1 kg each) soil samples were collected from the governorate of Basra, 9 from Abo Al-Kasib (30.252° N, 48.0737° E), and 9 from Aldayr (30.829° N, 47.574° E) during winter. Another 18 hina leave samples (0.5 g each) from Al-Faw (29.993° N, 48.452° E) were collected during summer.

The hina leaves and the soil samples were treated separately in the same manner. Samples were dried at 70 °C for 1 h in a laboratory oven, then crushed, sieved through 2 mm mesh, and stored in sealed plastic bags for 60 days to allow radon and its daughter products to reach equilibrium.

2.2 Radionuclide Concentration and Radiation Hazard Indices Measurements

The activity concentration for soil samples was measured using a high-purity germanium detector (HPGe) operates in conjunction with Genie 2k Canberra software. The detector was covered with lead to prevent the environmental radiation from reaching the samples. The activity concentration was estimated utilizing the following formula (Faanu et al. 2016),

$$A = \frac{N_{\mathrm{D}}}{p \cdot T_{\mathrm{c}} \cdot \eta(E) \cdot m} \tag{1}$$

where N_{D} is the background-subtracted count of gamma-ray at energy E, p is the yield of gamma-ray, T_{c} is the counting time, $\eta(E)$ is the detector efficiency, and m is the mass of the sample in kg.

The radiation hazard indices including the radium equivalent activity, the external hazard index, the internal hazard index, the radioactivity level index, and the excess lifetime cancer risk ELCR, have been estimated. The calculation methods for the radiation hazard indices can be found in the literature according to the references (Xinwei et al. 2006; Ramasamy et al. 2009).

The radon concentration in hina samples was measured using a solid-state nuclear track detector (CR-39) with 100% detection efficiency. The detector has a thickness of 500 μm and a density of 1.36 gm/cm^3. Each detector was cut into 1 cm × 1 cm area and fixed at the bottom of the cover of a plastic container. A volume of 5.02E^{-06} m^3 of hina sample was placed inside the container. The container was tightly sealed and left for 60 days. The tracks are then etched for 7 h in 6.25 N NaOH solution at 60 °C, washed, and dried. The tracks are then counted using an optical microscope with a magnification of 400×. By obtaining the radon concentration in the samples, the radon exhalation rate (E_x) in Bq kg^{-1} d^{-1} has been measured (Abu-Jarad et al. 1980).

3 Results

The radon activity concentration in hina samples was found to range from 12.14 to 16.26 Bq m^{-3} with an average value of 14.04 ± 1.53 Bq m^{-3} in Al-Faw and from 7.61 to 11.11 Bq m^{-3} with an average value of 9.65 ± 1.22 Bq m^{-3} in Abo Al-Kasib. The average value in both regions was found to be 11.84 ± 1.37 Bq m^{-3}. The radon exhalation rate was found to range from 1.46 × 10^{-7} to 1.96 × 10^{-7} Bq kg^{-1} d^{-1} with an average value of 1.96 × 10^{-7} Bq kg^{-1} d^{-1} in Al-Faw and from 9.17 × 10^{-8} to 1.34 × 10^{-7} Bq kg^{-1} d^{-1} with an average value of 1.16 × 10^{-7} Bq kg^{-1} d^{-1} in Abo Al-Kasib.

Figure 1a illustrates the radionuclide concentration in soil samples as obtained from the HPGe detector. Starting from the uranium series, ^{214}Pb was found to range from 19.4 to 41.4 Bq kg^{-1} with a mean value ± standard deviation of 27.0 ± 8.0 Bq kg^{-1}. Radium-226 was found to range from 32.0 to 99.6 Bq kg^{-1} with a mean value of 52.1 ± 19.1 Bq kg^{-1}. Uranium-232 concentration has been estimated from the average value of ^{214}Pb and ^{226}Ra series and found to range from 26.5 to 69.0 Bq kg^{-1} with a mean value of 39.5 ± 13.0 Bq kg^{-1}.

Concerning the thorium-232 series, ^{212}Pb concentration was found to range from 9.2 to 28.1 Bq kg^{-1} with an average value of 13.8 ± 5.1 Bq kg^{-1}. Actinium-228 exhibited a range from 16.8 to 34.8 Bq kg^{-1} with an average value of 24.1 ± 4.8 Bq kg^{-1}. Accordingly, ^{232}Th was determined and found to range from 14.7 to 32.2 Bq kg^{-1} with an average value of 19.9 ± 5.3 Bq kg^{-1}. Potassium-40 was found to range from 25.8 to 528.2 Bq kg^{-1} along with an average value of 329.4 ± 116.8 Bq kg^{-1}. The presence of cecium-137 was identified solely in samples 3, 6, and 10 with values of 4.6, 1.8, and 1.1 Bq kg^{-1}, respectively. The radiation hazard indices including the parameters such as radium equivalent activity, the external hazard index, the internal hazard index, the radioactivity level index, and the excess lifetime cancer risk (ELCR) demonstrated a range of values. Specifically, these indices were found to span from 60.5 to 184.3 Bq kg^{-1}, 0.2 to 0.50 Bq kg^{-1}, 0.3 to 0.8 Bq kg^{-1}, 0.4 to 1.3 Bq kg^{-1}, and 2.0 to 0.7 × 10^{-3} Bq kg^{-1} in Abo Al-Kasib region. Similarly, in Al-Faw region, the corresponding ranges were 77.2 to 157.0 Bq kg^{-1}, 0.4 to 0.2 Bq kg^{-1}, 0.3 to 0.6 Bq kg^{-1}, and 0.6 to 1.1 Bq kg^{-1}. The average values of the radiation hazard indices across both regions are illustrated in Fig. 1b.

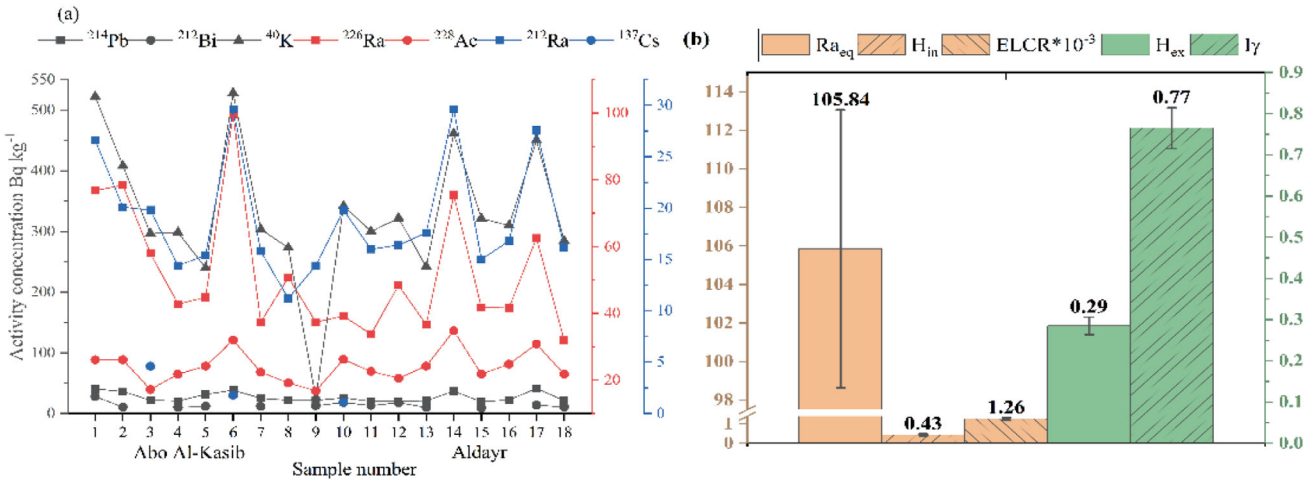


Fig. 1 **a** Radionuclide activity concentration in soil samples collected from Abo Al-Kasib (No. 1–9) and Al-Faw (No. 10–18). **b** Average ± standard deviation of radiation hazard indices in Abo Al-Kasib and Al-Faw

4 Discussion

The findings revealed that radon concentrations in hina leaves collected from Al-Faw are slightly elevated compared to those in Abo Al-Kasib. These concentrations also exhibited small variations between the samples but were determined to meet the safety standards recommended by the ICRP (200–600 Bq/m^3), posing no health risk. The small differences in values could be attributed to the specific type of phosphate fertilizer used in cultivating hina trees, which transfers onto the plant's leaves. Additionally, the variation could be attributed to the variations in uranium levels at both sites.

The results revealed that the radon exhalation rate is within the safe limits as it depends directly on the radon concentration.

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) gives reference values for the world mean activity concentration of naturally occurring radionuclides in soil which are 35, 30, and 400 Bq kg^{-1} for uranium, thorium, and potassium, respectively. The activity concentration in the soil of Basra was found to be within the normal limits for uranium, thorium, and potassium. Accordingly, the radium equivalent activity was found to be lower than the recommended limits of 350 Bq kg^{-1}. The assessment of radiation hazard is deemed nonsignificant if both H_{ex} and H_{in} are below unity. This suggests that these indices calculated in this investigation are within the suggested threshold. The radioactivity level index was found to be lower than unity which implies that these soil samples do not pose any risk. ELCR is an additional radiation risk that someone might have of getting cancer if exposed to cancer-causing materials for a long period. The results show that ELCR is below the world average value of 1.45 × 10^{-3}. The reason behind the low levels of radioactive materials may be attributed to the fact that the study area is being used for agriculture, and as it is widely acknowledged, plants possess the unique ability to purify the soil from radioactive materials.

5 Conclusions

The results demonstrated that the hina samples collected from Basra Governorate contain radon concentrations below the allowed limits. Furthermore, the concentrations of radioactive nuclei and radiation hazard indicators are also considered low corresponding to the allowed values. Therefore, these concentrations do not pose a health hazard to the residents in the area.

Due to the absence of funding for this research, we were unable to carry out additional examination on a larger number of samples. Similarly, the concentrations of radioactive nuclei in the hina leaves were not estimated for the same reason, and the measurements were limited to radon only. We recommend performing a comprehensive environmental study including broader regions within Basra Governorate. Additionally, it is appropriate to carry out examinations on larger sample numbers from various environments, such as water and air.

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Peak Discharge Prediction Using Machine Learning and HEC-HMS Models in Oued Kebir River Catchment in Northeast of Algeria

Fares Laouacheria, Leila Djellit, Moncef Chabi, Said Kechida, and Lotfi Zeghadnia

Abstract

An adequate knowledge of the peak discharge in a catchment is essential to protect people and property from flooding and to design related projects. This study aims to compare an applied machine learning (ML) model including Multilayer Perceptron Neural Network (MLP-NN) with HEC-HMS model to predict the peak discharge of the Oued Kebir river catchment in the Northeast of Algeria. The models were calibrated for daily streamflow values from February 26, 1995 to December 31, 1999 and then validated from January 01, 2000 to August 31, 2003. The reliability of model runoff predictions is evaluated using statistical parameters such as Nash–Sutcliffe efficiency (NSE) and coefficient of determination (R^2) values. The results of training and testing data with MLP-ANN show an NSE of 0.84 and 0.72, respectively, while R^2 had a value of 0.73 and 0.66 respectively. Similarly, the NSE, and R^2 were 0.63 and 0.55 for the calibration period and 0.68 and 0.54 for the validation period, respectively, for the HEC-HMS model. From the obtained results, the MPL-NN model outperforms well than HEC-HMS model. The finding of this research could further enhance flood management and its application to sites with similar hydrological conditions.

Keywords

Machine learning · HEC-HMS · MLP-NN · Flooding · Peak discharge

1 Introduction

It is essential to predict the behavior of rainfall-runoff process in catchments, given their complex nature and the significant damage who exposing more population and property at risk (Fahad and Wang 2019). Rainfall-runoff process is affected by many factors, as well as the phenomenon of surface runoff, where the management and predicting these phenomena is a complex and challenging task because of dynamic nature of catchment characteristics and rainfall patterns, as well as the number of variables analyzed in physical process modeling (Kumar et al. 2005). Therefore, various models have been developed to analyze this process, including stochastic models (e.g., regression, neural networks) or deterministic models (e.g., HEC-HMS). They are usually based on meteorological observations and catchment characteristics. Previous research has shown the efficacy of the Hydrologic Modeling System (HEC-HMS) in this context (Halwatura and Najim 2013; Laouacheria and Mansouri 2015; Gholami and Khaleghi 2021). Moreover, in recent decades, the development of artificial intelligence technologies, such as artificial neural networks (ANN), multilayer perceptron (MLP), and more, has brought about a major development in forecasting hydrological phenomena (Dastjerdi et al. 2019; Hawamdeh and Kuisi, 2021). The study was conducted in the Oued Kebir river catchment, where the primary objective of this study was to integrate the MLP-ANN model and the HEC-HMS model to predict daily discharge.

F. Laouacheria (✉) · L. Djellit · M. Chabi · S. Kechida
Laboratory of Soils and Hydraulic, Faculty of Technology, Badji Mokhtar-Annaba University, P.O. Box 12, 23000 Annaba, Algeria
e-mail: fares.laouacheria@univ-annaba.dz

L. Djellit
e-mail: leila.djellit@univ-annaba.dz

M. Chabi
e-mail: moncef.chabi@univ-annaba.dz

S. Kechida
e-mail: said.kechida@univ-annaba.dz

L. Zeghadnia
Laboratory of Modeling and Socio-Economic Analysis in Water Science (MASESE), Mohamed Cherif Messaadia University, Souk Ahras, Algeria
e-mail: lotfi.zeghadnia@univ-souk-ahras.dz

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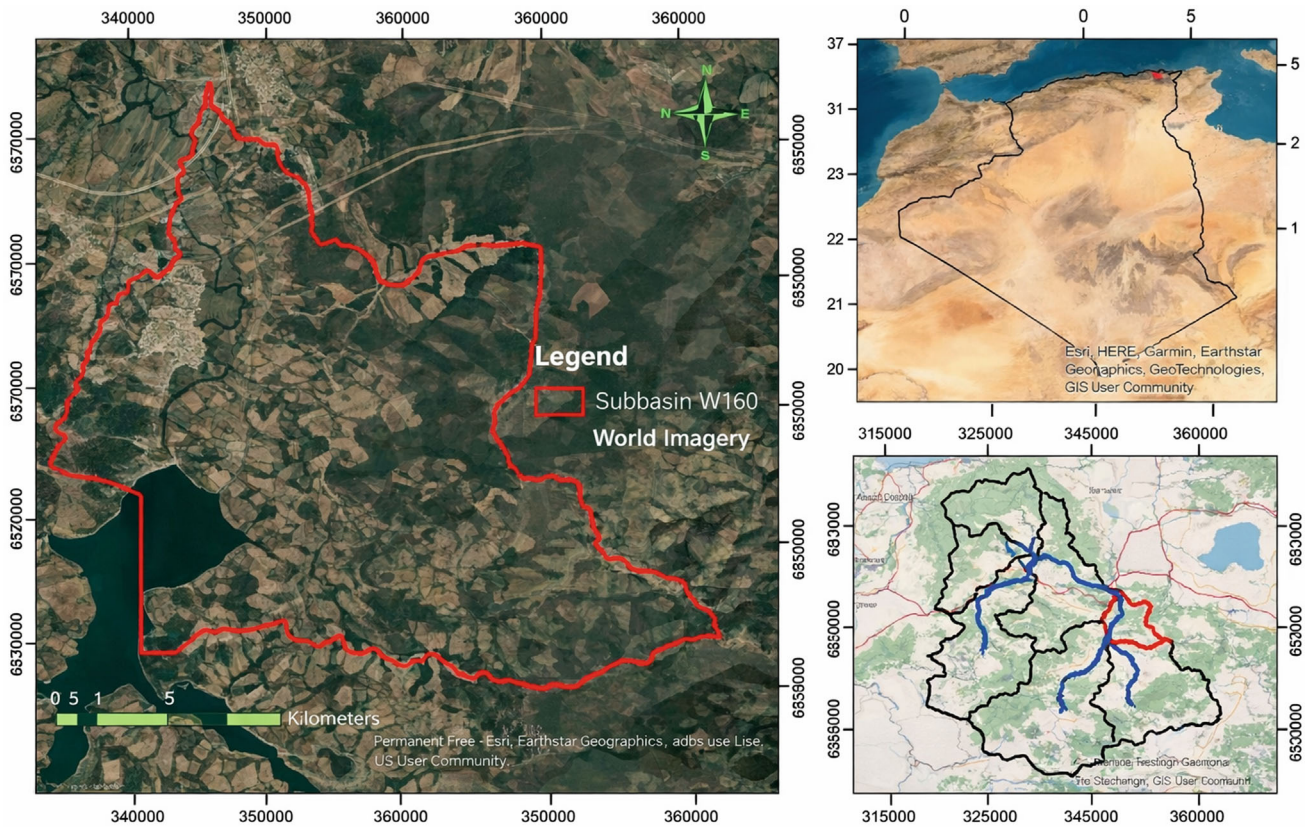


Fig. 1 Location of Oued Kebir river catchment

2 Materials and Methods

2.1 Study Area

The study area is estimated at 43,225 km^2, which is a part of the large basin of the West Kebir river situated in the north-eastern of Algeria between latitudes 36° 39′ and 36° 44′ North and longitudes 7° 17′ and 7° 24′ East (Fig. 1).

2.2 Model Structure

The initial phase of the research involved constructing a rainfall-runoff model that utilizes HEC-HMS and MLP-ANN to estimate daily discharge with rainfall as an input variable for the Oued Kebir river catchment. The HEC-HMS model was carried out using the methods of SCS and curve number (CN). These latter methods were used to estimate runoff and discharge values.

$$R = \frac{(P - 0.2S)^2}{(P - 0.8S)}, \tag{1}$$

where R: Runoff rate in (m^3/s); P: Precipitation (mm); S: The maximum retention capacity after a history of precipitation for 5 days. In this study, two events were considered: the storm event from February 26, 1995, to December 31, 1999, for data training in MLP-ANN and the storm event from February 26, 1995, to December 31, 1999, and from January 01, 2000, to August 31, 2003, for data testing. To select the accurate model, the coefficient of determination and Nash–Sutcliff was used.

$$\mathrm{NSE} = 1 - \frac{\sum \left(Q_{\mathrm{obs}(t)} - Q_{\mathrm{sim}(t)}\right)^2}{\sum \left(Q_{\mathrm{obs}(t)} - \overline{Q_{\mathrm{obs}}}\right)^2} \tag{2}$$

$$R^2 = \frac{\left(\sum \left(Q_{\mathrm{obs}(t)} - \overline{Q_{\mathrm{obs}}}\right) \sum \left(Q_{\mathrm{sim}(t)} - \overline{Q_{\mathrm{sim}}}\right)\right)^2}{\sum \left(Q_{\mathrm{obs}(t)} - \overline{Q_{\mathrm{obs}}}\right)^2 \sum \left(Q_{\mathrm{sim}(t)} - \overline{Q_{\mathrm{sim}}}\right)^2}, \tag{3}$$

where NSE: Nash and Sutcliffe coefficient, $Q_{\mathrm{obs}(t)}$: observed discharges at the time "t," $Q_{\mathrm{sim}(t)}$: simulated discharges at the time "t," and $\overline{Q_{\mathrm{Obs}}}$: mean observed discharges. While R^2 represent the coefficient of determination. Where, $\overline{Q_{\mathrm{Sim}}}$: mean simulated discharges.

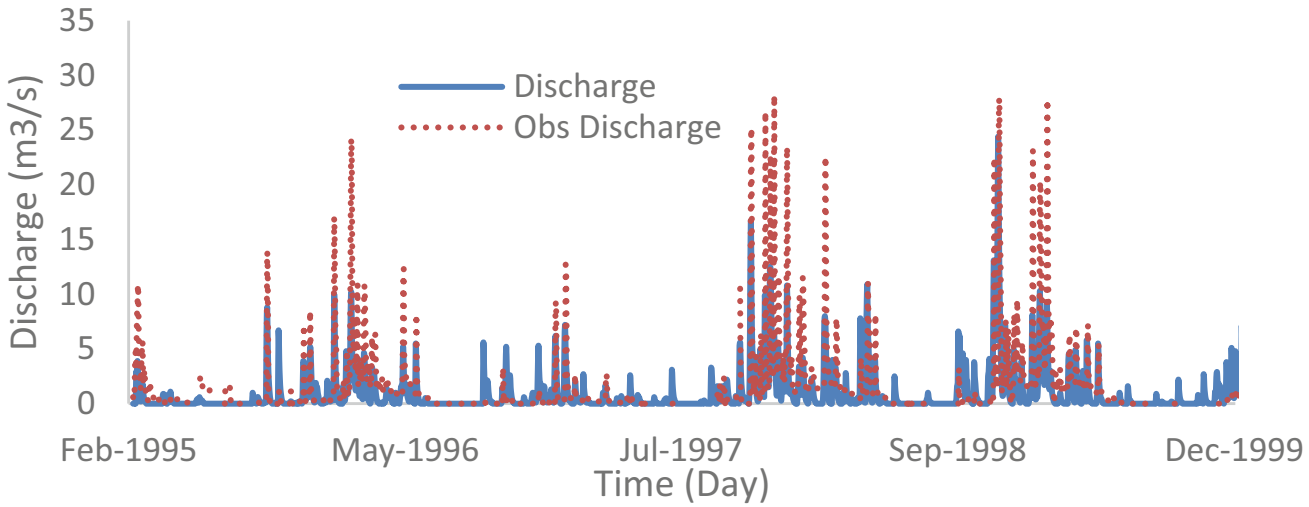


Fig. 2 Observed versus simulated hydrographs (calibration period from February 27, 1995, to December 31, 1999, by the HEC-HMS model)

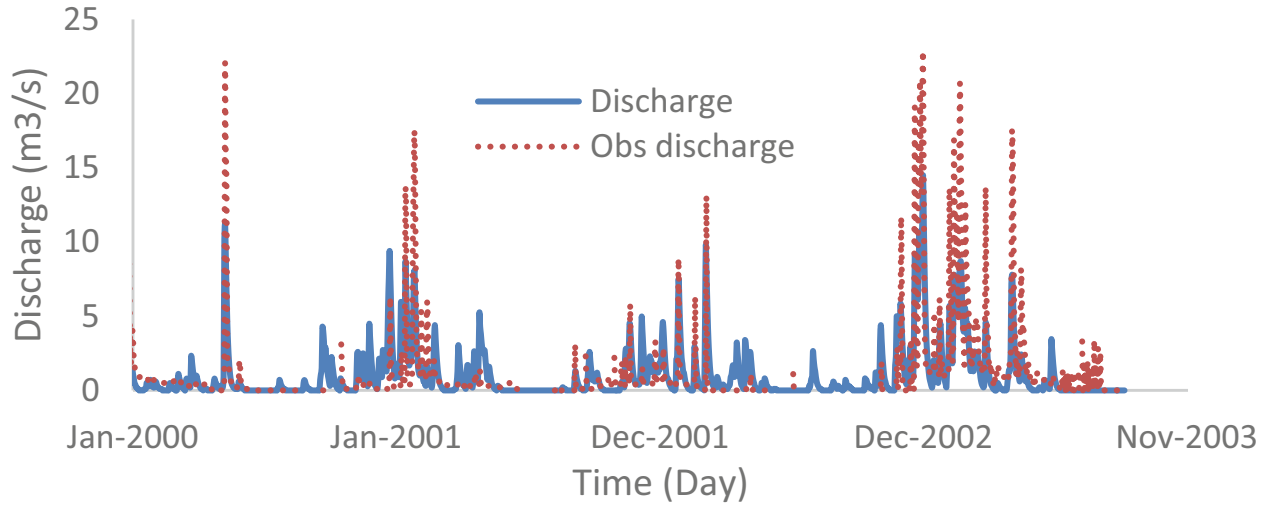


Fig. 3 Observed versus simulated hydrographs (validation period from January 1, 2000, to August 31, 2003, by the HEC-HMS model)

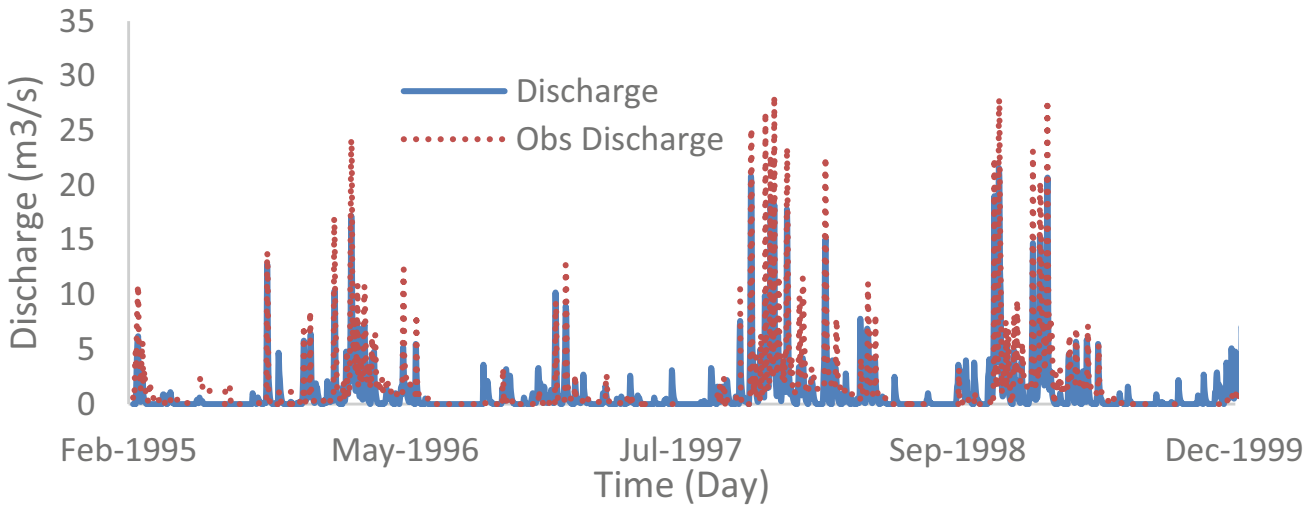


Fig. 4 Observed versus simulated hydrographs (training period from February 27, 1995, to December 31, 1999, by the MLP-ANN model)

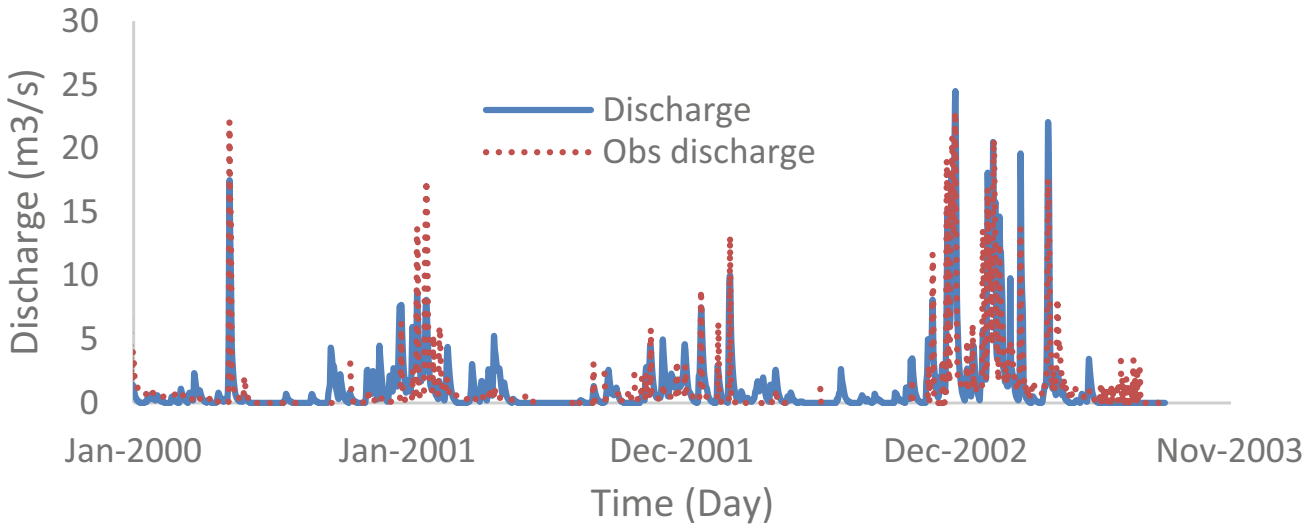


Fig. 5 Observed versus simulated hydrographs (testing period from January 1, 2000, to August 31, 2003, by the MLP-ANN model)

Table 1 Performance criteria of HEC-HMS and MLP-ANN

Model	Performance measure			
	NSE		R^2	
	Calibrated	Validated	Calibrated	Validated
HEC-HMS	0.63	0.68	0.55	0.54
MLP-ANN	0.84	0.72	0.73	0.66

3 Results and Discussion

Modeling and enhancing discharge events were accomplished using the HEC-HMS model. The HEC-HMS model and MLP network were calibrated and validated through a comparison of observed and simulated discharges for the two storm events from February 27, 1995, to December 31, 1999, and January 1, 2000, to August 31, 2003, respectively. The MLP-ANN model had higher NSE and R^2 than the HEC-HMS model (Table 1). Also, simulation results illustrated in Figs. 1, 2, 3, 4 and 5 show that the HEC-HMS model has a lower accuracy than the MLP-ANN model in predicting discharge.

4 Conclusions

This study aimed to simulate discharge and runoff values using the MLP-ANN and HEC-HMS models in the Oued Kebir river catchment. This study demonstrates that the MLP-ANN model is more capable and performs better than the HEC-HMS model. In the future research, we will integrate MLP-ANN model and observed data for predicting discharge and runoff for different land use change scenarios.

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Flood Mapping Using HEC-HMS and HEC-RAS Model in Oued Kebir River Catchment in Northeast of Algeria

Said Kechida, Fares Laouacheria, Lotfi Zeghadnia, and Moncef Chabi

Abstract

The aim of this study is to map the extent of flooding in a section of the Oued Kebir, which forms part of the large central Constantine sub-basin in northeastern Algeria. To achieve the aim of this study, we used hydrological modeling by the Hydrological Engineering Centre (HEC-HMS) software for the "W160" basin with a surface area of 43,225 km^2 to transform rainfall with return periods of 10, 20, 50, and 100 years. The peak flows obtained are 153.60 m^3/s, 199.10 m^3/s, 234.90 m^3/s, and 271.20 m^3/s, respectively. Hydraulic modeling of the flow in the selected section of the Oued was carried out using HEC-RAS software. This software is used to obtain flow heights and velocities in the cross-sections of the Wadi, as well as the extent of flooding. The results of the HEC-RAS hydraulic simulation show that the maximum flood depths are 4.779 m, 5.315 m, 5.523 m, and 5.593 m, respectively. The risk maps obtained for the four return periods show that the areas subject to flooding are 4438.43 m^2, 6244.95 m^2, 6911.50 m^2, and 7164.54 m^2, respectively.

Keywords

GIS · Flood modeling · HEC-HMS · HEC-RAS · Unsteady flow · Flood mapping

S. Kechida (✉) · F. Laouacheria · M. Chabi
Laboratory of Soils and Hydraulic, Faculty of Technology, Badji-Mokhtar Annaba University, P.O. Box 12, 23000, Annaba, Algeria
e-mail: said.kechida@univ-annaba.dz

L. Zeghadnia
Laboratory of Modeling and Socio-Economic Analysis in Water Science (MASESE), Mohamed Cherif Messaadia University, Souk Ahras, Algeria

1 Introduction

Floods are one of the world's most destructive natural hazards, having caused significant loss of life and property damage in recent decades (Munich 2018). Even if floods cannot always be avoided, their catastrophic effects can be significantly reduced by identifying at-risk areas in advance and implementing appropriate risk management measures (Plate 2002; Mojaddadi et al. 2017; Apollonio et al. 2021; Komolafe 2022).

Good river flow modeling, as well as the determination of flood-prone areas, requires the construction of an accurate model based on well-chosen and carefully processed hydraulic (roughness coefficients), geometric, and topographic (DTM) parameters (Tamiru and Wagari 2022). Many researchers have used hydraulic models of various capacities and accuracies to simulate rivers and floodplains, employing one-dimensional (1D) and two-dimensional (2D) approaches. 1D hydraulic models, such as HEC-RAS and Mike11, are simple to apply and can simulate large areas with high accuracy, although they have certain limitations in overflow analysis (Falter et al. 2013). In contrast, 2D hydraulic models, such as HEC-RAS 2D, TELEMAC 2D and MIKE 21, have attracted more interest for two-dimensional low-water simulation (Horritt and Bates 2002; Papaioannou et al. 2016; Rangari et al. 2021; Kumar et al. 2017).

This current study is the first in the region in terms of the hydrological behavior of individual streams where the analysis will be performed from both hydraulic and hydrological characteristics. The city on its lower side and the agricultural lands bordering the river are exposed to flood damage during the rainy season and the morphological characteristics of the main riverbed change every year with the flow in the system. For this reason, it requires a detailed evaluation of river properties. The general objective of the study is to evaluate the hydrologic and hydraulic behavior of the Oued Kebir River using available models for flood mapping.

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2 Materials and Methods

2.1 Description of the Study Area

The study section is part of the Wadi Kebir located at Bakouche Lakhdar in northeastern Algeria, exactly south of the Skikda department. The large basin is geographically located between latitudes 36° 28′ 38.15″ N and 36° 53′ 21.02″ N and longitudes 6° 58′ 54.37″ E and 7° 28′ 58.81″ E, as shown in Fig. 1. It has a surface area of approximately 1133.8 km^2 with altitudes ranging from 32 to 1215 m. The study area belongs to the subtropical Mediterranean region, characterized by hot, dry summers and relatively mild, wet winters.

2.2 Methodology

The Hydrologic Engineering Center-River Analysis System (HEC-RAS) software, developed by the US Army Corps of Engineers (USACE), performs calculations of one-dimensional steady flow, one- and two-dimensional unsteady flow, sediment transport, and moving bed (Brunner 2016). The integration of the HEC-RAS hydraulic model with ArcGIS can be achieved via the HEC-GeoRAS extension, which enables the creation of geospatial data such as streamlines, cross-sections, bank stations, and storage areas, which can then be imported into HEC-RAS. The unsteady flow method is used for flood zone management, flood insurance studies, and also for sub-critical flow regimes, particularly in the case of dam failures and pressure flow modules.

The flood maps were produced in four stages: (1) extraction of geospatial data, (2) determination of flow hydrographs, (3) calculation of water surface profiles, and (4) mapping and visualization of flood zones.

2.3 Geometric Data

The geometry of the Oued Kebir River under HEC-RAS was obtained after analysis, processing, and transfer of the geometric data of the Oued Kebir River from HEC-GeoRAS to HEC-RAS under the ArcGIS 10.8 environment (Fig. 2).

2.4 Flow Data

River analysis system (RAS) requires flow data (hydrograph) to plot the flood inundated area of the flood plain. For the purpose of this objectives, 20 years (1983–2003) hydro-meteorological data, and then processed in HEC-HMS model (Fig. 3). The rainfall depth for the return periods of 10, 20, 50, and 100 years was taken from the calibrated and validated HEC-HMS model (Table 1).

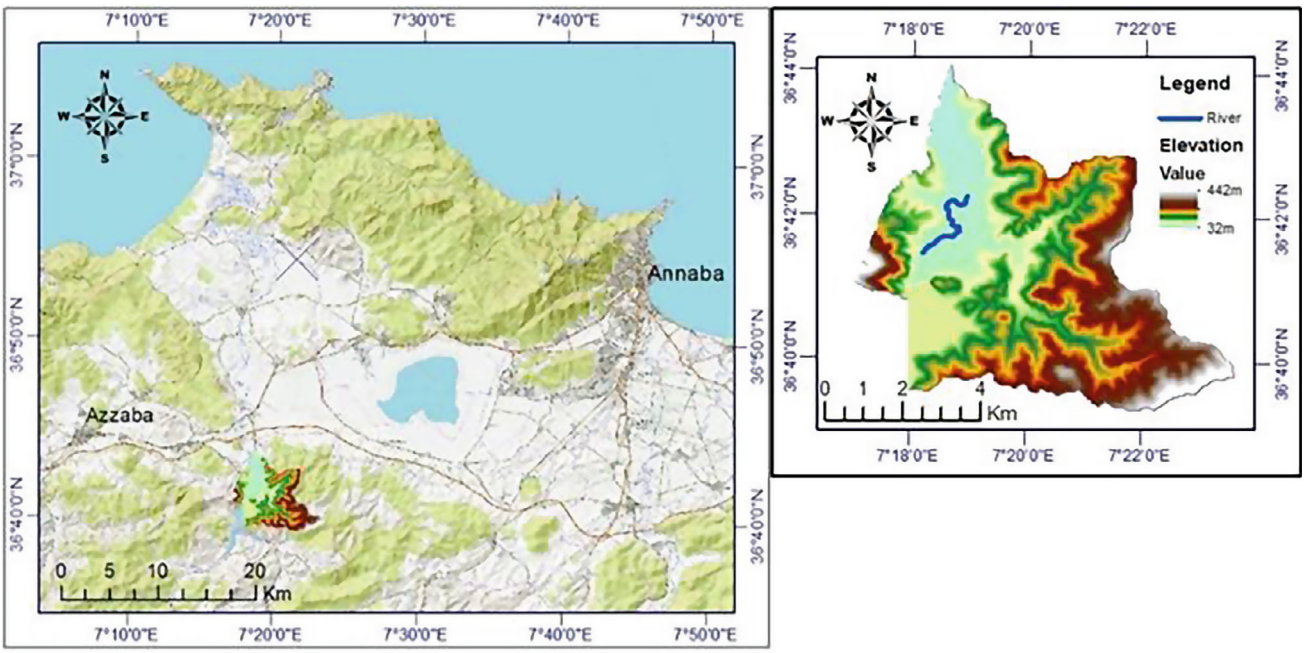


Fig. 1 Location of the study area

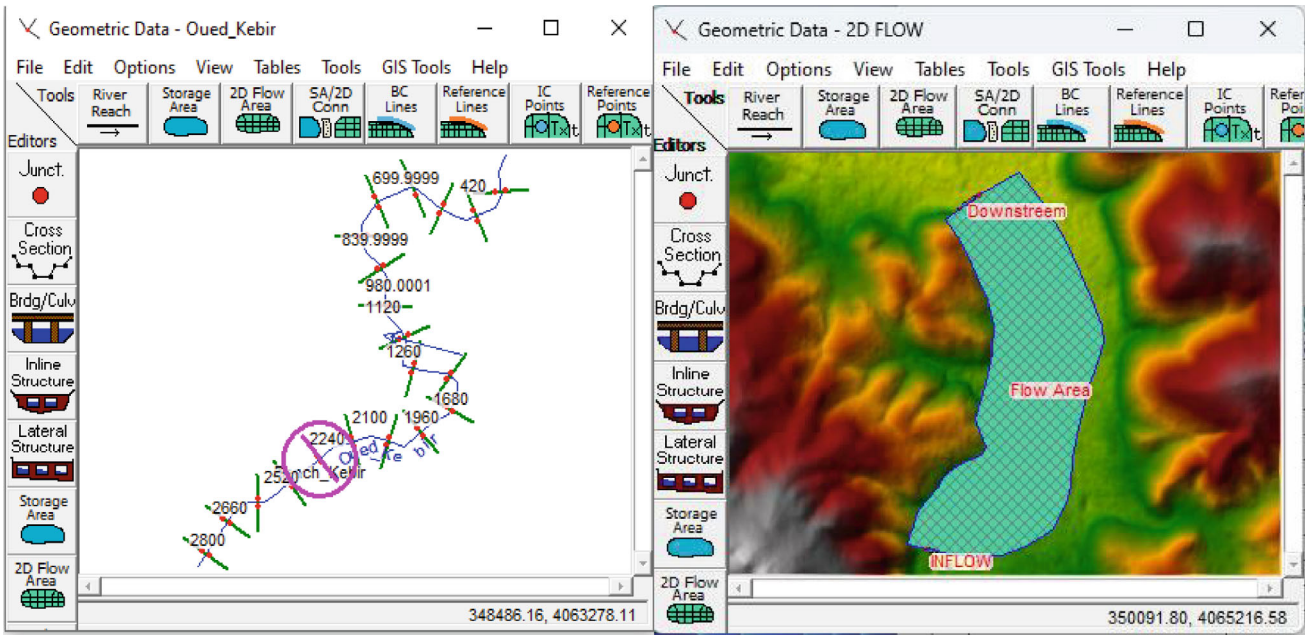


Fig. 2 Geometric data and flow area of Oued Kebir River (from left to right)

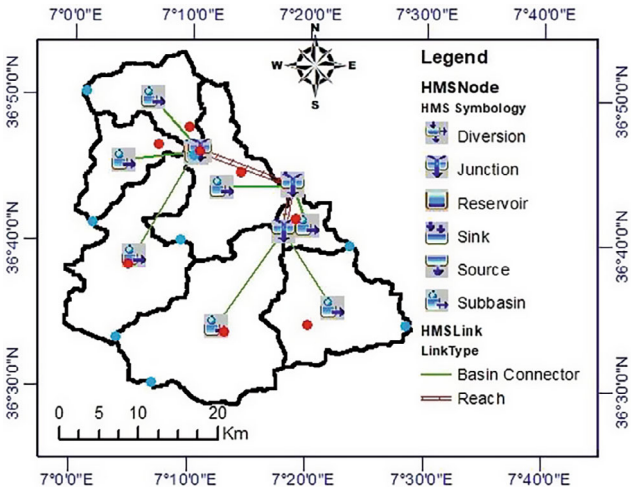


Fig. 3 HEC-HMS model of study area

Table 1 Maximum discharge for deferent return period

Return period (years)	Flow max (m^3/s)
10	153.6
20	199.1
50	234.9
100	271.2

3 Results and Discussion

For calibration, we used the flood of 02/27/1995 to 12/31/1999 at the watershed outlet, resulting in a discharge of 24.40 m^3/s, which is close to the observed discharge of 28.20 m^3/s. The basin parameters derived from model calibration are used to simulate the flood hydrograph.

The simulation results obtained by RAS Mapper are flood risk maps for flood events with return periods of 10, 20, 50, and 100 years. The areas subject to flooding (Fig. 4) are 4438.43 m^2, 6244.95 m^2, 6911.50 m^2, and 7164.54 m^2, respectively, and the maximum flood depths are respectively 4.779, 5.315, 5.523, and 5.593 m.

4 Conclusions

In this study, hydrological and hydraulic models were developed for the Oued Kebir River catchment, which features diverse climatic and geographical characteristics. The hydrological model, created using HEC-HMS, was designed to analyze the impact of rainfall on surface runoff and peak discharges in the study area. Flood maps generated using HEC-RAS can subsequently be used to examine the extent and characteristics of floods. At the basin discharge site, the hydrological and hydraulic modeling case study is developed taking into account different return periods 10, 20, 50, and 100 years upstream of the chosen site.

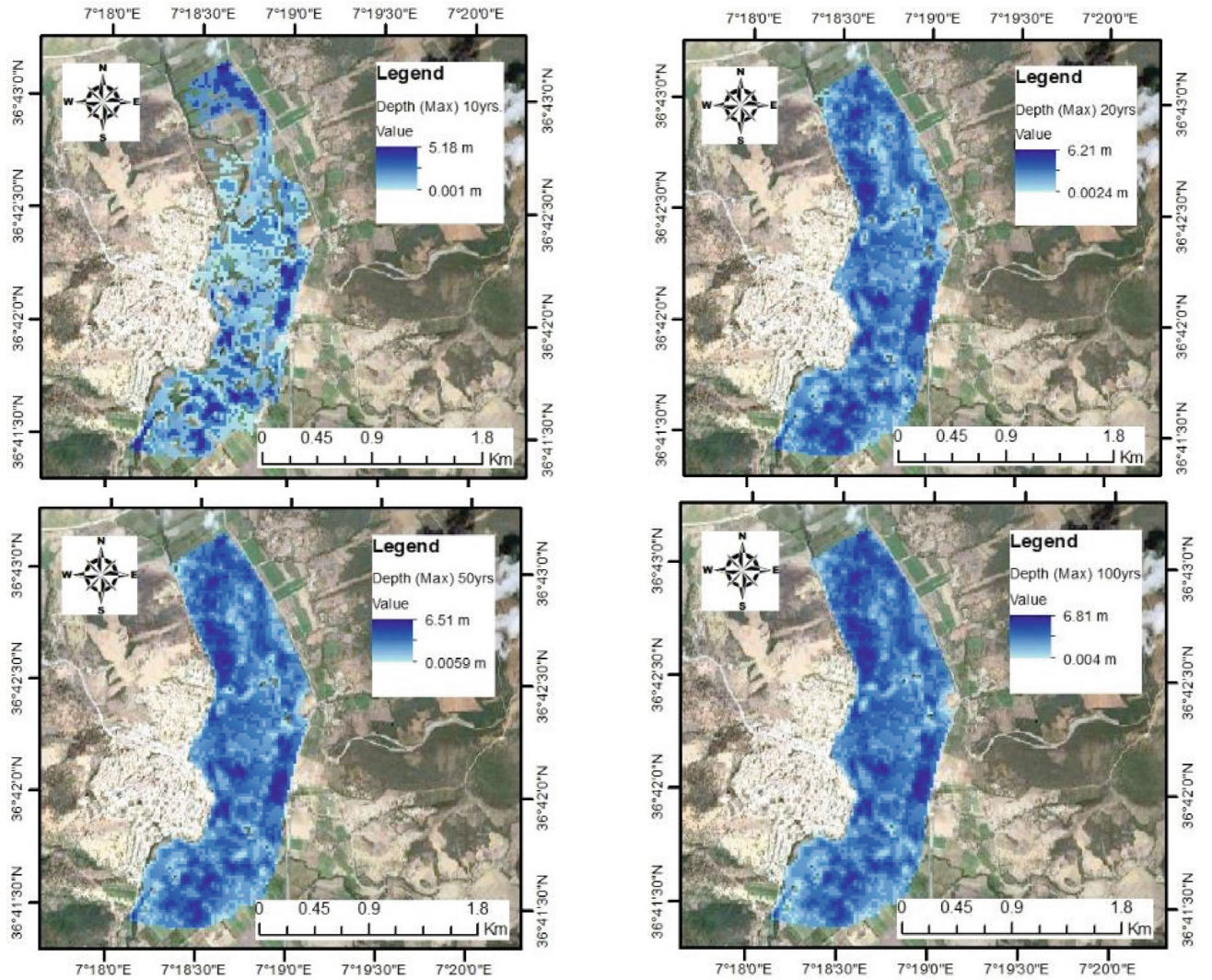


Fig. 4 Water depth in Oued Kebir River for deferent return period

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The Impacts of Solid Waste Dumpsite on Vulnerable Communities: A Case of Tsosane in Lesotho

Johanes A. Belle, Lemohang P. Mokoka, and Zachariah H. Mshelia

Abstract

Urbanization, industrialization, population growth, production and consumption of goods have been rising and so too have the volume of generation, transportation and deposition of domestic and industrial municipal solid waste (MSW). Lesotho's solid waste is disposed at poorly managed dumpsites. This action results in pollution and environmental degradation which eventually poses human health risks. This paper assessed the impacts of solid waste dumpsite of Tsosane on the local community. To establish such impacts data was collected from 114 households divided into two concentric circles. The data was analyzed using descriptive statistics. Field observation by the researchers was used to support the findings from the survey. Landfill/dumpsite suitability map was produced using the Weighted Overlay in ArcGIS. The research findings revealed that people who live near the dumpsite are driven there by push factors rather than pull factors. Waste harvesters use the dumpsite for livelihood and most respondents living near the dumpsite were self-employed. The general trend was that most identified hazards, risks and impacts where higher within 0–250 m from the dumpsite where especially children and scavengers were at risk, therefore posing serious threats to the community. The study recommends that the dumpsite be decommissioned and move to safer areas identified using the suitability map to mitigate the impacts of hazards emanating from the dumpsite; that could be exacerbated by the current climate change impacts. The security and management of the dumpsite should also be improved, maximize waste reduction and minimize waste disposal.

Keywords

Waste management · Environmental degradation · Pollution · Disaster risk · GIS · Suitability map

1 Introduction

The earth has a natural capacity to assimilate harmful products or change them into harmless ones. This made the amount of waste generated in the past insignificant (Adamcová et al. 2017; Siimane 2005; Singh et al. 2018; Barr et al. 2013). However, as the human population and consumption patterns have grown exponentially, the volume of waste has increased dramatically, posing significant environmental and public health challenges (Vyas 2010; Barman et al., 2023). In 2022, global municipal solid waste (MSW) was 2.01 billion tons estimated to increase by 70% to about 3.4 billion tons by 2050. An estimated 3825 tons of MSW is generated every minute in the world and more than 80% of MSW end up in landfill or dumpsite with less than 20% recycled. Though Africa contributes only 4% of global MSW, 19 out of 50 biggest dumpsites are in sub-Saharan Africa. About 90% of Africa MSW is deposited in uncontrolled dumpsites and landfills and only 9% recycled (UNEP 2017; Hayes 2021; Statista 2023; United Nations Development Programme 2015, 2018; Bulane 2009, Chakela 1999).

Effective waste management strategies must account for local waste characteristics, which can vary considerably based on cultural, climatic and socioeconomic factors (Vergara and Tchobanoglous 2012). In industrialized nations, where waste generation is particularly high, municipal and regional authorities have taken a lead role in managing this growing challenge (Vergara and Tchobanoglous 2012). In contrast, developing regions often

J. A. Belle (✉) · L. P. Mokoka · Z. H. Mshelia
Disaster Management Training and Education Centre for Africa (DiMTEC), University of the Free State, Bloemfontein, South Africa
e-mail: BelleJA@ufs.ac.za

Z. H. Mshelia
e-mail: Mshelia.ZH@ufs.ac.za

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struggle to keep pace with the volume of waste, leading to issues like the growth of informal waste picking sectors (Schenck et al. 2016).

The challenges of developing nations keeping up with waste are evident in Lesotho. The Ha Tsosane Dumpsite which is a landfill site but popularly referred to as a dumpsite in this article, dumpsite and landfill are used interchangeably to denote a demarcated area where solid municipal wastes are disposed in Lesotho), was established in 1983 in the capital city of Maseru in Lesotho. This dumpsite poses serious threats to the Ha Tsosanane Community (World Bank 2008; World Bank 1999). This study therefore looked at the risks and the impacts of this dumpsite with the hope to provide recommendation that will improve the management of the dumpsite, create awareness and reduce potential disaster risks, improve the lives and livelihood of the immediate community and contribute to the Sustainable Development Goals (SDGs) especially Goals 3 on good health and wellbeing; 11 on sustainable cities, 13 on climate action and 15 on life on land (United Nations Development Programme 2015).

2 Materials and Methods

2.1 The Study Area

Ha Tsosane is a suburb located in the capital city of Maseru in the Kingdom of Lesotho (Fig. 1).

Besides a comprehensive review of related literature on dumpsites and solid waste management, the authors collected two sets of primary data. The Disaster Risk and Impact Model (DRIM) (Belle 2019) was used as the theoretical framework. First a survey comprising of 114 randomly selected households at Ha Tsosane was conducted in 2021 followed by field observations by the researchers using a field guide. The primary data was analyzed using descriptive statistics. The study area was divided into two concentric zones to examine the impacts of distance on the identified hazards and risk from the dumpsite. This gave a guide on possible zoning of different land uses in the area. The first 250 m radius comprised the first zone while the second zone was between 251 and 500 m. Landfill Site Suitability analysis was carried out to assess the possibility of relocating the landfill to other suitable locations at the outskirt of Maseru City. Landfill siting criteria was firstly reviewed and identified based on literature and landfill siting guidelines that were based on government guidelines, experts' judgment, local and international references. Each criterion was classified into classes, and each class was given a suitability score from 1 to 5 where 1 implied that the area is not suitable and 5 means the condition for that criterion is suitable. Land use and land cover, distance from the road, distance from river, and distance from residential area and slope were the five factors used to analyze the suitable site for landfill siting in Maseru with the aid of ArcGIS 10.71.

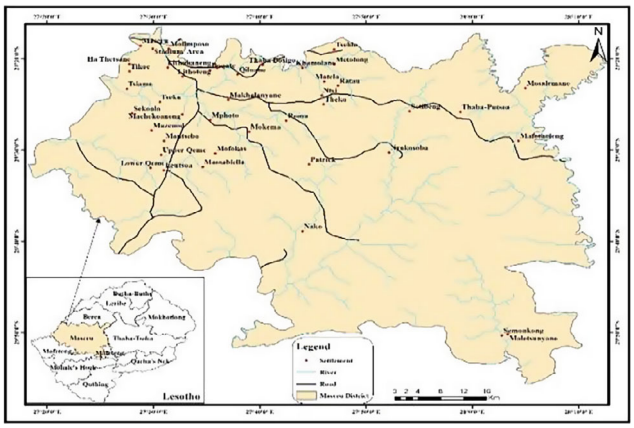


Fig. 1 Maseru district, Lesotho

3 Results

3.1 Proximity to the Dumpsite

The majority of respondents, according to these findings, are uneasy about the dumpsite's proximity to their residences; spontaneous fire could be seen burning from the dumpsite and children playing with waste. Every respondent within a 500 m radius agreed that the dumpsite is a contributing factor to the community's water contamination, bad-smelling air and environmental degradation (Fig. 2).

3.2 Field Observation Study at Tsosane Landfill

Table 1's checklist was used for field observation in order to evaluate the dumpsite's effects on the Ha Tsosane community. The dumpsite's condition and potential effects on the neighborhood were the main points of interest.

An observational study conducted at the dumpsite yielded a general view that the safety of the community is jeopardized. People from many walks of life can dispose of various types of rubbish in and near the dumpsite because, for example, it is not clearly walled off or manned. Also, garbage plastics and papers, as well as smoke from the landfill, have been seen to fly into the air, particularly on windy days, causing pollution in the vicinity. Leachate was also coming out of the dumpsite (Chen 2020; Markham 2020; Ansari et al. 2019).

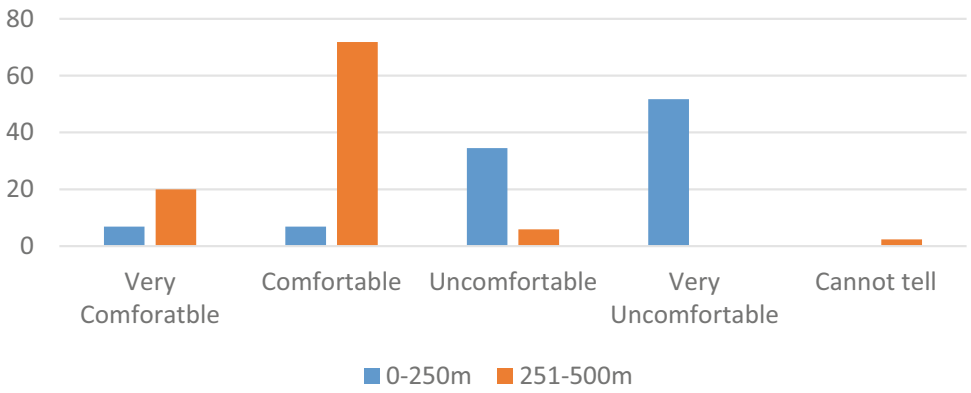


Fig. 2 Proximity to the dumpsite within 0–250 m and 251–500 m

Table 1 Physical observation of the landfill and its environs

Checklist questions	Yes	No
1. Is the dumpsite clearly fenced or guarded?		X
2. Is the dumpsite surrounding area clean and orderly?		X
3. Are there any visible spilled materials or liquids observed from the dumpsite?	X	
4. Is combustible scrap, debris and waste observed from the dumpsite?		X
5. Are there visible signs of cleaning inside and outside the dumpsite?		X
6. Are confined spaces of entry thoroughly safe and emptied of any hazards?		X
7. Is there personnel at the dumpsite controlling the movement of the people within the dumpsite?		X
8. Are hazardous substances which may cause harm or are prohibited at the dumpsite checked upon entry?	X	
9. Is proper waste compaction practiced to minimize the risk of fire including spontaneous combustion?	X	
10. Are members of the community potentially exposed to infectious diseases?		X
11. Have occasions of potential accidents as a result of the dumpsite been identified?		X

3.3 Dump Site Suitability Analysis

The highly suitable areas are areas of dark green color on the map with area coverage of 459.36 hectares (Table 2) which account for 11.6% of the total landmass of Maseru. As shown in Table 2, the suitable area for landfill sitting has the highest area coverage of 1870.29 hectares which is 47.3% and is shown in light green color on suitability map (Fig. 4). The restricted or not suitable areas account for the least landmass of 6.84 ha, which is 0.2%. Unfortunately, that is the area where the current landfill is sited leaving over 4000 people at risk in Ha Tsosane area of Maseru (Fig. 3).

Table 2 Area of suitability

S. No.	Suitability	Area (Ha)	%
1	Not suitable	6.84	0.2
2	Less suitable	500.31	12.7
3	Moderately suitable	1112.31	28.1
4	Suitable	1870.29	47.4
5	Highly suitable	459.36	11.6
	Total	3949.11	100

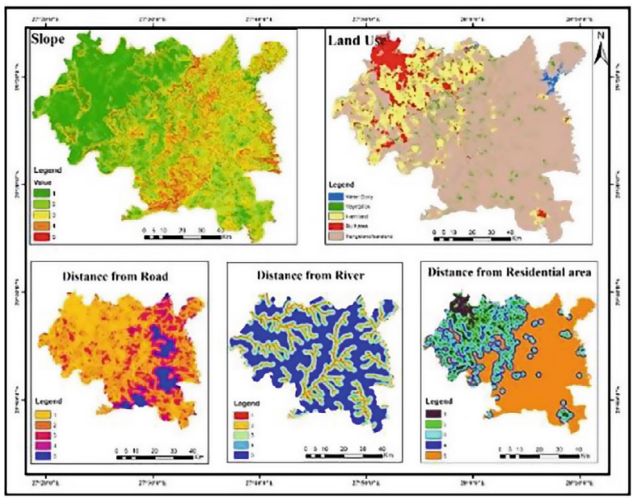


Fig. 3 Landfill suitability factors mapping

4 Discussion

The results of the study showed that push forces, as opposed to pull factors, are what lead residents of the dumpsite to live there. In contrast, people who live far from the dumpsite report fewer unfavorable experiences and are content with the dumpsite's current location. According to the study,

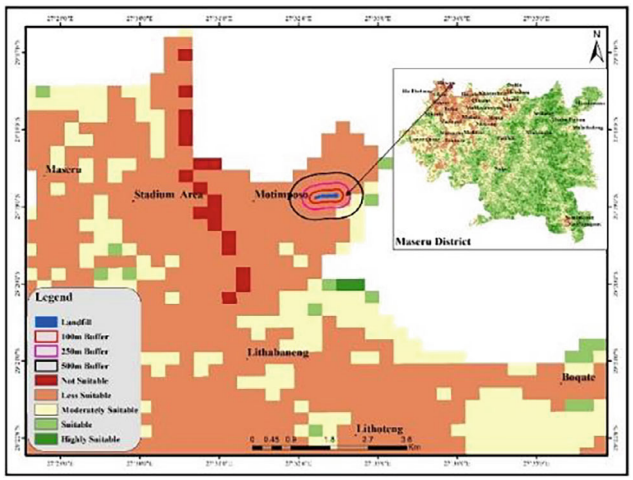


Fig. 4 Landfill site suitable

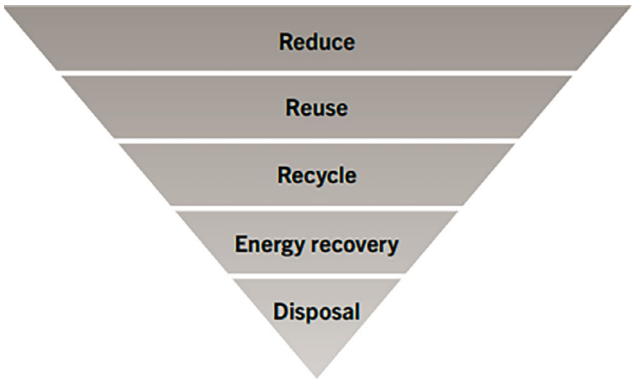


Fig. 5 Hierarchy of waste management

waste harvesters who depend on collecting waste for their living used the dumpsite as a commercial harbor. This is clear from the demographic data, which shows that the majority of residents in the vicinity of the dumpsite reported being self-employed. Furthermore, the results show that the participants don't think the nearby dumpsite has an impact on the water quality.

This may imply a lack of awareness or attributed to the fact that most of their water needs are served by the Lesotho Water Supply Authority-WASCO. Normally, runoff from the dumpsite carries along toxic elements that pollute nearby streams, aquifers, or underground water storage. Lastly, the participants are very keen to have the dumpsite managed more safely and efficiently to minimize identified disaster risks or to have it relocated altogether as the suitability studies indicate in this research.

5 Conclusion and Recommendations

The Ha Tsosane Dumpsite is poorly located and poorly managed posing health problems to the immediate community especially children and waste harvesters. Therefore, it is advised that no economic activity or settlement should exist within the first 250 m around the dumpsite. This region should serve as a community buffer against any potential risks posed by the dumpsite. This study, also recommend that the landfill be decommissioned, and a suitable site should be used to mitigate the negative impact already experienced by residents of Ha Tsosane especially those residing within 0–250 m. The landfill site suitability analysis can be used which considered socioeconomic and environmental factors. Also recommended is the emphasis on education and awareness, as well as the general management of waste as shown in Fig. 5.

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Flood Risks in the MBO Plain (West Region, Cameroon): Analysis of Causes and Risk Management

Sylvie Noelle Djukem Fenguia
and David Guimolaire Nkouathio

Abstract

The present study carried out in the Mbo plain analysed the factors responsible for flooding in this locality with the aim of proposing simple and adapted methods to reduce the impact of these floods. The results of this work showed that the natural conditions of this environment coupled with anthropic activity are very favourable to the flooding process. Indeed, from a geomorphological point of view, the Mbo plain is mostly made up of flat land with slopes that vary from slight (0°–4°) and to (17°–24°) steep. Soil texture is dominated by sand (13–61%) at the surface and clay (27–41%) at depth. Hydrologically, rainfall is high (2413 mm/year) and falls very suddenly over very long periods (March to October). The hydrographic network is meandering, which slows down the speed of flow. The water table is very close to the surface (1–4 m) and is charged very quickly following the first rains, which prevents the water from continuing to infiltrate. Finally, the ever-increasing anthropic pressure (39,980 inhabitants) on the environment amplifies the consequences of flooding on the population. The main triggering factor is rain. Effective solutions to reduce the impact of flooding in the Mbo plain include deepening the riverbeds, particularly the Nkam and Menoua rivers, restoring the flood expansion field and raising the level of houses in relation to the height of the floods.

Keywords

Flood risk · Mbo plain · Analysis · Risk management · Cameroon

S. N. Djukem Fenguia (✉) · D. G. Nkouathio
Department of Earth Sciences, University of Dschang, Dschang, Cameroon
e-mail: djukemsylvie9@gmail.com

1 Introduction

Since the 1990s, there has been a sharp increase in natural disasters worldwide (floods, earthquakes, landslides, tropical storms, droughts), particularly in the countries of the South, an increase that many researchers attribute to climate change (Mendonça et al. 2015; Organisation des Nations Unies (ONU) 2008). Floods are the most recurrent, accounting for 47% of natural disasters (between 1995 and 2015) and affecting 2.3 billion people. In lowland regions in particular, floods are the most dramatic manifestations of geomorphological, hydrological and climatic variability. The Mbo plain, which is the subject of this study, is not immune. Every year, it experiences numerous floods, particularly between July and October with numerous economic, agricultural, social, health and environmental consequences (Nguiffo 2013). It is with the objective of understanding the causes of these floods that this study was conducted. It will enable simple and adapted methods to be proposed for effective prevention (Fig. 1).

2 Methods

The processing of SRTM data with Quantum GIS software allowed the extraction of details on the morphology. Rainfall was measured using a rain gauge every day for several months, enabling rainfall to be spatialised. With a piezometer probe, the depth of the wells was measured in order to establish the piezometer map with the Surfer 13 software. The hydrographic network was produced by manual digitisation of the 1:50,000 scale topographic map of Bafoussam and Mamfe. Soil pits 1–3 m deep were dug according to their morpho-landscape location and lithology and described using the FAO method for morphological description of soils in the field (Food and Agriculture Organization of the United Nations (FAO) 2006). Soil perme-

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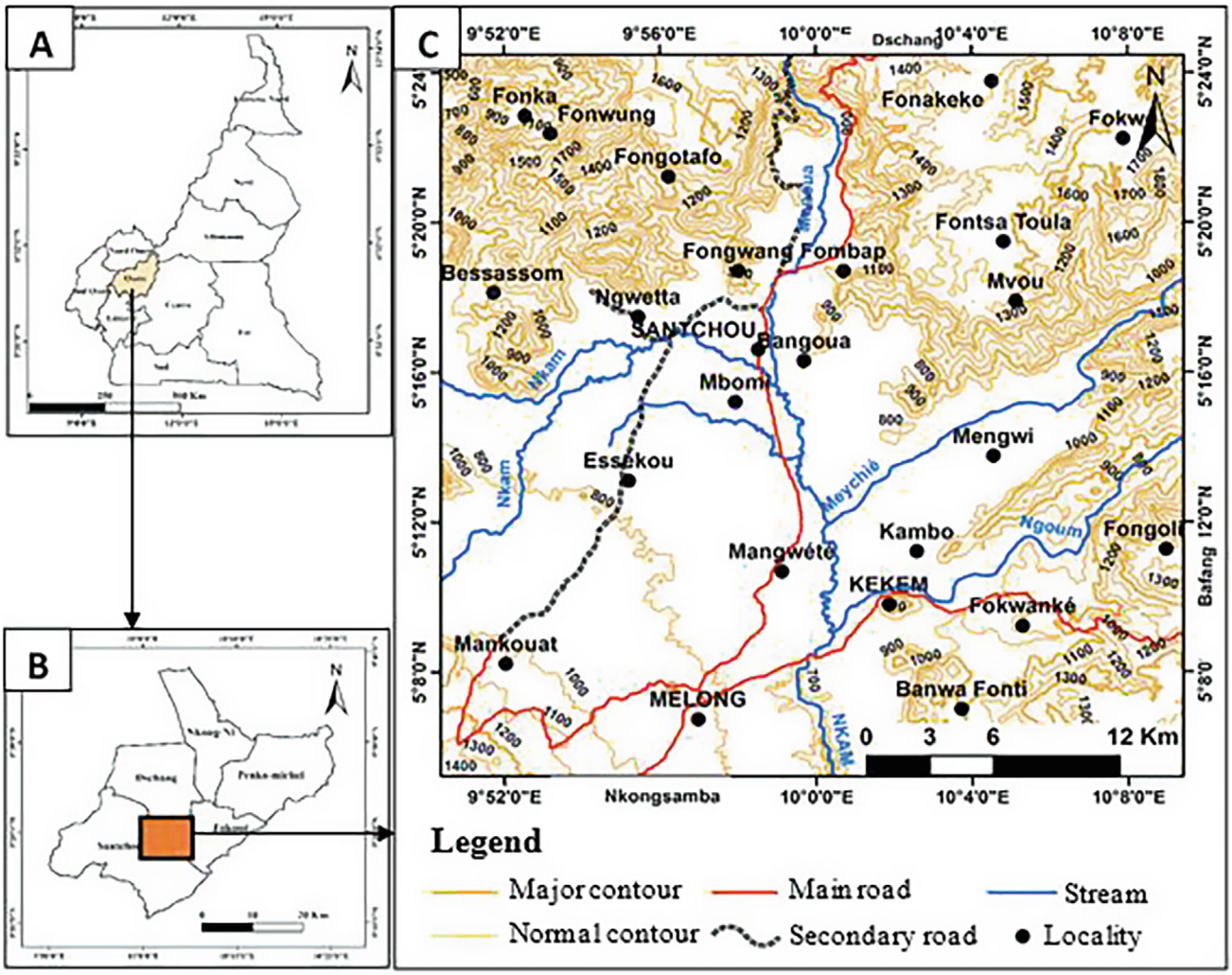


Fig. 1 Location of study area

ability was determined in site using the Porchet method. Subsequently, undisturbed soil samples taken in the field according to the different horizons and phases were analysed and the physico-chemical parameters were determined.

3 Results

Factors responsible for flooding in the study area

Natural flooding of a given area occurs when there is an excess of groundwater that can no longer be drained. It can be of natural or anthropogenic origin.

3.1 The Natural Causes

3.1.1 Slopes

The Mbo plain is made up of five types of landscapes with slope values varying from 0° to over 24°. Landscapes with low slopes ($\leq 10°$) represent more than 60% of the study area, i.e. approximately 290.52 km^2 out of 1394.78 km^2 and constitute areas favourable to flooding.

3.1.2 The Soils

Macroscopic Description of Soil Profiles

Two (02) standard pedological profiles were used in the study area.

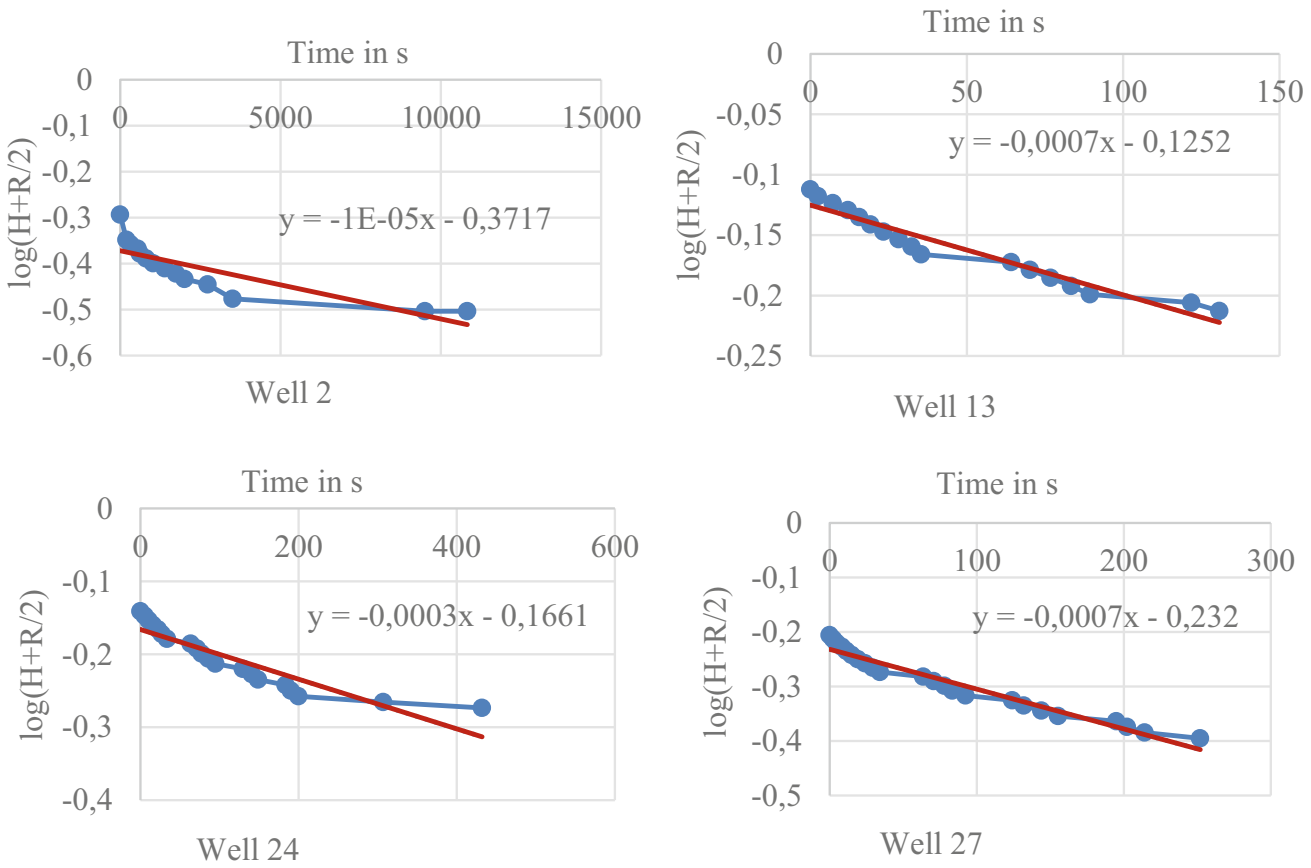


Fig. 2 Evolution of water infiltration speed in the soil on the Mbo plain

Table 1 Permeability values in the study area

Well	K value in m/s	Soil type	Degree of permeability	Type of training
Well 2	1.00×10^{-7}	Very fine sand, coarse loam to clay loam	Medium to low	Semipermeable
Well 13	1.81×10^{-5}			
Well 24	7.76×10^{-6}			
Well 27	1.81×10^{-5}			

Type 1 profile is characteristic of low-lying areas situated between 706 and 711 m. It is a thin profile, little evolved and little differentiated with a sheet of water at the base of the profile.

Type 2 profile is characteristic of altitudes between 720 and 730 m. It is very thick, not very evolved and not very differentiated.

Finally, the soil profiles developed on the alluvial cover of the study area define type A/Cg profiles.

Soil Permeability

The rate at which water infiltrates the ground varies from one point to another on the plain. It is constant in well 2, stabilises at a certain depth and then starts to change again in others wells (13, 24, 27) (Fig. 2). After a while, it reduces sharply and stabilises.

The permeability values have been calculated and grouped together in Table 1. They range from 10^{-5} and 10^{-7} m/s, which indicates bad permeability in the study area.

Source Musy and Soutter (1991) cited in Barraud (2006)

Physic and Chemical Parameters

Bulk density varies from 0.87 to 1.00 g/cm^3 at the surface and from 0.97 to 1.01 g/cm^3 at depth. The soils are very porous (over 50%) and compact. They are rich in sands, clays and silts. Silty-sandy, silty and silty-clay textures are more prevalent at the surface. Clayey, silty-clayey and silty-clayey textures are more prevalent at depth. They are acidic, with a water pH of between 3.9 and 5.8. Organic matter is abundant in the superficial horizons (3.08–4.20%) and decreases towards depth (1.66–3.68%). The water content is between 16.27 and 46.19% (Table 2).

Table 2 Physical and chemical parameters of soils in the study area

	Samples	Horizon (cm)	Physical parameters								Chemical parameters	
			S (%)	L (%)	A (%)	Da (g/cm^3)	Dr	H (%)	Porosity	Compactness (%)	pH water	OM (%)
P2	P2-1	0–20	47.0	22.0	31.0	1.00	2.59	16.33	61.37	38.63	5.8	3.08
	P2-2	20–50	29.0	30.0	41.0	1.00	2.62	16.27	61.78	38.22	5.0	1.68
P13	P13	0–75	50.5	31.5	18.0	0.97	2.57	31.87	63.27	36.73	4.4	4.07
P24	P24-1	0–55	26.0	27.0	47.0	0.97	2.57	32.27	55.90	44.10	4.5	3.83
	P44-2	55–85	22.0	28.0	50.0	1.01	2.62	46.19	49.68	50.32	4.8	1.66
P27	P27-1	0–20	23.0	45.0	32.0	0.87	2.57	29.09	66.99	33.01	3.9	4.20
	P27-2	20–50	26.5	20.0	53.5	1.00	2.58	34.68	62.40	37.60	5.5	3.68

3.1.3 The River System

The hydrographic network is dendritic in the hills and meandering in the plain. It is made up of two main rivers (the Nkam and the Menoua) to which are attached secondary rivers and seasonal rivers that form only during the rainy season. The Menoua river extends from the mountains to the plain where it flows into the Nkam at Santchou. The Nkam is the main collector in the plain. It receives all the water and spreads out in all directions.

3.1.4 Rainfall

Rainfall on the Mbo plain consists of a fairly long rainy season of nine months (March to November) and a dry season of three months (December to February). In general, the annual rainfall in the plain is quite high (2413 mm/year). Rainfall is present throughout the year. During the dry season, it is moderate and very irregular. In the rainy season; however, it falls violently and produces large volumes of water. This water quickly saturates the soil, which becomes impermeable.

3.1.5 The Level of the Water Table

Piezometric mapping from field surveys conducted in February (2017, 2018, 2019, 2020) and September (2018, 2019, 2020) shows areas of piezometric troughs and domes. The piezometric troughs are mainly located in the centre and south of the plain. The domes are located in the north-east, north-west, south-east and south-west of the plain. In the dry season, the highest elevation is 900 m while the lowest is 350 m. In the rainy season, the highest elevation is 729 m and the lowest is 714 m.

3.2 Anthropogenic Causes

They are aggravating elements that have a fundamental role in the formation and increase of watercourse flows and soil sealing:

- Land use.
- The suppression of flood expansion fields by urbanisation.
- Deforestation of large areas.
- Agricultural practices.
- Poorly calibrated drainage works.
- Obstruction of watercourses by rubbish dumping.

4 Discussion

Environmental factors have a major influence on the formation of floods in the Mbo plain. The soils of the plain are formed on clayey, sandy and silty alluvium. They are hydromorphic and are marked by the predominance of sandy textures (around 60%) on the surface and clay (around 41%) at depth, generally from 25 cm upwards. This type of soil is similar to that found on many alluvial plains (Leumbe Leumbe et al. 2015; Mamadou 2000; Barbery and Gavaud 1980; Vizier 1984; Charreau and Fauck 1965; Dasylva et al. 2019). These soils receive huge amounts of rainfall averaging 2413 mm/year. This rainfall starts in March and begins to saturate the clay soils, which, as they swell, they close the drying cracks and become impermeable. The same rains also saturate the water table, which becomes impermeable. From June onwards, the rains cause the first run-off and flood the shallows. From August to October, the overflowing of the Nkam and Menoua rivers combined with violent rainfall brings the most important water mass. This water mass then forms the floods in the plain. These floods are favoured by the morphology of the plain. Indeed, the Mbo plain is limited on both sides by hills that can reach an altitude of 1200 m. This morphology causes the water to converge towards the plain. Once in the plain, whose slope is less than 5° in places, the water is blocked and can no longer circulate easily. As a result, it accumulates and causes flooding, such as the floods in the Maga (Musy and Soutter 1991). Uncontrolled anthropic pressure is also an aggravating factor in the risk of flooding on this plain.

Proposed solutions for flood risk prevention in the Mbo plain

In the multitude of flood control measures, the main focus is on non-structural prevention measures to reduce damage to people and property in a sustainable way, while respecting environmental requirements. This includes Limiting urbanisation in flood-prone areas around watercourses; Restoring flood expansion fields; deepening the bed of watercourses and rivers, mainly the bed of the Menoua and Nkam rivers; digging new gullies or waterways to facilitate the circulation of water and avoid stagnation; regularly removing sand from watercourses and rivers; reduce tree felling and promote reforestation; build protective walls; raise the level of house foundations (at least 1 m); raise the ground level at the entrance to houses; create retention basins and redirect water; raise dykes and earthen levees on the banks of watercourses; create refuge areas.

5 Conclusions

Natural environmental conditions combined with human activities are particularly conducive to the flooding process in Mbo plain. The natural factors involved are the nature of the soil, the morphology of the land, the hydrography, the rainfall and the proximity of the water table to the surface of the ground. In addition, agricultural exploitation, deforestation and uncontrolled urbanisation weaken and increase the impermeability of the soil and expose it to major floods. Deepening the river beds, increasing the number of gullies and waterways in the various districts and preserving the floodplain are some of the methods proposed to limit the impact of flooding.

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Experimental Study of Particle Transport in a Vegetated Environment

Hela Romdhane and Amel Soualmia

Abstract

Naturals watercourses generally receive domestic, industrial, and agricultural wastes. The pollutants transport in rivers is associated to the suspended particles mobilization which generally occurs during floods, subsequently causing different problems for water quality, for infrastructure, for the river's morphology, and even damage to hydraulic and road structures. It is therefore important to know the rivers capacity to mix, transport and trap these pollutants. It has already been recognized that vegetation has the capacity to remove fine solid pollutants by retention and absorption. Indeed, the solid pollutants generally settle in the vegetated flow bed, which later infiltrate in the terrain and accumulate in the cultures to threaten the human health, or they will be transported again during flood's events and causing structural problems. Since the turbidity measurement is often used to assess the suspended solid quantity in water, it can therefore be used as an approximation for several highly hydrophobic organic pollutants in water river. On this basis, this experimental work was developed, where we created in a laboratory rectangular channel, an environment similar to a natural stream with vegetation and sediment at the bottom. The aim of this study is to investigate and analyze the impact of vegetation on the transport of suspended particulate matter of sediments injected upstream and to follow their evolutions using turbidity measurements. It was inferred that the presence of dense vegetation significantly promotes the accumulation of sediment in the local area, leading to a reduction in the bed cross sections and, consequently, an elevated risk of flooding.

Keywords

Watercourse · Experimentation · Pollutants · Particulate transport · Turbidity · Vegetation

1 Introduction

Conventional methods for studying sediment transport in rivers typically focus on the interaction between water and sediment within the system. However, the presence of vegetation along the riverbanks or riverbed necessitates the incorporation of this additional element into the analysis (Luhar et al. 2008; Romdhane et al. 2018; Wu and He 2009). Vegetation exerts an influence on various aspects of water flow, including velocity and turbulence (Romdhane et al. 2019). Specifically, vegetation tends to raise flow resistance, creating conducive circumstances for the deposition of fine sediments. This, in turn, retards the transport of coarser materials and enhances the stability of riverbanks and benches (Romdhane et al. 2018). The interconnections between vegetation and sediment transport yield both morphological and ecological implications (Luhar et al. 2008; Wu and He 2009). These interactions play a dual role: first, they shape the morphological development of the watercourse, influencing transitions between braiding and meandering, for instance. Second, they create a distinct habitat with unique features, such as local sediment composition, turbidity, turbulence levels, and nutrient availability (Abdoulaye et al. 2013).

2 Experimental Study

The experiments were carried out into an experimental flume which was designed and built in our team at the LSTE laboratory of INAT in collaboration with INP Toulouse). This is a rectangular open channel with a 5% slope, measuring 10 m in length and featuring a cross section of 0.80 ×

H. Romdhane · A. Soualmia (✉)
University of Carthage, Carthage, Tunisia
e-mail: amel.inat@hotmail.fr

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Fig. 1 Experimental device at the INAT laboratory and the artificial flexible vegetation used

Table 1 Experiments conducted under a consistent flow rate while varying the quantities of sediment injected upstream

Poured sand quantity (kg)	Initial geotextile mass (kg)	Final geotextile mass (kg)	Released sand quantity (kg)	Retained sand quantity (kg)
0.3	0.5	0.6	0.1	0.2
0.5	0.5	0.7	0.2	0.3
0.7	0.6	0.8	0.2	0.5
1	0.8	1	0.2	0.8

0.60 m^2. The channel operates in a closed-loop circuit as shown in Fig. 1. Within the central 4 m of the channel, the channel bed is adorned with artificial flexible vegetation. These vegetation stems are aligned in the longitudinal direction of the flow and have a height of 40 mm, with a density of 86,000 stems/m^2.

We conducted two series of experiments:

- Series 1: We varied the quantity of sediment injected upstream while keeping the flow rate constant.
- Series 2: We kept the quantity of upstream injected sand constant and varied the flow rate. Before each experiment, we covered the downstream basin with geotextile, the dry mass of which is known. This allowed us to measure the amount of sand recovered at the end of each experiment.

2.1 Series 1

Table 1 provides an overview of the experiments conducted under constant flow conditions ($Q = 15$ l/s), with varying quantities of sediment injected upstream.

We observed that as we increase the quantity of sand injected upstream, the amount retained within the vegetation also increases for the same flow rate of 15 l/s. Furthermore, when 300 g of sand were injected, only one-third of this quantity emerged from the vegetation environment, whereas with 1 kg injected, only one-fifth emerged. This phenomenon may explain the changes in turbidity shown in Fig. 2: the higher the injected quantity, the lower the turbidity. At the conclusion of all these experiments, we retained approximately 2 kg of sand (1800 g) within the vegetation, in contrast to the total of 2.5 kg that was initially poured.

2.2 Series 2

Here is a comparison of turbidity levels both upstream and downstream of the vegetation, using a consistent upstream injection of 2 kg of sand at various flow rates (Fig. 3).

We observed that as the flow rate increases, the amount of sand retained within the vegetation decreases, while the quantity of sediment released increases. Consequently, turbidity levels decrease.

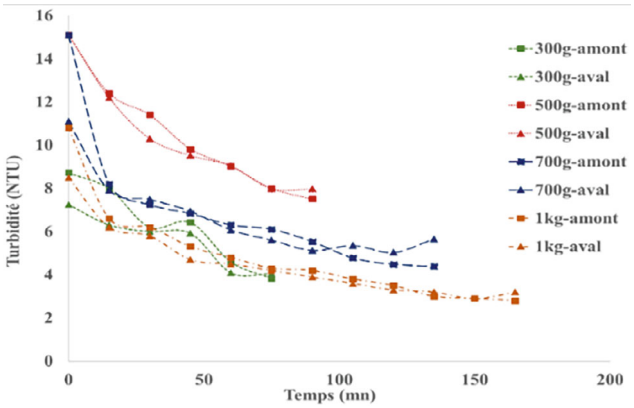


Fig. 2 Comparing turbidity levels upstream and downstream for varied amounts of injected sand and a flow of 15 l/s

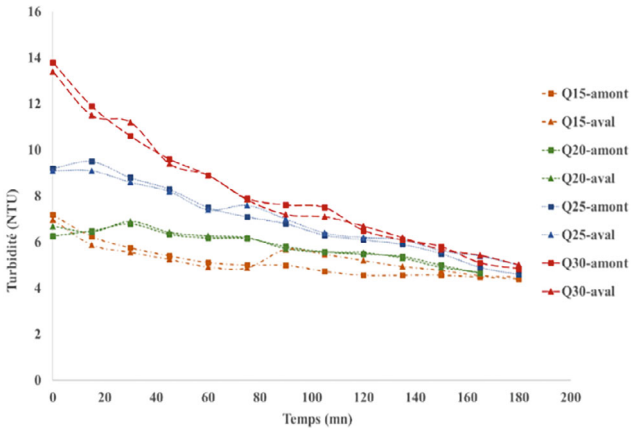


Fig. 3 Comparing turbidity levels upstream and downstream for various flow rates, with a consistent injection sand of 2 kg

3 Discussion

In our experiments, we observed a consistent decrease in both upstream and downstream turbidity within the vegetated system over time, following an exponential trend. Initially, the downstream turbidity was lower than the upstream turbidity, but after some time, they converged to a stable level across different flow rates, representing a state of stabilization. This behavior can be attributed to the fact that, upon sediment injection, an initial quantity of sand is promptly discharged, while the remainder becomes trapped in the center of the vegetation and is subsequently released gradually.

4 Conclusions

We have concluded that dense vegetation strongly promotes the deposition of local sediments, leading to a reduction in the bed's cross-sectional area, which, in turn, could elevate the risk of flooding. To address these challenges, various maintenance techniques are essential to mitigate these risks, including cleaning, leveling, and clearing vegetated islands.

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Study of Radioactive Characteristics of Soil and Assessment of Radiation Hazard on the Examples of the Khrami and Dzirula Crystalline Massifs (Georgia, Caucasus)

Kakhaber Kapanadze, Archil Magalashvili, and Platon Imnadze

Abstract

Radioisotopes of natural origin distributed in the soil are the significant component for the formation of background radiation. In addition, the problem is influenced by soil contamination after nuclear fallout and the deposition of anthropogenic materials. Thus, the importance of an in-depth investigation of the contributors of the radiation from this environment and assessment of exposure risks is obvious. This study was conducted on soils of the Khrami (Eastern Georgia) and Dzirula (Western Georgia) crystalline salients. When choosing these study areas, the petrology of the soil parent rocks, the presence of agricultural and industrial activities were taken into account. Soil samples were collected and processed in accordance with well-proven methodologies. The specific activities of U-238, Th-232, and K-40 as natural radioisotopes, as well as the anthropogenic radionuclide Cs-137 were determined using gamma spectroscopy method. As a result, the basic parameters for assessing the radiation hazard to humans were determined and the characteristics of the natural background radiation and technogenic pollution of the studied territories were identified. In addition, a correlation was revealed between radiological parameters and geological peculiarities of the studied territories. An analytical comparison of the characteristics of the studied areas was also carried out. Research findings and relevant information from different regions of the world were also collated. Comparative analysis showed that radioactive characteristics in the studied areas are somewhat increased, although remain within the recommended limits.

Keywords

Soil · Natural radionuclides · Khrami massif · Dzirula massif · Radioactive contamination

1 Introduction

The distribution of radioisotopes of natural origin in soils is mainly related to the petrology of the parent material (mother rock) of the soil, the topography of the territory, and the nature of the geochemical migration of radionuclides. Generally, igneous rocks reveal relatively high natural radioactivity then other types of rocks. Although, different igneous rocks have different features in this matter. For instance, natural radionuclides are found in greater quantities in felsic than in mafic and ultramafic rocks of igneous groups (UNSCEAR 2000; Dhawal et al. 2013).

Significant outcrops of sialic rocks in the relatively populated and economically developed territories of Georgia are associated with three salient of the Caucasian intermountain Variscan crystalline massif—Dzirula and located to the southwest of it, the smaller Khrami and even smaller Loki massifs. These locations are known as salients of Variscan terrain of "Georgian Massif" (Adamia et al. 2011).

The main goal of the research is to define specific activities and content (concentrations) of natural radioisotopes, such as U-238, Th-232, and K-40, as well as Cs-137 as a technogenic radioisotope in soils formed by sialic igneous rocks of the Khrami and Dzirula massifs, their joint analysis, and assessing the exposure risks.

2 Materials and Methods

First study area (Khrami massif) includes agricultural lands and pastures of Kvemo Kartli region of Georgia. According to geological data (Pruidze and Gamkrelidze 1995;

K. Kapanadze (✉) · A. Magalashvili
Ilia State University, Tbilisi, Georgia
e-mail: kakhaberi.kapanadze.2@iliauni.edu.ge

P. Imnadze
Institute of Physics of Tbilisi State University, Tbilisi, Georgia

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Adamia 2004), in the study area are predominantly prevalent rocks of the following variety: Granites, granodiorites, gneisses (Upper Paleozoic), as well as calc-alkaline basaltic continental lavas (Upper Pliocene), and shallow marine volcanoclastic rocks (Upper Visean–Namurian–Bashkirian). According to soil variety, typically black and forest soils are presented in this territory (Urushadze et al. 2015). The second study area (Dzirula massif) is located in western Georgia in the region of Imereti. This area is characterized by a diverse landscape with a subtropical humid climate and intensive soil formation processes. As for soils, Forest Yellow-brown soils of various granulometric compositions predominate in the studied territory (Urushadze et al. 2015). According to available geological materials (Pruidze and Gamkrelidze 1995; Geguchadze et al. 1972), the studied area is mainly composed of the following types of rocks: sedimentary (Cenozoic-Mesozoic); gabbro (Paleozoic); quartz-diorites, migmatites and microclinized granitoids (Middle-Late Paleozoic); Microcline (pink) granites (Paleozoic) and granitoids (Middle Jurassic).

The systematic grid method (Mehdi et al. 2016) of soil sampling was used to uniformly represent the character of soil radioactivity. In each study area, 19 samples were taken (a total of 38 samples for both study areas) and processed. Gamma spectroscopy method (with HPGe detector) was used to determine specific activities (in Bq/kg) in samples of soil. Consequently, results of the following radiological parameters were determined and assessed: gamma dose rate absorbed in air (outdoor); effective dose rate (annual, outdoor); radium equivalent activity (used to assess risks of using building and other industrial materials); indices of internal and external hazards and cancer risk caused by external gamma irradiation. Modeling of all parameters and geospatial analysis of the results was conducted.

3 Results

3.1 Specific Activities

A shortened version of the results of the specific activities of radioisotopes U-238, Th-232, K-40, and Cs-237 is presented below (Table 1). As is known, that global averages of specific activities for natural radioisotopes U-238, Th-232, and K-40 are 35, 30, and 400 Bq/kg, respectively (UNSCEAR 2000). Comparison of the obtained results with these data shows that all the average values of the results obtained are noticeably higher than the corresponding world averages.

3.2 Joint Analysis of Absorbed Dose

The results obtained for specific activities can be used to calculate the gamma radiation dose rate absorbed in air (in nGy/h) at a height of 1 m, using the following equation (UNSCEAR 2000):

$$D\ (\text{nGy/h}) = 0.462A_{U\text{-}238} + 0.604A_{Th\text{-}232} + 0.0417A_{K\text{-}40}$$

$A_{U\text{-}238}$, $A_{Th\text{-}232}$, and $A_{K\text{-}40}$ in the above equation represent the corresponding specific activities of natural radionuclides of U-238, Th-232, and K-40, and 0.462, 0.604, and 0.0417 are corresponding dose conversion factors.

Figure 1 graphically presents the distribution of dose rates for both study areas by sampling sites, comparing them with 57 nGy/h (world average (UNSCEAR 2000)). As it seems from Fig. 1, results for absorbed dose rate are relatively higher than worldwide value.

4 Discussion

Spatial analysis of processed GIS data showed that the distribution of natural radionuclides noticeably depends on the soil-forming material and to a lesser extent depends on the soil type and migration factors. Indeed, soils formed as a product of weathering of Variscan granitoids are clearly characterized by an increased content of naturally radioactive elements compared to soils formed from gabbroids and sedimentary rocks.

Concentrations of the technogenic radionuclide Cs-137 are apparently high in both study areas (Table 1). The average concentrations of Cs-137 in soils are between 1 and 10 Bq/kg according to studies conducted in Georgia (Kekelidze et al. 2017). Apparently, the relatively increased levels of Cs-137 in the soils of the study areas are due mainly to traces of

Table 1 Summary of specific activity measurements for 38 soil samples from both study areas

	Specific activities for Khrami massif (Bq/kg)				Specific activities for Dzirula massif (Bq/kg)			
Radionuclide	^{238}U	^{232}Th	^{40}K	^{137}Cs	^{238}U	^{232}Th	^{40}K	^{137}Cs
Min	26	40	691	4	33	34	636	12
Max	49	65	1008	33	54	82	1260	46
Mean	39	53	880	11	44	58	994	27
World mean	35	30	400	–	35	30	400	–

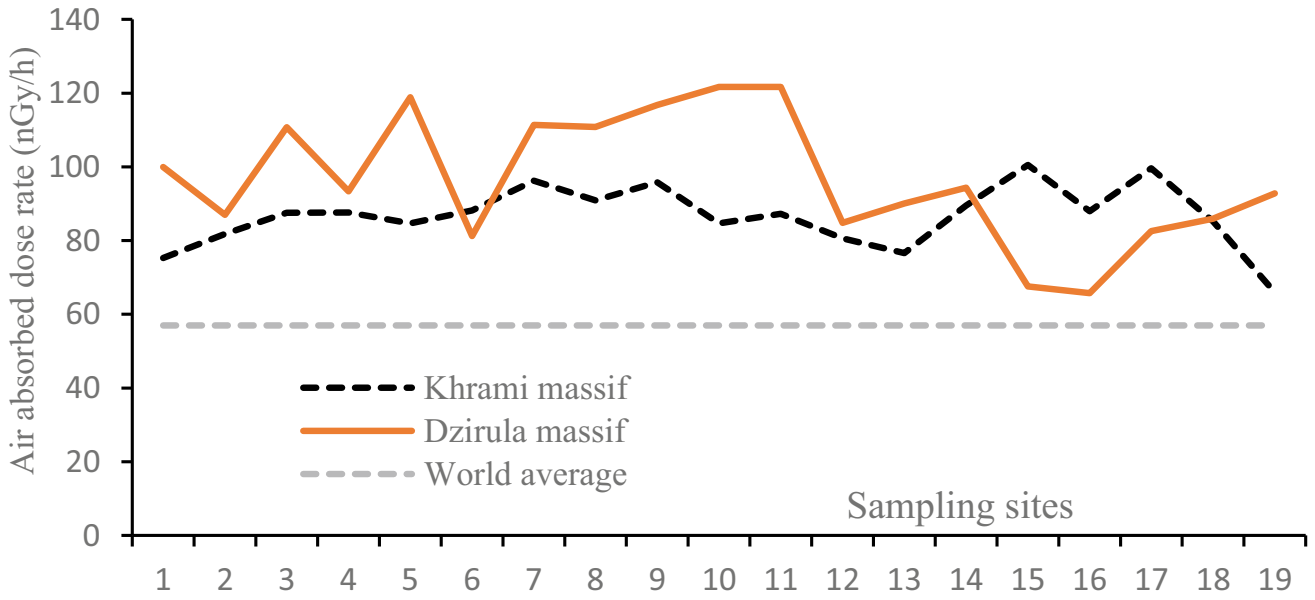


Fig. 1 Distribution of dose rates absorbed in air by sampling sites

the Chernobyl disaster, and to a lesser extent, other nuclear accidents and nuclear tests associated with radioactive fallout. Moreover, there are more traces of pollution on Dzirula than on the Khrami massif. This probably is related to the Likhi ridge, separating western and eastern Georgia, which after the Chernobyl disaster became a natural obstacle to the polluted atmospheric flows from the north-west to the Caucasus.

5 Conclusions

In terms of the content of natural radionuclides in soils, the studied areas do not differ significantly from each other. This indicates a certain similarity between these crystalline salient. The results showed a slight increase of the annual effective dose, absorbed dose and concentrations of natural radionuclides in soil, as compared with the relevant global average values. Results for hazard indices as well as for radium equivalent activity are in accordance with internationally recommended limits. Consequently, the radioactive characteristics of the studied territories are quite interesting, which deserves some attention and, possibly, a more detailed study.

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Activity Concentration of ^{210}Pb, ^{226}Ra, ^{234}Ra, and ^{235}U in Surface Soil Samples from Southern Algeria

Mohamed Nadri, Malika Alili, Brahim Beladel, and Chams-Eddine Khiari

Abstract

The surface profiles of **^{210} Pb, ^{226} Ra, ^{234}Th, and ^{235}U** concentrations in different types of soil from **Bordj Badji Mokhtar, Raggane, and Ghardaia** sites of south of Algeria were examined and characterized by the sandy soil. The soil collection areas are situated in close proximity to the designated locations where France conducted a total of 17 nuclear tests in the Sahara Desert during the period of 1960–1966. Soil samples were sifted through the sieve and prepared for gamma spectrometry. The samples were gathered manually, using a small pickax and a small shovel. They were obtained in rectangular blocks. (10 × 10) cm^2 up to 70 cm: cut in to vertical layers 2 cm, 5 cm, and 10 cm thicknesses, respectively. All samples were evaluated utilizing a state-of-the-art HPGe detector, boasting high resolution (1.9 keV at 1.33 MeV), exceptional efficiency (42%), and minimal background noise. Specifically, for the assessment of 210Pb (E_γ = 46.50 keV), a Ge planar detector with a generous active area of 2000 mm^2 and thickness of 20 mm was employed, yielding an energy resolution (FWHM) of 400 eV at 5.9 keV or 700 eV at 122 keV. Calibration was performed with calibration sources having identical geometry as the samples. Activities of natural and man-made radionuclides 210 Pb, 226 Ra, 234Th, and 235 U are as follows: ^{235}U ranged between 0.0841 ± 0.354 Bq kg^{-1} at (Zaouiet Kounta Raggane), 5.58 ± 0.242 Bq kg^{-1} at Zawiya Erragani Reggane and 0.0225 ± 0.466 Bq kg^{-1} at Bordj badji mokhtar. ^{226}Ra ranged between 3.67 ± 0.468 Bq kg^{-1} at Bordj Badji Mokhtar and 15.3 ± 0.242 Bq kg^{-1} at Zaouiet Kounta Raggane site; ^{210}Pb ranged between 45.68 ± 0.083 Bq kg^{-1} at Berriane, Ghardaia, and 55.42 ± 0.083 Bq kg^{-1} at Zelfana, Ghardaia. ^{234}Th ranged between 11.9 ± 0.38 Bq kg^{-1} at Reggane site and 146.6 ± 0.0521 Bq kg^{-1} at Tagorayt Reggane site. ^{226}Ra was marked for the lowest value in Borj Badji Mokhtar site and highest value at Zaouiet Kounta Raggane site. ^{210}Pb was marked for the lowest value in Bordj badji mokhtar site Adrar and the highest value in Ghardaia. Thorium concentrations at all sites were higher than values reported by International Atomic Energy Agency and other international standards. The correlation between soil layers and radiological properties implies a connection between soil processes and the distribution of radionuclides.

1 Introduction

The radioactivity levels originating from Naturally Occurring Radioactive Material (NORM) vary based on the geological conditions and geographical positions (Bunzl et al. 2000). Considerable quantities of NORMs can be identified in food, water, rocks, soil, gypsum, concrete, and various building materials. In addition to the existence of naturally occurring radioactive sources from millions of years ago in our surroundings, humans have introduced synthetic sources of radiation into the environment since the early twentieth century. The initiation of nuclear tests in the 1940s led to a vast release of man-made radionuclides into the environment, with the highest levels observed in the 1960s when numerous other nuclear activities were

M. Nadri (✉) · C.-E. Khiari
Physics Department, Ecole Normale Supérieure (ENS), Algiers, Algeria
e-mail: nadri@ens-kouba.dz

M. Alili
Animal-Ecobiology Laboratory, Ecole Normale Supérieure (ENS), Algiers, Algeria

B. Beladel
Physics Department, University Ziane Achour, Djelfa, Algeria

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concurrently introduced. Due to its short half-life, it nearly vanishes after one year.

Various regions across the globe have experienced the impact of radioactive remnants. Several of these remnants stem from previous nonviolent undertakings, whereas others arise from military operations, encompassing remnants created during the testing of atomic weaponry. The radionuclides have the potential to migrate deeper into the soil, thereby influencing their residence time in soil layers, which in turn affects their uptake by plant roots. This vertical migration also has a significant impact on internal exposure, as radionuclides incorporated through ingestion of contaminated food are directly influenced by this migration. Consequently, understanding the dynamics of radionuclide transport in soil is crucial for comprehending their potential impact on human health (Fujiyoshi and Sawamura 2004).

Nuclear explosions serve as the primary origin of man-made radioactive substances, which significantly contribute to external radiation. This is due to the utilization of nuclear energy (Dragović and Onjia 2006).

In the early 1960s, France carried out a multitude of nuclear tests, both above ground and underground, within the southern region of Algeria. France conducted a total of 17 nuclear tests in the Sahara Desert from 1960 to 1966. The initial four tests were carried out in the atmosphere, while the subsequent 13 were conducted underground. The atmospheric tests, known as Gerboise (Bleue, Blanche, Rouge, and Verte), took place in 1960 and 1961 at the specified location "Centre saharien d'expérimentations militaires" (CSEM), the Saharan Military Test Centre; the first four tests between 1960 and 1963 were atmospheric and 35 experiments were conducted on plutonium pellets at CSEM in close proximity to Reggane, and the following 13 were underground. Between 1961 and 1966, five plutonium dispersal experiments, known as Pollen, were conducted northwest of the Taourirt Tan Ataram massif at the CEMO facility, located near Adrar Tikertine (IAEA 2005).

Between 1961 and 1963, a total of 35 experiments took place at the CSEM, which was located near the epicenter of the Gerboise Rouge test. These experiments primarily focused on plutonium pellets. One aspect of these experiments involved measuring the velocity of a shock wave within a pellet of plutonium (IAEA 2005).

This study aims to analyze the contents of natural radioisotopes, namely ^{235}U, ^{226}Ra, ^{210}Pb, and ^{234} Th at three important regions in Algeria.

2 Materials and Methods

The sampling locations were chosen at three zones: Bordj Badji Mokhtar (S13), Ghardaia (S16), and Reggane (S17) (Table 1). The climate, vegetation type, soil characteristics, and precipitation composition differ significantly across different zones. Stones and plant roots were eliminated prior to the treatment, and the soil samples underwent the process of sifting through a sieve to get rid of any impurities. Consequently, the samples were meticulously prepared for gamma spectrometry analysis. The samples were obtained by using a small Pickax and a small shovel, with a manual collection method. These samples were taken in the form of rectangular blocks. (10 × 10) cm^2 up to 70 cm: cut in to vertical layers 2 cm, 5 cm, and 10 cm thicknesses, respectively.

Table 1 Codes of different measurement sites

Site's code	Location	Site's code	Location
S13	Bordj Badji Mokhtar	S17e	Safety street Reggane
S16a	Berriane Ghardaia	S17f	Reggane
S16b	Zelfana Ghardaia	S17g	Zawiya Erragani Reggane
S17a	Safety street Reggane	S17k	North Reggane
S17b	Downtown Reggane	S17l	Taourire Reggane
S17c	Dangerous place near explosion	S17m	Tagorayt Reggane
S17d	Bordj Badji Mokhtar way south reggane	S17n	Zaouiet Kounta

Bordj Badji Mokhtar site S13: A city with approximately 30,000 residents sits atop an elevation of 1000 m. It is situated roughly 2000 km south of Algiers and around 500 km north of the Niger border.

Within the In Ekker region, two locations served as settings for nuclear testing endeavors. The initial site, known as Taourirt Tan Afella, derived its name from the towering granite mountain reaching about 2000 m in height. It housed tunnels specifically employed for nuclear weapon experiments. Adjacent to this site lies Adrar Tikertine, named after a granite mountain standing approximately 1250 m tall.

Adrar Tikertine, found about 30 km west of the Taourirt Tan Afella mountain, became the site where experiments regarding the dispersion of plutonium in the air took place.

Ghardaia site S16: The soils sampling location Berianne (S16a) situated about 50 km N-E Ghardaia center near the national way N49 via Algiers, and the site of Zelfana (S16b) situated about 35 km S-E national way N49 via Ouargla (first petroleum City). Ghardaia city, situated between the majestic Atlas Mountains and the enchanting Sahara Desert, exudes a serene atmosphere due to its limited number of inhabitants, characterized with different soil types. The main focus of economic activity centers on the rearing of sheep and cattle. It represents a commercial zone connect the northern and southern regions of Algeria.

Reggane site S17: The Reggane sites can be found in a desert, consisting solely of sand and rocks, situated approx-

Table 2 Surface profile of ^{210}Pb, ^{226}Ra, ^{234}Th and ^{235}U in Algerian soil samples

Sites code	^{210}Pb activity	Errors %	^{226}Ra activity	Errors %	^{234}Th activity	Errors %	^{235}U activity	Errors %
S17a	12.5	21.3	4.28	42.5	71.7	23.3	0.3	42.5
S17b	12.8	10.2	–	–	77.1	–	–	–
S17c	11.8	10.2	7.44	20	82.5	10.2	0.52	22.5
S17d	17.8	8.2	–	–	28.5	8.2	1.54	17.2
S17e	7.73	19.7	9.58	18.6	14.6	35.6	0.66	18.6
S17f	7.24	20	7.84	26.5	11.9	38	0.52	26.5
S17g	6.92	21.4	15.3	24.2	100	21.4	5.58	24.2
S17k	8.02	23	9.92	21.8	16.0	32.2	0.69	21.8
S17l	6.5	22.1	–	–	77.1	22.1	0.99	27.2
S17m	6.5	26.7	–	–	146	–	1.23	21
S13n	2.24	62.2	3.67	46.8	41.6	39.4	0.23	46.6
S13	7.92	17.8	–	–	12.9	17.8	–	–
S16a	45.68	8.3	–	–	–	–	–	–
S16b	55.42	8.3	–	–	–	–	–	–

imately 50 km south of Reggane. Reggane itself is an oasis village with a population of few thousand residents, located around 150 km south of Adrar, and this region is periodically affected by sandstorns.

All samples underwent measurement employing a cutting-edge HPGe detector that boasts exceptional characteristics: high resolution (1.9 keV at 1.33 MeV), high efficiency (42%), and low background. The Ge planar detector employed for 210Pb analysis ($E_\gamma = 46.50$ keV) possessed an active area of 2000 mm^2 and a thickness of 20 mm, with energy resolutions (FWHM) of 400 eV at 5.9 keV or 700 eV at 122 keV. Calibration was performed with calibration sources having the identical geometry as the samples.

3 Results and Discussion

The levels of natural and man-made radioactive elements in soil samples of selected sites were assessed by gamma spectrometry. Data are listed in Table 2. Activities of natural and man-made radionuclides 210 Pb, 226 Ra, 234Th and 235 U are as follows.

235 U range between 0.0841 ± 0.354 at S17n (Zaouiet Kounta Adarar) and 5.58 ± 0.242 at S17g Reggane. 226 Ra range between 3.67 ± 0.468 at S13 and 15.3 ± 0.242 at S17g site; 210 Pb range between 55.42 ± 0.083 at 16Sb and 21.4 ± 0.073 at S18a. 234 Th range between 11.9 ± 0.38 at S17f site and 146.6 ± 0.0521 at S17m site.

For 235 U range between 0.0225 ± 0.466 at S13 and 5.58 ± 0.242 at S17g site. 226Ra was marked for the lowest value in Borj Badji Mokhtar S13 site and highest value at Zawiya Erragani Reggane S17g site. 210 Pb was marked for the lowest value in Bordj badji mokhtar S13 site Adrar and the highest value in Ghardaia S16b. The 210 Pb concentration at two sites was in agreement with values reported by other measurements (UNSCEAR 2000; Noureddine et al. 1997). 234 Th was marked for the lowest and highest values at S17f. S17m sites in Reggane Adrar, respectively. Thorium concentrations at all sites were higher than values reported by international organizations (UNSCEAR 2000; NCRP 1977).

4 Conclusion

The environment in the surveyed location, including the desert, has undergone substantial disruptions, which have likely led to significant alterations in the original data. However, despite these considerable changes, we can still observe the impact of major nuclear incidents and tests on the examined subset.

These findings can be employed in current domestic or global databases to supply meaningful data for evaluating the characteristics of potentially contaminated areas.

The movement and transportation of radioactive materials in the top layer of soil in southern Algeria are influenced by the natural composition of the soil.

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Evaluation of the Sustainability Conditions of the Pine Tree near the Forest Fire Environment

Eusébio Conceição, João Gomes, Mª Manuela Lúcio, Jorge Raposo, Domingos Viegas, and Teresa Viegas

Abstract

This numerical work presents an evaluation of the sustainability conditions of the pine tree, PT, near the forest fire environment. The numerical study of the PT considers energy integral and energy differential balance equations. The heat exchanges by convection between the surfaces of the PT and the surrounding environment and the heat exchanges by radiation between the surfaces of the PT and the fire front, FF, are considered in these equations. The PT, represented by its trunk and its geometry, was built using adaptive mesh. The numerical study was performed considering the 0.01 m/s fire spread rate of 5 m distance of upstream of the PT. The trunk has 2 m height and 0.2 m diameter. The FF has 45° tilt angle, 10 m wide, and 2 m high. The 0.1 m/s wind speed and 500 °C flame temperature are considered. The temperature distribution will make it possible to assess which areas of the PT are most affected by the fire passage. The results show that only the superficial layers of the trunk reach temperatures above 60 °C, so their survival is not jeopardized.

Keywords

Fire front · Numerical simulation · Pine tree · Sustainability

1 Introduction

Nowadays, more and more forest fires occur, with burnt areas becoming more extensive. This causes increasing negative impacts on "carbon storage, biodiversity conservation, hydrologic processes, and economic and social services" (Bowman et al. 2009). Hence the importance of carrying out studies on the effect of fires on the sustainability of forests and their impact on trees' survival. The mechanism of direct tree death from FF is the cambium necrosis through heat transfer (by convection, by conduction and by radiation) on the PT (Sharon et al. 2018). The trees' lethal threshold occurs for temperatures above 60 °C. However, longer exposure (with lower temperatures) can cause also tissue death (Kelsey and Westlind 2017).

The PT trunk numerical study used in this work was developed from the numerical model that simulates the geometry of the human body which is, in turn, applied in the body of the human thermal response of Conceição and Awbi (Conceição and Awbi 2021).

The purpose of this study is to evaluate the extent of the damage caused to a PT during the passage of an FF. This extension will be evaluated by analyzing the temperature distribution in the PT for a 500 °C temperature of the flame and a 0.1 m/s speed of the wind.

2 Materials and Methods

The numerical study is built on equations of integral energy balance for boundary conditions and on equations of differential energy balance to evaluate the thermal response within the

E. Conceição (✉) · M. M. Lúcio
Universidade do Algarve, Faro, Portugal
e-mail: econcei@ualg.pt

M. M. Lúcio
e-mail: maria.manuela.lucio@gmail.com

J. Gomes
CINTAL, Faro, Portugal

J. Raposo · D. Viegas · T. Viegas
Universidade de Coimbra, Coimbra, Portugal

E. Conceição · J. Raposo · D. Viegas · T. Viegas
Departamento de Engenharia Mecânica, ADAI, Rua Luís Reis Santos, Pólo II, Coimbra, Portugal

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PT trunk. These equations defined the thermal flow processes in the PT trunk using the conduction phenomenon with its interior, using the convection phenomenon (by forced, by natural, or by mixed) between its surface (bark) and the air environment, and using the radiation phenomenon between its surface and the surroundings (FF and other materials). This concept is similar to the one used to evaluate the heat exchanges between surfaces inside buildings' rooms. The application of this heat exchange process is shown in the works of Conceição and Awbi (2021) and Conceição et al. (2019)

This study uses a numerical generation of adaptive mesh to define the PT trunk surface with 30 × 20 points. The input data of the model are: (1) wind speed (0.1 m/s), (2) FF dimensions (10 m wide and 2 m high), (3) tilt angle (45°), (4) flame temperature (500 °C), (5) fire rate spread (0.01 m/s), (6) tree dimensions (0.2 m in diameter and 2 m in height), (7) initial distance (5 m upstream) between the FF and the tree, and (8) other initial thermal conditions. The output of the numerical study is the temperature distribution in a plane at 2 m height.

The scheme of the FF scenery used in the numerical study is shown in Fig. 1.

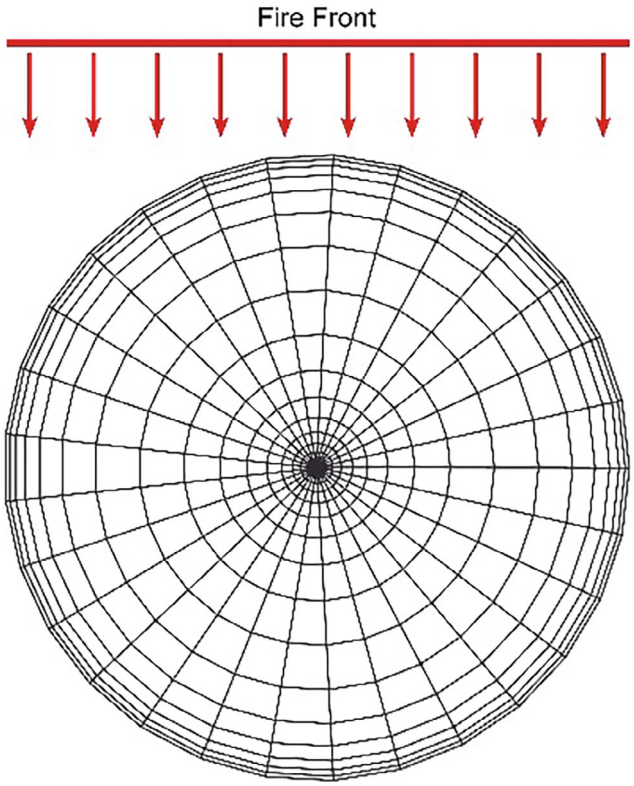


Fig. 1 Scheme of the FF and PT. The red line represents the moving FF. The adaptive grid generation used in the PT trunk has 30 × 20 points

3 Results

The temperature field in the PT, over time, is shown in Fig. 2. In the initial simulation time, the FF is 5 m upstream of the PT.

The PT most influenced by the passage of FF are essentially positioned on the surface (in the bark and in the outermost ring). The highest value of temperatures is obtained after 700 s when FF approaches the PT on the upstream side, which is due to the slope of the FF. On the downstream side of the PT, the temperatures reached show lower values due to the radiative heat exchanges with the FF being less significant. The lateral areas of the PT are affected by the passage of FF, because the heat exchanges by conduction heat flux between the surface of the PT and the interior of the PT are of small amplitude. At the end of 2000 s, the areas of the lateral PT have cooled down to the external ambient temperature (20 °C).

In general, it can be considered that the passage of this FF, which progresses at a slow rate (0.01 m/s), does not jeopardize the sustainability of the tree trunk as it only damages its most superficial layers.

4 Conclusions

In this work, it was evaluated the extent of the damage to a PT during the passage of a 45 °C inclined FF with a 500 °C FF temperature and a 0.01 m/s spread rate, from a 5 m upstream distance of the PT. Its most affected areas are located on the surface (bark and outermost ring). The upstream side is more affected than the downstream side due to the inclination of the flame. The cooling period around the external environment temperature lasts for about 2000 s.

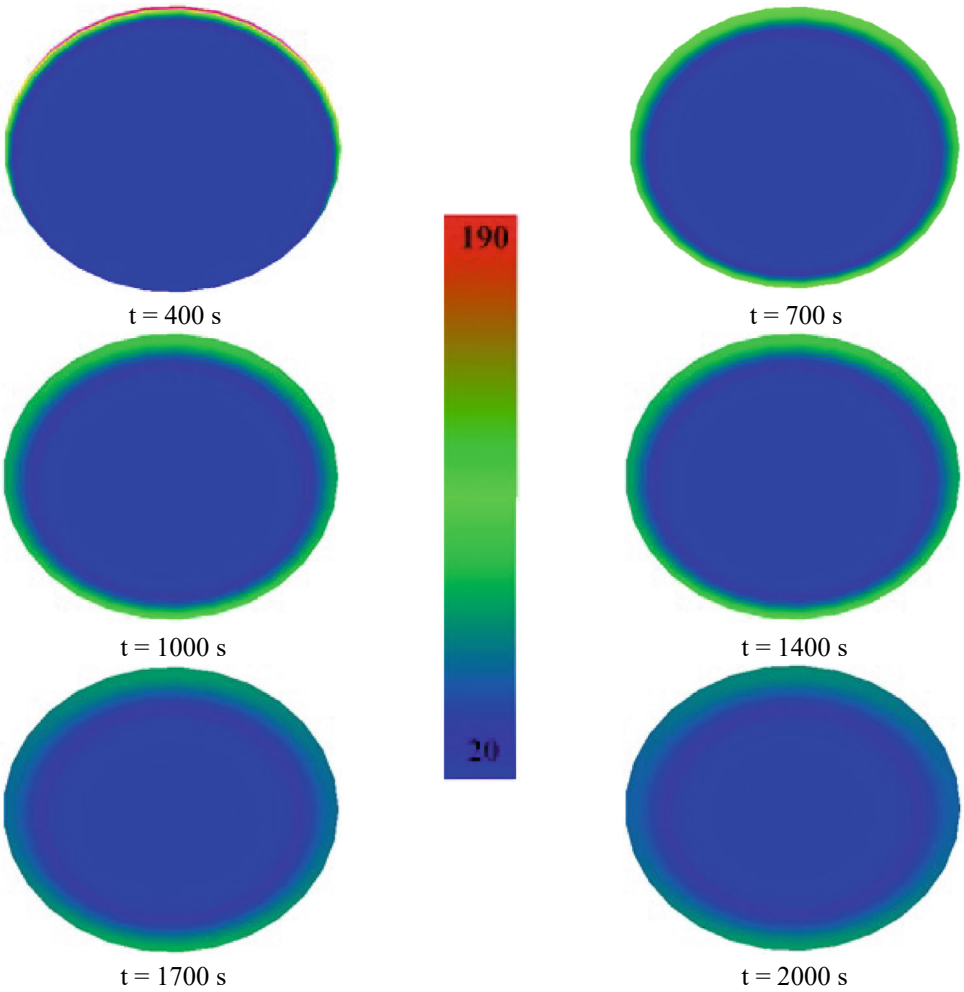


Fig. 2 Temperature field in the PT

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Defense Responses of Apple Rootstock MM106 Infected by *Pratylenchus vulnus*: Biochemical and Plant Nutrient Modifications

Noura Chihani-Hammas and Najet Horrigue-Raouani

Abstract

Pratylenchus spp. are the most dangerous genus of plant-parasitic nematodes, which were infected the major fruit trees essentially in nurseries and orchard of apple (*Malus domestica*). The objective of this study was to evaluate the enzymatic antioxidant and determine the nutrient content of apple rootstocks MM106 at 7 days post infection by *Pratylenchus vulnus*. A pot experiment was conducted under greenhouse conditions at Higher Agronomic Institute of Chott-Mariem, Sousse University, Tunisia. Four different nematode doses (0, 100, 500, and 1000 nematode/plant) were applied per plant (3 months old) with 10 replicated for each dose. At 7 days post inoculation, the enzyme activity: Catalase (CAT), Peroxidase (POX), Polyphenol-Oxidase (PPO), Ascorbate Peroxidase (APX), and lipid peroxidation marker (MDA), total phenol and protein content were determined in roots of apple rootstock MM106. At the end of experiment, nutrient content was quantified by atomic spectrometry in leaves. The result showed the increasing of POX, PPO, and APX compared to the control while CAT decreased. Total protein content and MDA revealed augmentation with high dose however total phenol reduced. The high dose of *P. vulnus* has decreased significantly ($P < 0.05$) the Zn and Fe. However, N, P, and K were augmented significantly ($P < 0.05$) in leaves. This experiment showed new results about defense responses of apple infected by root lesion nematode.

Keywords

Apple rootstock MM106 · *Pratylenchus vulnus* · Biochemical analyses · Defense responses

1 Introduction

In Tunisia, pome fruit trees occupy an important economic place in the crop sector with production 139,500 tones and exportation 653 tons (GIFruit, 2018). Apple trees are damaged by different species of *Pratylenchus* which are reducing the development and production of trees in majority region of the worldwide (Askary et al., 2012). In Tunisia, the rootstock apple MM106 has been attacked by *P. vulnus* (Chihani-Hammas et al., 2018). The presence of nematode hung up the translocated of nutrient and inducing modifications in the roots and leaves post parasitism (Hajji et al., 2017). The resistance mechanisms of plants attained maximum at seventh day after inoculation (Vaganan et al., 2014). The roots and leaves permit the evaluated the biochemical response and nutrient content of host post infection by nematode (Hajji et al., 2017). In the present study, we aimed to (1) estimate the enzymatic antioxidant (2) to determine the nutrient content quantification of apple rootstocks MM106 at 7 days post infection by *P. vulnus*.

2 Materials and Methods

2.1 Population of *P. vulnus*

The population of *P. vulnus* used in the experiment was collected from an apple nursery located in the governorate of Jendouba, Tunisia. The monoxenic population of the root lesion nematode was multiplied on carrot disks in accordance with Moody et al. (1973). Nematode inoculum was prepared to have four doses per each infestation.

N. Chihani-Hammas (✉) · N. Horrigue-Raouani
Higher Agronomic Institute of Chott-Meriem, Sousse University, Sousse, Tunisia

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Table 1 Enzymes activities of seedling apple MM106 (five replicates) 7 days after inoculation by *P. vulnus*

Treatments/enzyme activity	Catalase (CAT) (unité.mg proteine^{-1}.min^{-1})	Polyphenol-oxidase (PPO) (unité.g^{-1} ml^{-1}.min^{-1})	Ascorbate-Peroxidase (APX) (unité.mg proteine^{-1}.min^{-1})	Peroxidase (POX) (unité.g^{-1}.ml^{-1}.min^{-1})
Control	5.06b	4.9a	6.23a	2.9 a
100	4.18a	9.03b	15.36b	3.52b
500	3.64a	9.31b	16.82b	3.55b
1000	3.7a	9.03b	23.63c	3.7b

Means in the same column followed by the same letter are not significantly different according to Tukey's test (P = 0.05).

2.2 Greenhouse Experiment

MM106 seedling (3 month old) was taken from an apple nursery "Mabrouka" originated of the Governorate of Tunis, Tunisia.

Plant was transplanted into 2-liter pots filled by sterilized mixture with equal part (soil, peat, and sand). Four doses of inoculation were considered (0, 100, 500, and 1000 *Pratylenchus*/pot). A total of 40 pots were used in this essay, 10 replicates of plants per each dose of inoculation. 7 days post infection; five replicates of plants per each dose were ripped off and carefully cleaned and washed for our analysis.

2.3 Biochemical Analysis

2.3.1 Preparation of Enzymes Extract

7 days after inoculation, 1 g of sample root per each treatment was homogenized, cleaned, and mixed in mortar with 5 mL potassium buffer (50 mM; pH 7), 0.2 mM EDTA, 1% polyvinylpyrrolidone, and 0.1% Triton X100. The mixture was centrifuged at 12000 × g for 10 min at 4 °C. At the last step, we recuperated the supernatant in the other Eppendorf tubes and used for enzymatic activity assays.

2.3.2 Enzymatic Activity

The activity of CAT, POX, PPO, APX**,** total phenols, total proteins, and MDA content were estimated according to different authors.

2.3.3 Determination of Plant Nutrient Modifications

The content of N, P, K, Zn, and Fe is measured by flame atomic absorption spectroscopy (ThermoSpectronic Heλios γ, Cambridge, England) (Pinta, 1973), and nutrient variables were converted to concentrations (% or ppm).

2.3.4 Statistical Analysis

All statistical analysis is conducted the analyses of variance (ANOVA) using SPSS 20 for software and comparisons of means with the Tukey's multiple range test.

3 Results

3.1 Quantification of Biochemical Modifications

3.1.1 Quantification of Enzyme Activity

The Catalase activity decreased significantly ($p < 0.05$) with augmentation of inoculation dose (Table 1). However, the rest of enzyme activity showed a significant increase.

3.1.2 Variation in Total Phenol, Total Protein, and MDA

Table 2 showed that the total phenols decreased significantly ($P < 0.05$) with augmentation of inoculation doses but the quantity of total proteins and MDA is increased.

3.2 Changes in Mineral Absorption

The result in Table 3 indicates that Zn and Fe concentrations are high in the leaves of uninoculated plants. The presence of nematodes reduced the Fe and Zn content of plants.

Table 2 Effect of inoculation with *P. vulnus* on content of tot phenols, tot proteins, and MDA

Treatments	Tot phenols (mg. g-1)	Tot proteins (mg. g-1)	MDA (µmol g-1)
Control	7.52a	4.11a	1.25a
100	6.94a	3.46a	2.24b
500	7.42a	4.19a	2.53b
1000	6.01b	8.61b	3.44c

Means in the same column followed by the same letter are not significantly different according to Tukey's test (P = 0.05).

Table 3 Variation in concentrations of micro and macronutrients in response to *P. vulnus* (five replicates plants)

Treatments	Micronutrient		Macronutrient		
	Zn (ppm)	Fe (ppm)	K+ (%)	P (%)	N (%)
Control	546.66c	4206.66b	4.77a	0.09a	2.46a
100	370a	3710b	4.98a	0.11b	2.73a
500	520c	2760a	5.67a	0.12c	2.9a
1000	446.66b	3040a	5.24a	0.1b	2.73a

Means in the same column followed by the same letter are not significantly different according to Tukey's test (P = 0.05).

The concentration of K+ and N macronutrients in the leaves of the seedling MM106 increased following an infestation by *P. vulnus* compared to the control (Table 3).

The phosphorus content of the leaves of infested plants increased significantly ($p < 0.05$) in comparison with the uninoculated plants (Table 3).

4 Discussion

The results of the assays relating to the enzymatic activities showed that POX, CAT, Polyphenol-Oxidase, and Ascorbate Peroxidase elevated significantly ($P < 0.05$) at post infection by *P. vulnus* and play a role in the resistance of apple trees to this pathogen. (MaIik & Singh, 1980) showed that elevated of APX in the cell wall starts after plant inoculation. CAT decreased significantly ($p < 0.05$) with important inoculation dose, our results are in agreement with the work of (Molinari, 2001). Fe and Zn decreased with elevated inoculum doses. Pinochet et al. (1995) showed the similar results.

5 Conclusions

In conclusion, the modification in enzymes activities and plant nutrient in apple seedling roots and leaves in resistance to *P. vulnus* affirm defensive mechanisms in host. In fact, Apple rootstock MM106 shows different response (susceptibility/resistance) to *Pratylenchus vulnus.* The biochemical and plant nutrient modifications could offer several advantages for nematode control in an integrated management system.

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Urban Flooding Impact Related to Synoptic Meteorological Conditions over the Western Part of Athens Basin, Greece

Elissavet Feloni, Panagiotis Nastos, Angelos Chasiotis, Andreas Anayiotos, and Evangelos Baltas

Abstract

There is a high consensus that severe rainfall events in recent years contribute to flood occurrence in the urban environment within Athens basin, Central Greece. Adverse weather conditions that are more frequent in the Anthropocene Period drive extended damage in urban agglomerations, especially to public and private infrastructure, even loss of life. In the previous decade, three rainfall events caused significant impact in the area, resulted in more than one hundred flooded properties. The objective of this work is to analyze these flood events from a meteorological perspective and also their relative impact on urban environment. On the one hand, synoptic meteorological conditions of these events are investigated based on the available rain gauge records, SYNOP reports and composite mean and anomalies of surface and upper-air synoptic patterns. On the other hand, the corresponding impact is analyzed taking into account the entire dataset of flood events on residential property, to provide an overview on several characteristics that determined by utilizing street view imagery and GIS techniques and to highlight the level of differentiation found in the urban fabric. The findings of the analysis give evidence that urban flooding is a result of intense urbanization in synergy with heavy rain of convective structure triggered by atmospheric circulation.

Keywords

Floods · Climate change · Urbanization · Heavy rain · Attica

1 Introduction and Scope

As cities continue to grow and climate change brings more extreme weather patterns, understanding and mitigating urban floods becomes increasingly crucial for ensuring the resilience and sustainability of urban environments (Prashar et al. 2023), as urban flooding is influenced not only by local factors like drainage systems and land use but also by larger-scale synoptic meteorological conditions (Qin et al. 2023). There is a clear indication that alteration in rainfall characteristics will contribute to the further growth of destructive frequency and power of floods (UNISDR 2022). Thus, the study of rainfall conditions inducing floods is significant for understanding these larger-scale weather patterns, and it is crucial for improving flood forecasting, preparedness, and resilience in urban areas.

The scope of this work is to present and analyze the synoptic conditions of selected severe flood events occurred in Athens basin (Fig. 1) in the previous decade. The study area is frequently hit by heavy flooding especially in recent years, as the socioeconomic development over the past few years is linked to the expansion of human activities and infrastructure in areas of high flood risk (Feloni et al. 2022). Three flood events are selected for the analysis of the synoptic features of the corresponding weather patterns,

E. Feloni (✉) · A. Anayiotos
Department of Mechanical Engineering and Materials Science and Engineering, Cyprus University of Technology, Lemesos, Cyprus
e-mail: efeloni@uniwa.gr

E. Feloni · E. Baltas
Department of Water Resources and Environmental Engineering, School of Civil Engineering, National Technical University of Athens, Athens, Greece

P. Nastos · A. Chasiotis
Department of Surveying and Geoinformatics Engineering, University of West Attica, Athens, Greece

A. Anayiotos
Laboratory of Climatology and Atmospheric Environment, Department of Geology and Geoenvironment, National and Kapodistrian University of Athens, Athens, Greece

E. Feloni
ERATOSTHENES Centre of Excellence, Limassol, Cyprus

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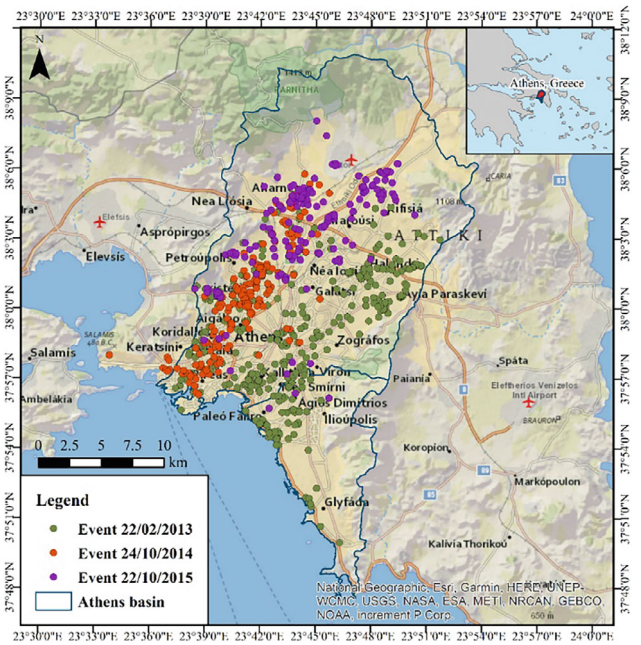


Fig. 1 Study area and the positions of flooded properties for the three events

Table 1 Selected events

Date	Maximum precipitation (mm)	Total precipitation (mm)
February 22, 2013	98	78
October 24, 2014	49	42
October 22, 2015	71	50

as shown in Table 1. All events are of high rainfall intensity and the events occurred in October are more localized (Fig. 1).

2 Flood Events; Datasets and Analysis

2.1 Synoptic Conditions

Mostly similar synoptic conditions appeared for the three rainfall events, caused significant impact in the wider area of Athens basin. Over the west Greece, the synoptic conditions at 500 hPa level, are characterized by a broad trough along central and southern Italy, associated with a SW upper-air stream over the study area. The center of the cyclonic circulation at the surface (~ 1005 hPa) is located over the central Italy and Gulf of Taranto (Fig. 2a). The passage of cold fronts was associated with heavy precipitation, identified by high intensity. The respective radiosondes from the Athens airport shed light to the strong atmospheric instability over the area (Fig. 2b), which was also captured by the negative values of thermodynamic indices; namely Lifted Index (LI): − 4 K and Convective Available Potential Energy (CAPE): 1200 J/kg) (Fig. 2c), indicating the formation of thunderstorms. The daily composite anomalies of the synoptic conditions for the three rainfall events were calculated with respect to 30 years climatology (1991–2020) for the isobaric level of 500 hPa, the sea level pressure (SLP) and the surface precipitation rate, from NCEP/NCAR Reanalysis datasets (Fig. 2). The daily composite mean anomaly of geopotential heights (m) at 500 hPa level appeared to be more than -200 m for the three cases studied, centered over the Ionian Sea (Fig. 2d), while the daily mean anomaly of SLP was assessed to be less than − 10 hPa (Fig. 2e). The daily mean anomaly of surface precipitation rate exceeded 20 (mm/day) over the wider area of Greece and southern Italy (Fig. 2f). For the sake of brevity, we decided to depict the respective graphs for the rainfall event on October 24, 2014, which illustrate similar synoptic patterns regarding the other two rainfall events, contributed to floods within Athens basin.

2.2 Impact on Properties

The impact of the rainfall events on the urban environment is discussed through analyzing the number and spatial distribution of flooded properties after performing a geocoding process to the corresponding dataset provided by the Hellenic Fire Service. In the most severe flood events, the number ranges exceeds 100 incidents. Finally, various characteristics of the flooded structures were examined using the accurate address and the Google Street View (GSV) imagery, which has proven to be a competent tool for virtual inspections of urban environments, offering a wide range of applications (Diakakis et al. 2016). Particularly, GSV is used to identify specific building elements such as the lower opening of the building, its material, the condition of the building and the surrounding environment, as these characteristics may control the impact, as well. Indicatively, among the characteristics recorded the most crucial appears to be the existence of garden, as, among the events, about 60–90% of the flooded buildings do not share any permeability area. The existence of basement compared to a ground-flood lower opening is also recorded; however, properties are shared in these two categories for all examined events. Finally, the material of the lower opening is also checked, where the most vulnerable material (i.e., glass) was systematically observed as expected, but, due to the wide use of metal and wooden doors, the frequency of this type is higher, while no spatial relation is observed.

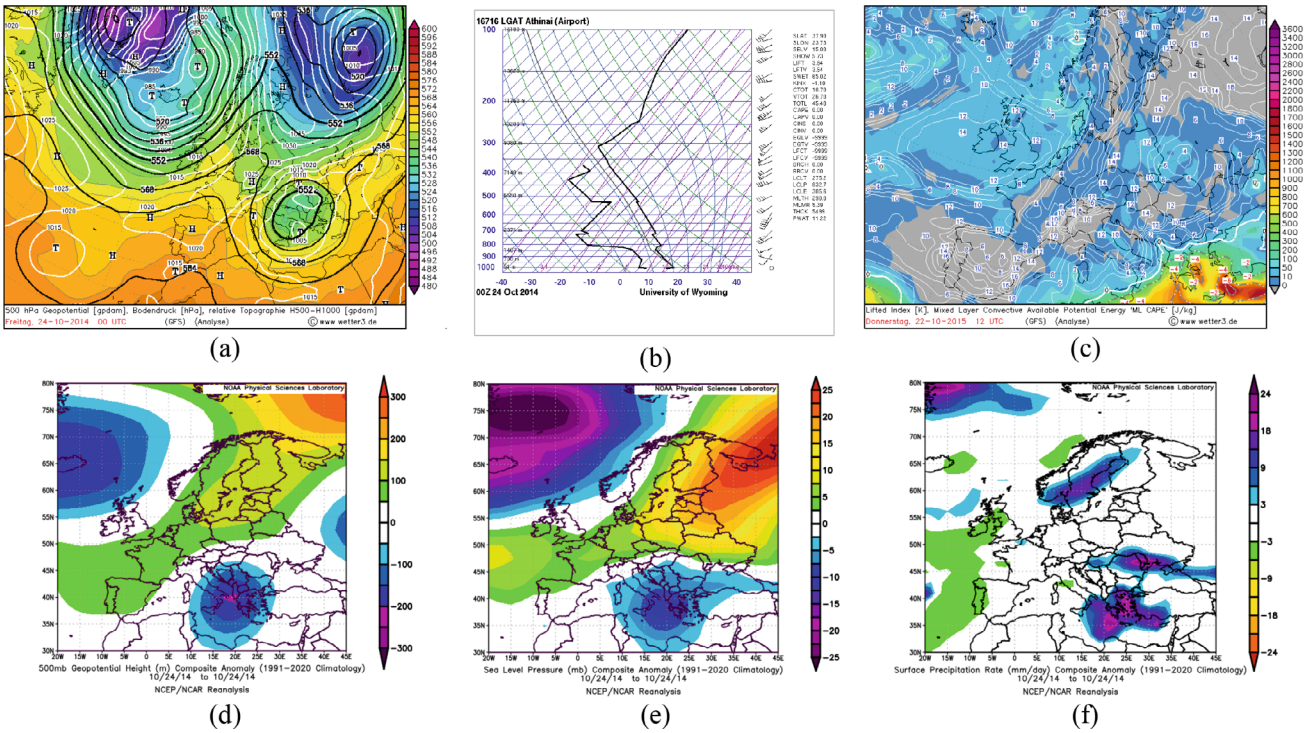


Fig. 2 **a** Geopotential heights at 500 hPa along with the sea level pressure at 00UTC, **b** radiosonde for Athens at 00Z, **c** thermodynamic indices, lifted index (LI) and convective available potential energy (CAPE) at 12 UTC, (d) geopotential heights (m) composite anomaly at 500 hPa, **e** sea level pressure composite anomaly (hPa), and **f** surface precipitation rate (mm/day), for October 24, 2014

3 Discussion and Concluding Remarks

The findings of the analysis give evidence that urban flooding is a result of intense urbanization in synergy with heavy rain of convective structure triggered by atmospheric circulation. Regarding flood impact on the urban environment, several characteristics of buildings that experienced flood in the interior were investigated. Although the condition of the building is not crucial, the surrounding environment is linked to the potential damage. Synoptic patterns show similar synoptic conditions for the three rainfall events, where the synoptic conditions at 500 hPa are characterized by a broad trough along central and southern Italy, associated with a SW upper-air stream over the study area, which is in accordance with previous research (Nastos and Matsangouras 2014). Among the daily composite anomalies, this of geopotential height (m) at 500 hPa is more intense, compared to the SLP and daily surface precipitation rate, which were also analyzed.

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Analyzing Spatial Determinants of Flooding in Urban Environments

Elissavet Feloni

Abstract

This research aims to explore the relationship between urban flood occurrences and factors that may trigger them. The study assesses flood impacts through the number of emergency calls received by the fire service. The factors under investigation include key geomorphological characteristics of the study area and various hydrometeorological parameters associated with storms. The analysis is based on GIS techniques, and the study presents results from two case studies for comparative purposes. Through binary logistic regression and a generalized linear regression model, the study investigates the potential influence of a range of static and dynamic factors on the spatial distribution of urban flooding. The findings highlight variations in results when different factors and events are considered. The study examines several factor combinations for both events and indicates that binary logistic regression, used for flood occurrence prediction, demonstrates a high predictive capability compared to the generalized linear regression model, which is employed for assessing the magnitude of flood impact.

Keywords

Urban flooding · Flood-influencing factors · Flood impact · GIS · Spatial analysis · Athens

E. Feloni (✉)
Department of Mechanical Engineering and Materials Science and Engineering, Cyprus University of Technology, Lemesos, Cyprus
e-mail: elissavet.feloni@cut.ac.cy; feloni@chi.civil.ntua.gr

Department of Water Resources and Environmental Engineering, School of Civil Engineering, National Technical University of Athens, Athens, Greece

1 Introduction

Urban flooding has emerged as a prevalent and globally pervasive crisis in urban settings, resulting in harm to infrastructure and property, disruptions to daily routines, and posing risks to public health. Urban floods refer to the inundation of urban areas, stormwater runoff, or the overflow of water bodies within densely populated regions that is mainly linked to excessive rainfall.

Implementing comprehensive plans for flood hazard and risk assessment is imperative in safeguarding communities and provide a structured approach to understanding the potential impact of floods, enabling informed decision-making and risk reduction strategies under the scope of designing resilient urban development. The identification of the most crucial flood-influencing factors plays a pivotal role in flood hazard and risk assessment. Thus, the study of historic flood events is a valuable tool for assessing flood risk (Diakakis et al. 2016), understanding its causes and consequences (Koç et al. 2020), and developing informed strategies for flood hazard mitigation and resilience building. Furthermore, this analysis is exceptionally valuable for the determination of the most significant factors to be incorporated into a GIS-based multi-criteria analysis (MCA) for flood susceptibility mapping (e.g., Papaioannou et al. 2015; Khosravi et al. 2016; Feloni et al. 2020) regarding factors' selection and weighting, and even for the purpose of calibration and validation (Feloni et al. 2020). Indicatively, there is a significant body of research (Fowler and Hennessy 1995; Cannon et al. 2008; Bracken et al. 2008) that has explored the impact of meteorological characteristics of storms, particularly rainfall patterns, on debris flows and consequential flooding. Furthermore, Patton (1988) and Beven et al. (1988) have examined the catchment's geomorphological characteristics in relation to the hydrological response, while Blanco-Vogt and Schanze (2014) illustrate the flood susceptibility of many building components. The

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relationship between various factors and the spatial distribution of floods has been examined using regression models in hydrology and flood risk research. Regression analysis is a statistical technique commonly employed to quantify the relationships between dependent variables (such as flood occurrence or severity) and independent variables (factors that may influence floods). This paper investigates the potential link between urban flood impact and several flood-influencing factors for two catastrophic events that occurred in Athens basin (Attica, Greece) on February 22, 2013 and October 22, 2015 and which are associated with extensive damages and fatalities. The extent of impact is quantified through the volume of emergency calls made by residents to the fire service in response to flash floods. Initially, this dataset undergoes a geocoding procedure to ascertain the geographical dispersion of properties affected by flooding. Subsequently, 12 potentially flood-triggering factors are determined with the aid of GIS techniques to finally perform a regression analysis to examine their spatial correlation to flood occurrence. Particularly, (i) binary logistic regression (BLR) is initially applied for flood occurrence assessment, as the outcome variable is binary (flood/no flood or flooded/unflooded), and (ii) generalized linear regression models (GLM) are performed to investigate the capability to predicting the magnitude of flood impact identification on a grid basis.

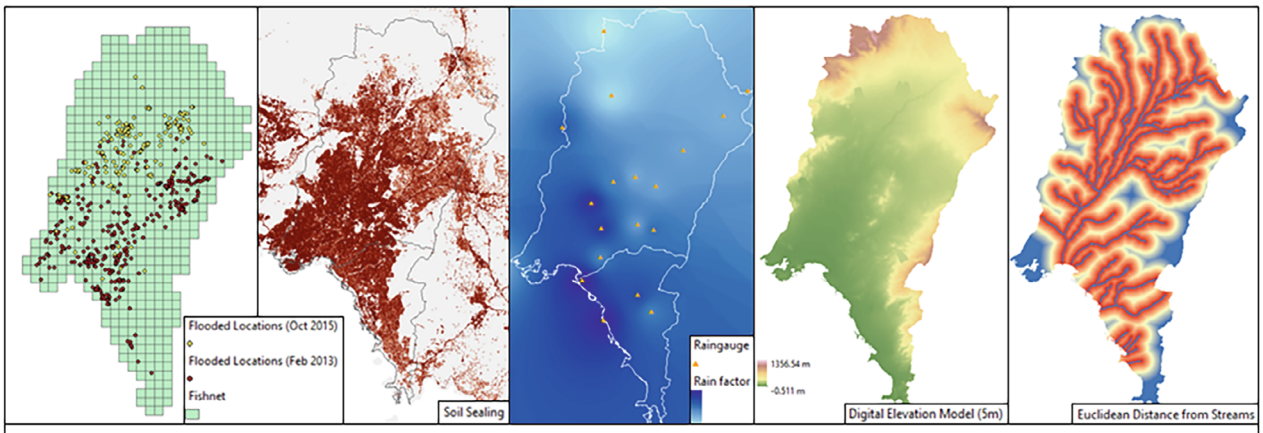
2 Materials and Methods

To perform the BLR and GLM on a grid basis, the dependent variables for the two case studies are initially defined, after dividing the area into cells by creating a 1000 m × 1000 m grid (Fig. 1: Fishnet polygon grid). For the dataset of flood impact (i.e., dependent variable in GLM), the absolute number of flood incidents per cell (i.e., locations of emergency calls) is calculated and for the dataset of flood occurrence (i.e., dependent variable of BLR), a Boolean map is created attributing the dichotomous value of (whether or not) any flooded locations are recorded in a cell. Accordingly, to link in space the aforementioned variables to a set of flood-triggering factors that are used as independent variables to the models, one raster dataset is created per factor (Fig. 1) and, finally, the average factor's value that falls within each cell of the analysis grid is assigned for all 12 influencing factors. After identifying pertinent research articles, we selected the influencing factors, followed by conducting the statistical analysis, as shown in Fig. 1.

3 Results and Discussion

BLR and GLM tests were applied utilizing spatial data to explore the connection between urban flood incidents and flood-triggering factors. Subsequently, we assessed the models' performance in predicting either the occurrence of flooding (yes/no) or the severity of flooding (total number of flooded locations) at a grid level. Various combinations among factors (i.e., the independent variables) are set for both case studies, among which a BLR model for the event of October, 2015—performed between the 12 factors and the '0'/'1' variable regarding the existence of flooded locations per cell—reaches 96.1% predicting ability for cells appearing flood occurrence and an overall predicting ability equal to 86.7%; on the contrary, the model's overall predicting ability for the event of February, 2013 is 72%. Apart from the test considering all 12 factors, various combinations among them are also examined, all of which are based on a selection of about six or seven factors. A general observation, regarding factors presenting the stronger correlation, which is evaluated through the b value, is that, among geomorphology-related factors, the ELV is important in both events, as the most flooded properties are concentrated at the lowlands, while, among the hydrometeorological factors, factor SOS appears to be highly related to flood occurrence in both case studies, as well. Rainfall-related factors' correlation differs between these two events. The GLM analysis conducted with the 12 factors and the variable representing the number of flooded locations per cell reaffirmed the statistical significance of multiple factors. In both scenarios, it was observed that the contributing area (FLA) did not exhibit statistical significance. Furthermore, the goodness of fit for the GLM results demonstrated a low R^2 value in both cases. Recommendations and suggestions for future research derived from the different results between the two case studies that are presented in this work, and there is a need to focus on the analysis of additional flood events, to compare the corresponding results using also grids of different size, as according to previous work, different grid cell-sizes show different predicting ability.

(a)



Geomorphology-related Factors:
Digital Elevation Model: factor **[ELV]**→ Surface slope through 3D Analyst toolbox (ArcGIS): factor **[SSL]**→ Flow direction and Flow accumulation through Hydrology toolset (ArcGIS): factor **[FLA]**→Reclassify tool through Spatial Analyst (ArcGIS)→Streams feature class→Euclidean distance through Spatial Analyst (ArcGIS): factor **[STR]**
Rainfall-related factors:
Spatial interpolation of rainfall point measurements (orange triangles: Rain gauge network)→ Total rainfall depth: factor **[PCP]**, Maximum Rainfall Intensity for various durations: factors **[RI10min]**; **[RI20min]**; **[RI30min]**; **[RI1h]**; **[RI2h]**; **[RI6h]**
Hydrologic factor:
Degree of soil sealing: factor **[SOS]**

(b)

Statistical analysis framework using the IBM SPSS Statistics for Windows, Version 26, Armonk, NY: IBM Corp.

- Input: Dependent variables (N, C), Independent variables (all examined factors, ELV etc.)
- Analysis: GLM - BLR
- Output: model determination and evaluation

Test 1	Binary logistic regression	Dependent variable: the dichotomous value (C=1(=yes), 0(=no)) describing whether a cell of the grid includes or not a flooded property.	Independent variables (predictors): the 12 factors (related to geomorphology, rainfall, hydrology)
Test 2	Generalized linear model	The number of flooded locations recorded in each cell of the grid (N=0, 1, 2, …, n)	

Fig. 1 **a** Factors' visualization and GIS procedure, **b** statistical analysis framework

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Evaluation and Mapping of Erosion Risk by RUSLE Model in the Boussellam Catchment in Northeast Algeria

Belkacem Merzouk, Elhadj Mokhtari, and Ali Berghout

Abstract

An essential step in creating effective territory management strategies and identifying possible hydrogeological danger areas is assessing the soil erosion rates in a basin. It is critical to evaluate the impacts of soil erosion because it has expanded significantly in Algeria. For this, a number of models and methodologies have been employed. Using RUSLE, RS data, and geographic information systems (GIS), this study set out to calculate the yearly soil loss in the Boussellam watershed in northeastern Algeria. For the purpose of simulating erosive occurrences, the RUSLE model has been employed. With its extended form and low relief, this basin occupies 4151 km^2. Its elevation can be anywhere from 189 to 1757 m, with an average of 931 m, and its slope can be anything from 0 to 266%, with an average of 18%. A thick and well-developed hydrographic network marks the level of two dams, where the majority of its water is released. The impoundment of these dams (Ain Zada and Tichi Haff) is of paramount importance for the supply of drinking water and irrigated areas in the surrounding region. According to the findings, the erosivity factor R ranges from 68 (MJ.mm/ha.h.an) to 140 (MJ.mm/ha.h.an). Soil erodibility factor K averages 0.11 (t.h.ha)/(MJ.ha.mm), with a range of 0.04 to 0.21.The LS topographic factor ranges from 0 to 216 with an average of 16. On average, the C factor is 0.076 and the P factor is 0.77. Erosion appears to be more prevalent in the northern part of the basin, according to the erosion map inferred from the several parameter maps; as of July 2015, the average erosion rate was 258 (t/ha/year). Soil conservation efforts aimed at enhancing food and water security in this crucial basin can greatly benefit from the usage of these maps, which can help identify regions of higher erosion risk and provide a basis for focused investigations and management actions.

Keywords

Boussellam watershed · GIS · RUSLE · Remote sensing · NDVI · Erosion

1 Introduction

One of the record severe natural disasters that has endangered human communities and ecosystems in the last several decades is soil erosion (Gomiero 2016; Duarte et al. 2016). In northern Algeria, water erosion is a major issue with soil degradation (Arar and Chenchouni 2012). More than 80% of farmed land lies in the most vulnerable regions to erosion, making an already dire situation even worse. Natural soil fertility, the hydrographic system, the microclimate, and vegetation and soil cover have all been degraded at an accelerated rate due to human activities that follow development, leading to an increase in runoff (Mokhtari 2017; Negm et al. 2020; Tariq and Shu 2020). The integration of various data sources in geo-spatial treatment systems, like GIS, allows for the complex tasks of detecting eroded areas and estimating the factors controlling erosion and its characteristics. Spatial data, measurements, and ground-based and satellite-based investigations are all part of this category of sources (Prasannakumar et al. 2012; Arar and Chenchouni 2014; Rahman et al. 2022).

In recent years, RUSLE combined with GIS has attracted great attention as an efficient method and is currently used in the estimation of soil losses in Maghreb region (Mokhtari 2017; Belasri and Lakhouili 2016). Nevertheless, only a

B. Merzouk (✉) · E. Mokhtari · A. Berghout
Laboratory of Water, Environment and Renewable Energies, Department of Hydraulics, Faculty of Technology, University of M'sila, University Pole, Road Bordj Bou Arreridj, M'sila 28000, Algeria
e-mail: belkacem.merzouk@univ-msila.dz

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small number of studies have utilized RUSLE in conjunction with GIS and remote sensing thus far (Duarte et al. 2016; Negese et al. 2021). Obtaining spatialized data on erosion is difficult due to the small number of locations where the concentration of suspended solids (SS) may be measured, which does not account for the spatialization of erosion. The purpose of this study is to use the RUSLE model, GIS, and RS to create an annual soil loss estimate in the Boussellam basin, which is located in the northeast of Algeria.

2 Materials and Methods

2.1 Study Area

The Boussellam watershed is located in northeastern Algeria and spans 4151 km^2. It is bordered by 35.75° N and 36.55° N latitudes and 4.5° E and 5.55° E longitudes, respectively (Fig. 1). This basin has its source at Meghris Mountain north of Sétif and drains water toward Soummam River over a length of approximately 129 km. The Boussellam River represents the main hydrographic axis. It drains 54.9% of the basin's total area to the sea and is one of the two main tributaries of the Soummam, the other being the Sahel River in the west. The annual regularizable volume is nearly 38 Hm^3. It is made up of the union of Gassar River which runs along the southern piedmont of the Meghris Mountain (Altitude 1737 m) and Ouricia River which is located in the southern part of this mountain. In the minds of the locals, the Boussellam River has long been one of the most important wetlands in the area. Many took advantage of it for swimming, fishing, recreation, and even resorts. The Ain Zada and Tichi Haff dams have enriched the basin's biodiversity and provided essential ecosystem services that allow millions of people to continue living in the area.

2.2 Methodology

Using the Revised Universal Soil Loss Equation, also known as Eq. (1), the erosion sensitivity of the study region was evaluated:

$$A = R \times K \times \mathrm{LS} \times C \times P \tag{1}$$

where A is the average yearly spatial loss of soil (t/ha/year), R is the rainfall-runoff erosivity factor (MJ mm/ha.h.year), K is the soil erodibility factor (t. ha.h/ha.MJ.mm), LS is the dimensionless slope length and steepness factor, C is the dimensionless cover management factor, and P is the dimensionless conservation practices factor (Renard et al. 1997).

The RUSLE model parameters were estimated using monthly and annual rainfall data from 1970 to 2017, soil type, digital elevation model (DEM), and Landsat images. A flowchart of the procedures used in this study is shown in Fig. 2.

3 Results and Discussions

Combining maps of erosion factors yielded a soil loss map for the Boussellam basin (Fig. 3). The soil loss rates for

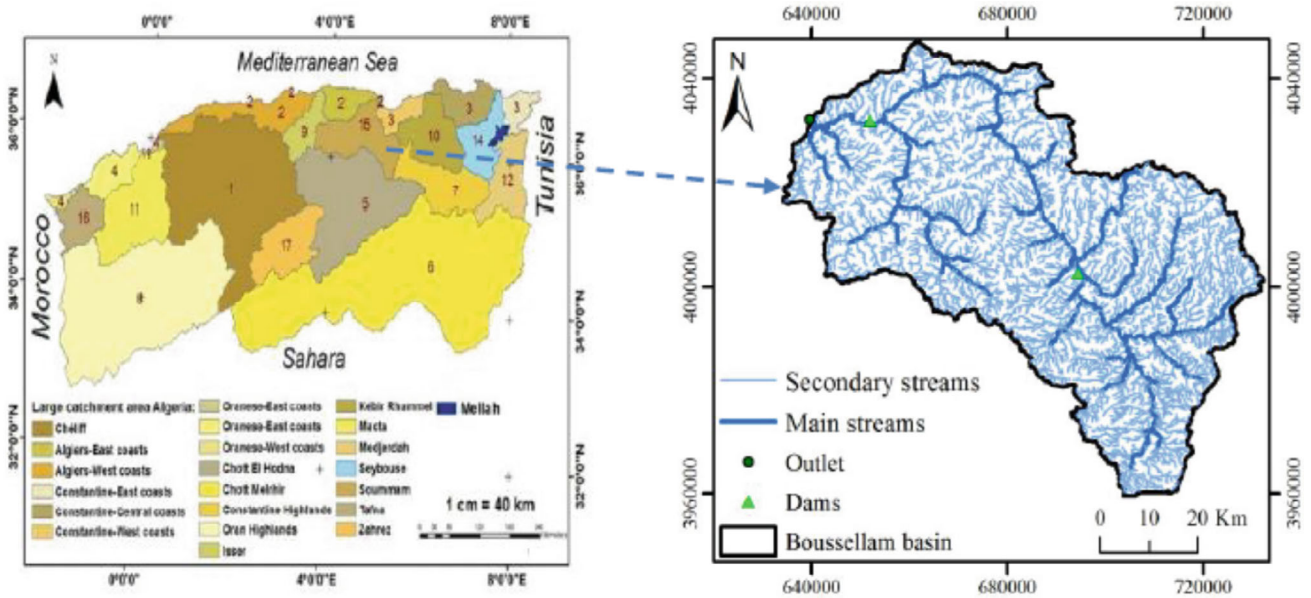


Fig. 1 Boussellam basin

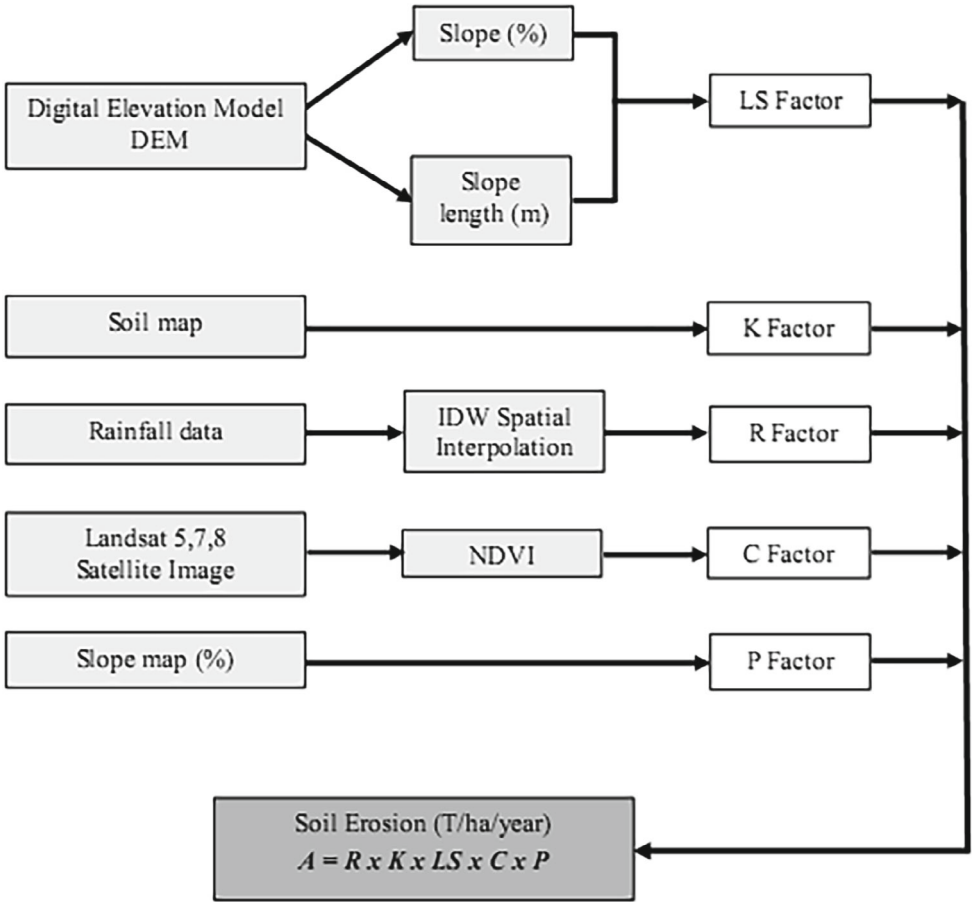


Fig. 2 Flowchart of the methods used for water erosion assessment

July 2015 were 258.06 t/ha/year, with a range of 0.01 to 1196.07 t/ha/year; for March 2016, the losses ranged from 0.0013 to 1164.89 t/ha/year, with an average of 190.92 t/ha/year. In March 2016, 66% of the basin had losses below the tolerance threshold (< 7 t/ha/year), while in July 2015, it was 56%.

Low erosion risk is in the flat southern basin, while high risk is in the steep northern region, attributed to steep slopes and high *R* factor values despite dense vegetation (Arar and Chenchouni 2014).

4 Conclusion

The results obtained show that the soils of the Boussellam watershed are subject to According to the erodibility of the soils, the significance of the slopes, and the lack of vegetative cover, these are three elements that contribute to erosion. Additionally, they show that the basin erodes at a rate of 27–1196 t/ha/year, which impacted 34% of the area in March 2016 and 43.34% in July 2015.

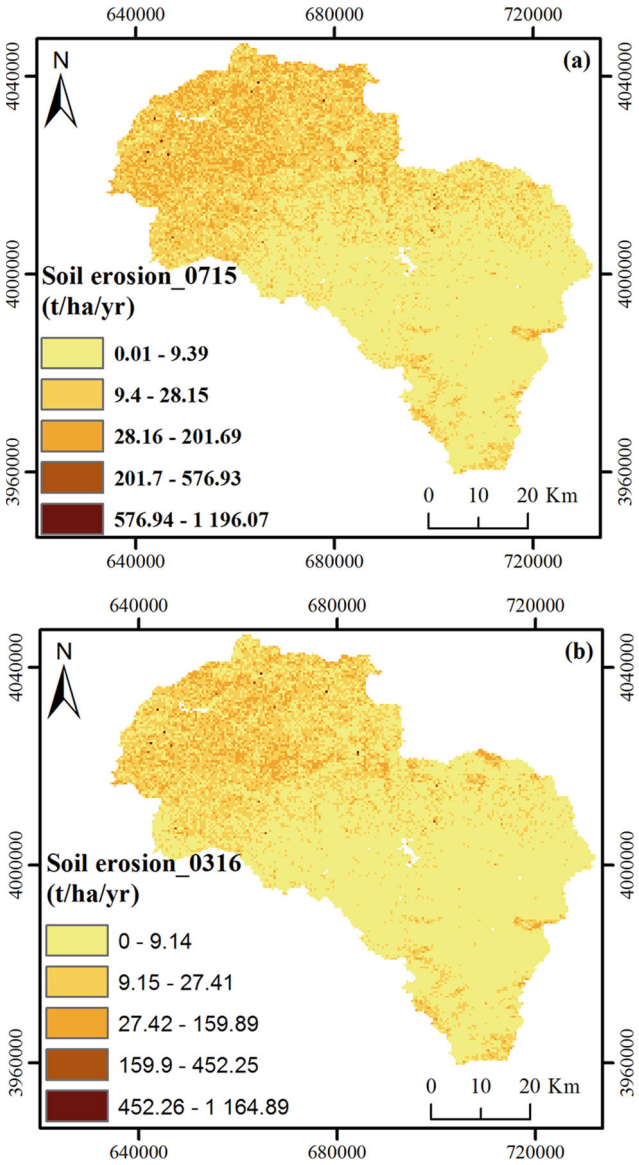


Fig. 3 Soil erosion risk map of Boussellam basin **a**: July 2015, **b**: March 2016

The study proved that the RUSLE model, when combined with GIS and remote sensing, produced very reliable results for simulating evolution scenarios and, consequently, for targeting priority areas requiring conservation actions, protecting the natural environment, and combating erosion. Management of land-use planning and decision-makers can benefit greatly from these findings, and they don't have to break the bank to get them. A number of benefits, such as the capacity to cover vast areas and the reduced necessity for field surveys, are associated with using satellite photos to produce the C factor.

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Sustainable Management of the Urban Environment, the Indoor and Built Environment

Environmental Sustainability Impacts of Solid Waste Management Practices: A Case Study of Kochi City, Kerala State, India

Adinarayanane Ramamurthy, Joseph P. Thomas, and Arpan Paul Singh Golla

Abstract

Solid waste management (SWM) is a critical aspect of good governance and has significant social, health, and economic impacts, particularly affecting the world's poorest. Globally, 4.35 billion urban residents generate solid waste daily, yet 2 billion lack waste collection, with over 90% of waste in low-income countries being dumped or burned. In India, despite efforts like the Municipal Solid Waste Rules (2000), solid waste hampers environmental sustainability. This research focuses on Kochi City in Kerala, India, specifically the Brahmapuram Waste Treatment Plant, operational since 2008. The plant processes up to 200 tons of solid waste daily through sorting and composting, but has long-term environmental and community impacts, exacerbated by fire hazards. The study aims to quantify these losses, establish correlations between land use change and solid waste accumulation, and propose effective solutions considering the impacts on soil, water, air, and society, including health risks and decline in land value.

Keywords

Solid waste management · Health impacts · Land degradation · Risk exposure · Environmental sustainability

1 Introduction

Efficient waste management is crucial for urban development and environmental sustainability (Simatele et al. 2017). Solid Waste Management (SWM) involves collection, transportation, treatment, and disposal, impacting public health, sanitation, and the environment. Currently, landfill sites are most widely adopted methods of disposal that, pose significant issues like groundwater contamination and methane emissions (Kawai and Osako 2013). They also cause air pollution, odors, aesthetic degradation, and consume vast land areas, limiting future land use options (Kamaruddin et al. 2017). In countries like India, where infrastructure and awareness are limited, landfills persist due to perceived simplicity and lower costs (Mani and Singh 2016). Yet, these disadvantages undermine their sustainability (Kaza et al. 2018).

Further these effects of landfill sites are exacerbated during hazard occurrences. Rising sea levels, as studied by Van Khanh (2019), lead to severe ecological pollution at these sites. Mishra (2022) highlights the health hazards magnified by extreme floods, like those in Kerala in 2018, on Solid Waste Management (SWM) practices. However, little attention has been given to fire hazards despite landfills being significant sources of combustible methane. Methane constitutes a 90–98% of landfill gas and can cause explosive mixtures, posing fire hazards (Themelis and Ulloa 2007). These hazards worsen existing environmental and societal impacts. Hence, there's a need to investigate the influences of landfill sites amidst escalating temperatures due to climate change and ensure sustainable SWM.

2 Study Area

The Cochin Municipal Corporation in Kerala covers 94.88 square kilometers with a population density of 7139 individuals per square kilometer, generating 106 metric tons

A. Ramamurthy (✉) · J. P. Thomas · A. P. S. Golla
Department of Planning, School of Planning and Architecture Vijayawada, Ministry of Education, Government of India, Vijayawada, Andhra Pradesh, India
e-mail: adinarayanane@spav.ac.in

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of waste daily. It has three Material Collection Facilities (MCF) and one Resource Recovery Facility (RRF) to manage non-biodegradable waste. Of the 60 metric tons of non-biodegradable waste produced each day, 2 metric tons go to MCFs in Kaloor and Edapally, while the rest heads to the Brahmapuram facility. The landfill, spanning 110 acres, faced a significant fire in March 2023, emitting smoke that affected Cochin City. Air pollution led to discomfort and health issues, with firefighting efforts lasting 12 to 13 days before containment. Another fire emerged on March 26th, compounding issues at the landfill (Nagendra 2023; Centre For Public Policy Research 2023).

3 Methodology

This study aims to understand the impact of the Brahmapuram landfill site on air, water, soil quality, and surrounding real estate values. The investigation follows a structured analytical framework, starting with assessing changes in land use and cover from 2009 to 2021. It then explores environmental effects, detecting alterations in air, water, and soil quality, alongside examining social implications like shifts in real estate prices during the same period. Identified changes are translated into monetary terms to comprehend the impact of landfill site's significance comprehensively.

4 Results

4.1 Change in LULC

The study leveraged Landsat 7 imageries to comprehend the dynamic alterations in Land Use and Land Cover (LULC). The analytical focus was directed toward the years 2009, 2013, 2017, and 2021 as shown in Fig. 1. Through the LULC analysis, discernible trends have been identified. Specifically, a noteworthy decline in wetland extent has been observed over the examined temporal spectrum. Concurrently, an evident increase in built-up areas has materialized during the stipulated timeframe.

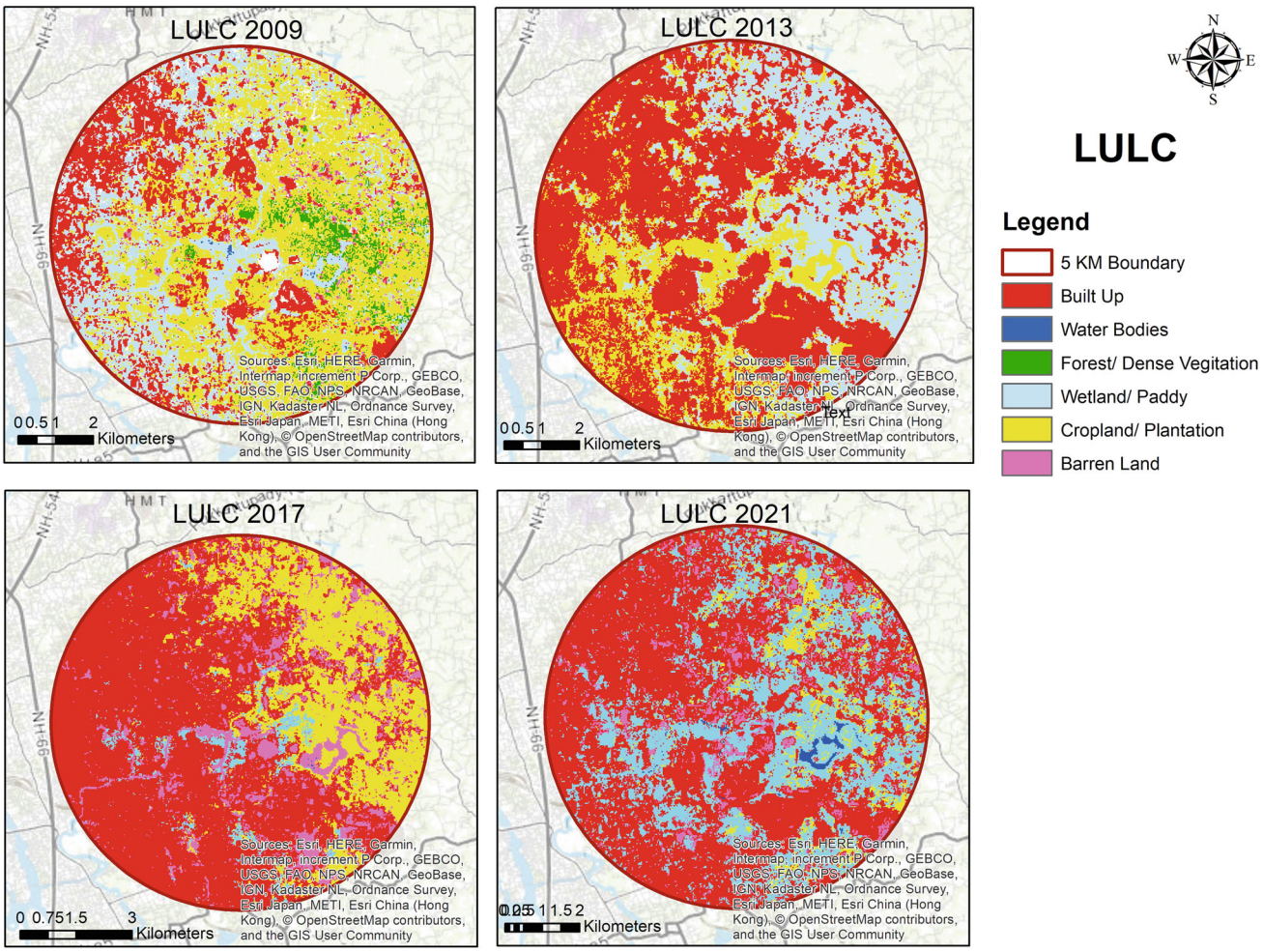


Fig. 1 Change detection in LULC (2009, 2013, 2017, and 2021)

4.2 Water Quality

Based on methods discussed in (Uddin et al. 2021) and focusing on specifically chosen parameters, the water quality index (WQI) was computed for the aquatic bodies proximate to the landfill site. While the computed WQI values fall within the "Good" range, a discernible decline in water quality is evident across successive years, as depicted in the Table 1 provided below. This observation indicates a progressive deterioration in water quality conditions over the assessed temporal span.

4.3 Air Quality

Air quality assessments were conducted across a defined temporal scope encompassing the urban area (Cpcb 2017), with particular emphasis on the vicinity adjoining the landfill site as shown in the Fig. 2. Notably, the most compromised air quality conditions were observed in this adjacent zone. The criteria employed to estimate this risk were congruent with the circumstances prevailing during the fire incident that transpired in March 2023. Further, using the AQI + tool, the risk assessment in the form of estimated attributed mortality rates for different levels of exposure to PM2.5 and PM10 was carried out.

Table 1 Water quality index

Point	2009	2013	2017	2021
Brahmapuram	22.33	28.82	31.6	29.83
Irumpanam	16.34	18.37	39.24	32.35
Manakkadavu	22.96	28.06	25.65	32.67

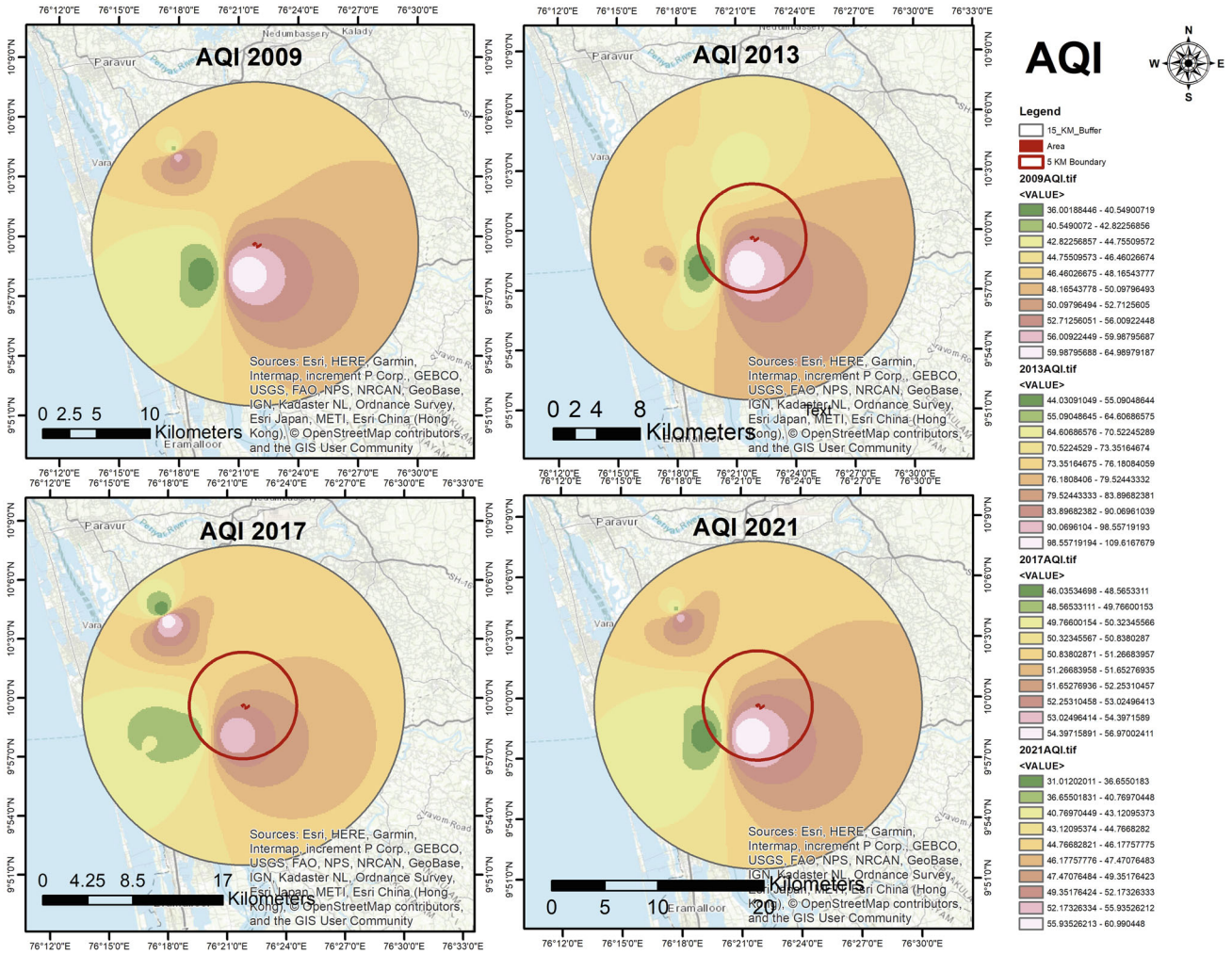


Fig. 2 Air quality modeling for the study area

4.4 Soil Quality

The leachate pollution index (LPI), sourced from a separate study (Parvin and Tareq 2021), was determined to be 31.944 mg/L. This value was then compared against the leachate disposal standard stipulated by the Municipal Solid Waste Rules of 2000 (Cpcb 2015), as established by the Government of India, which stands at 7.3787. This notably elevated LPI value, in contrast to other established standards, raises concerns regarding its potential ramifications for the agricultural productivity within the affected areas. Through analysis, a discernible negative correlation was observed between soil quality and agricultural productivity over the assessed time period. This underscores the potential adverse impact of the elevated LPI on the agricultural landscape.

5 Conclusion

In conclusion, the comprehensive study conducted on the Brahmapuram landfill site and its impact on the surrounding environment and community provides crucial insights into the urgent need for effective Solid Waste Management strategies. The findings underscore the complex interplay between waste disposal methods and their far-reaching consequences on air, water, soil quality, and even real estate values. The evident decline in wetland extent and the significant increase in built-up areas, as revealed through Land Use and Land Cover analysis, indicate the transformative impact of human activity, particularly landfill operation, on the landscape. The gradual deterioration of water quality in the aquatic bodies proximate to the site, as indicated by the water quality index, highlights the cascading effect of waste-related contaminants on local ecosystems. Moreover, the compromised air quality observed during and after the landfill fire incidents underscores the potential health risks associated with such mismanaged waste sites. These findings collectively emphasize the critical need for sustainable waste management practices that prioritize environmental health, public well-being, and the preservation of valuable natural resources. This study serves as a clarion call for policy-makers, urban planners, and communities to collaboratively address the challenges posed by conventional waste disposal methods, and to urgently transition toward innovative, eco-friendly alternatives that ensure a cleaner, healthier, and more sustainable urban environment for present and future generations.

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Assessment of Indoor Thermal Comfort of Students in an Institutional Building in the Moderately Warm Climate of India During Winter Season

Naveen Kishore Khambadkone

Abstract

Thermal comfort is an important parameter in the planning and designing of sustainable buildings. Presently there is a shortage of thermal comfort data available for developing region-specific thermal comfort standards in India. The reason for this is that there are very few thermal comfort field studies conducted to date in various climatic zones of India to address its vast climatic diversity. Moreover, very few studies have been conducted in the context of moderately warm climates in India. This study aims to assess thermal comfort of students in an institutional building in the moderately warm climate of Tumkur, Karnataka, India. Thermal comfort was assessed by quantifying thermal sensation, preferences, and acceptance levels of occupants by administering 159 questionnaires. Simultaneous measurements of indoor climatic variables were conducted during 1 week in the winter month of January 2020 and December 2021 during morning, afternoon, and evening on all days using calibrated instruments as per ASHRAE standard 55 protocols. Regression analysis of the collected data gave a neutral temperature of 26.9 ° C and comfort band temperature between 21.3 and 32.63 °C, indicating a wider range of acceptability by occupants. The results of the study bear significance in terms of providing useful data for the development of region-specific thermal comfort standards for inclusion in Indian standard codes. However, it is felt that a longer study period (2–3 months) and larger sample size of data is needed to get more deeper insights for thermal comfort assessment.

Keywords

Thermal comfort · Architectural studios · Naturally ventilated · Winter season · Warm-to-moderate climate

1 Introduction

Thermal comfort is a subjective phenomenon which depends on the user perception and expectations from the built environment. It is also an important contributor to indoor environmental quality (IEQ) (de Dear et al. 2015). In a recent study by Singh et al. (2019), classroom thermal comfort studies contribute to only about 36% of the total studies done within the domain of adaptive thermal comfort field studies all over the world. In India, this number is only 2.5% indicating that more such studies need to be conducted in classroom environments for the purpose of defining thermal comfort standards. Common observations from Indian field studies show that subjects preferred a cooler environment as most of these studies (Mishra & Ramgopal 2015; Vittal & Gnanasambandam 2016; Kumar et al. 2018) were conducted during hot or warm seasons. There are very few studies conducted in the temperate or winter season in warm climatic zones in India. This study aims to assess the winter thermal comfort of students in an institutional building in a naturally ventilated studio environment through a questionnaire field survey. Thermal comfort was assessed by quantifying thermal sensation, preferences, and acceptance levels of occupants by administering 159 questionnaires. Indoor climatic variables were measured simultaneously during 1 week in the winter month of January 2020 (January 23 to 28, 20) and December 2021 (December 16 to 22, 21) (during morning, afternoon, and evening) on all days using calibrated instruments as per ASHRAE standard 55 protocols. Regression analysis of the collected data was performed in order to determine the neutral temperature (°C) and comfort band temperature (°C) which were found to be acceptable by the subjects.

N. K. Khambadkone (✉)
BMS College of Architecture Design and Planning, Bull Temple road, Basavanagudi, Bangalore 560019, India
e-mail: naveen.k@bmsca.org

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2 Materials and Methods

The survey was conducted in studios (10.8 m × 10.1 m) of the architecture department. The survey respondents were students of architecture from first to fifth year in the age group of 18–23 years. A total of 159 questionnaires were distributed consisting of 71 male and 88 female students. The survey was conducted during the working hours of 9.00 a.m.–5.00 p.m. with a lunch break between 1.00 and 2.00 p.m. The questionnaire was administered three times in a day in morning (9.30–10.0 a.m.), noon (12.30–1.00 p.m.), and evening (4.30–5.00 p.m.) to evaluate the variation in subjective responses and adaptations to the indoor environment.

The ASHRAE 7-point scale was used to assess the thermal comfort variables like thermal sensations and five-point scale for preferences. The High-Tech Computer (HTC) easy data logger was used to measure the outdoor temperature, and the Kestrel 5000 weather meter was used to measure the indoor air temperature, humidity, and air velocity by mounting it on a tripod at a height of 1.1 m from floor level. Figure 1 shows the studio plan and survey conditions.

3 Results

The outdoor conditions in Tumkur were generally mild and cool during the survey period. The daytime (10 a.m.–4 p.m.) was drier than the early morning and late evening time. The indoor conditions were generally mild during morning hours which later became warmer during the noon and evening hours. The indoor climate statistics are given in Table 1. The indoor air temperature varied between 20.8 and 31.3 °C (mean = 26.52, SD = 2.21). Air velocity recorded was low due to the windows being partly closed, and ceiling fans were generally turned off. The mean indoor air velocity was 0.12 m/s, and the proportion of air velocity recorded was less than 0.2 m/s for more than 80% of the entire survey period and less than 0.5 m/s for less than 20% of the survey period.

Table 2 gives the statistics of subjective sensations and preferences of occupants based on a questionnaire survey. The mean thermal sensation (T_S) was −0.07 which is on the cooler side of the sensation scale. A total of 81% of the subjects (N = 159) voted on the comfort band (−1, 0, +1) of the ASHRAE thermal sensation scale (Fig. 2). Thermal preference evaluates how the subjects would prefer to feel. Although about 50% of

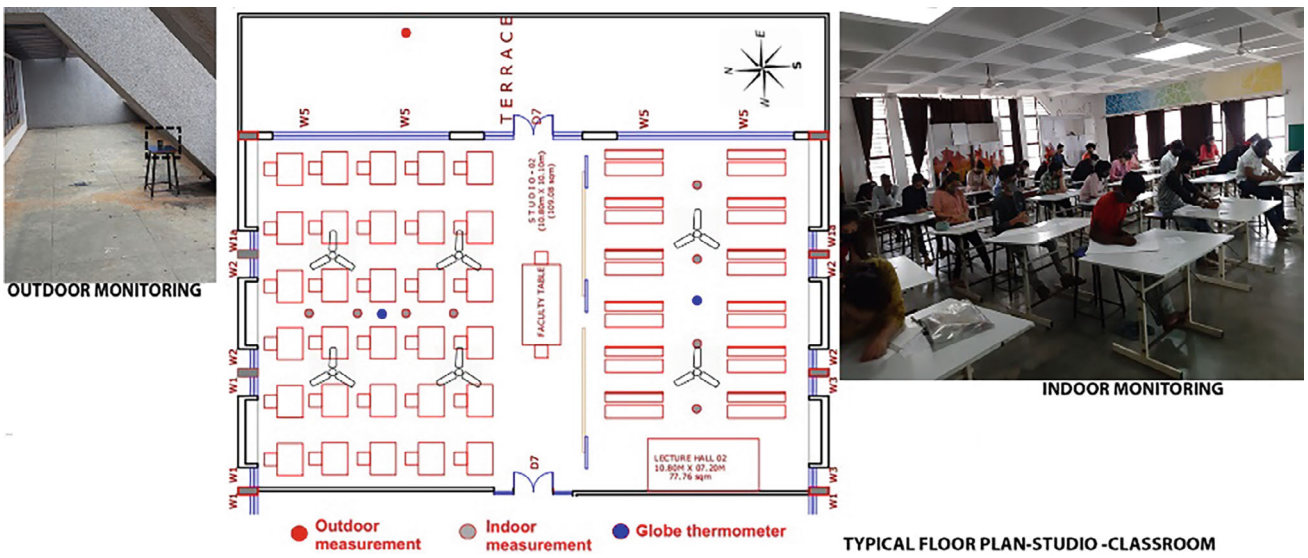


Fig. 1 Typical floor plan of studio showing position of measuring instruments and interior view

Table 1 Indoor climate statistics during the survey period

Parameter	Min	Max	Mean	SD
t_i (°C)	20.80	31.30	26.52	2.21
RH (%)	39.80	71.00	51.63	6.59
V_A (m/s)	0.00	0.40	0.12	0.06
I_{cl_tot} (clo)	0.33	0.45	0.36	0.01
Activity (MET)	1.00	1.20	1.06	0.06

t_i: Indoor air temperature (in °C); RH: Relative humidity (in %); V_A: Indoor air velocity (in m/s); I_{cl_tot}: Clothing insulation (in clo)

Table 2 Statistics of subjective sensations and preferences

Variables	Mean	SD	N (sample size)
T_S	−0.07	1.12	N = 159 (total no. of responses-477)
T_P	0.23	0.86	
H_S	−0.04	0.86	
H_P	0.05	0.56	
A_S	−0.11	0.90	
A_P	0.17	0.63	

T_S: thermal sensation; T_P: thermal preference; H_S: humidity sensation; H_P: humidity preference; A_S: air velocity sensation; A_P: air velocity preference;

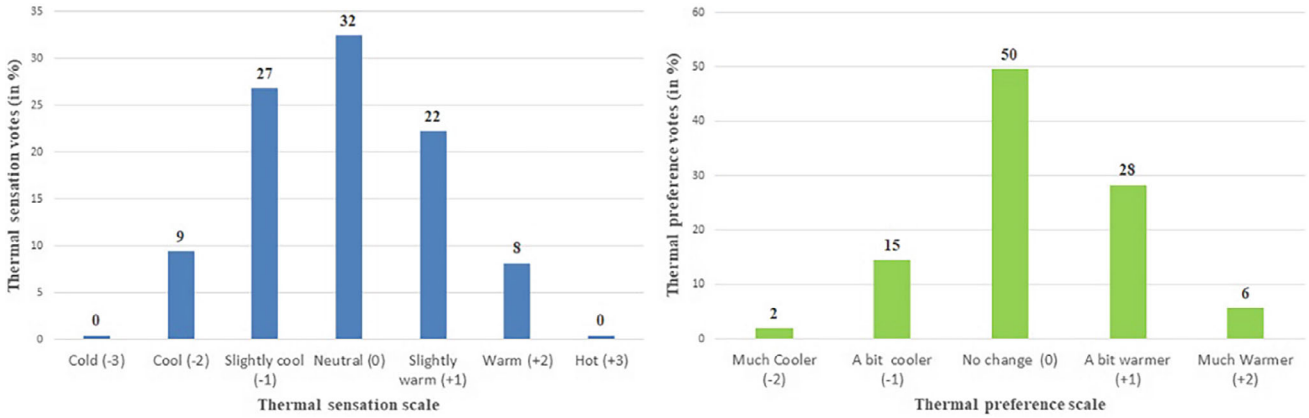


Fig. 2 Distribution of thermal sensation and preference votes (for the entire survey data)

the subjects wanted "no change" in their environment, about 28% wanted a "warmer" environment (Fig. 2).

Linear regression between indoor air temperature-t_i (in °C) and thermal sensation votes (T_s) (Fig. 4) gave a neutral temperature (t_n) of 26.9 °C and a comfort band temperature between 21.3 and 32.63 °C coinciding with the −1 and + 1 sensation on the thermal sensation scale, respectively. The regression equation used to obtain the above values is given below:

$$T_s = 0.176\ t_i - 4.744 \quad (R = 0.35,\ P < 0.001, \text{all data}) \tag{1}$$

4 Discussion

Thermal sensation and preference values show that occupants desired a slightly warmer environment ($T_p = 0.23$). A positive correlation ($R = 0.35, p < 0.001$) was found between indoor air temperature (t_i) and the thermal sensation (T_s) showing that subjects' thermal sensation changed with the changing indoor thermal environment. Air velocity sensation was found to be appropriate by 51% of the occupants, and 61% preferred no change in air velocity and accepted the existing conditions. The ceiling fans were mostly turned off during the entire survey period because subjects were not in favor of using ceiling fans as it would cause cold discomfort. This indicates that occupants preferred natural ventilation from outside air. As the indoor environment became slightly warmer during the day, some of the subjects desired a slightly higher airy environment although not through the ceiling fans. These were students who were sitting in the interior or center of the studios away from the windows. This is corroborated through the thermal sensation mapping of the studio rooms as given in Fig. 3. Thermal acceptability was evaluated in the questionnaire through "*Is the present thermal environment acceptable to you*?" More than 90% of the subjects accepted their existing thermal environment.

The neutral temperature (t_n) of 26.9 °C obtained in this study indicates the winter comfort temperature. The comfort band temperature (21.3–32.63 °C) indicates that subjects accepted a wider range of temperatures to be tolerable. This is further corroborated by a lower slope ($m = 0.176$) value in the regression equation. It shows that for every 5.7 °C change in the indoor air temperature, the thermal sensation changed by 1 unit. These results are in agreement with previous studies (Singh et al. 2019; Kumar et al. 2018) conducted in similar climates in classroom environments (Fig. 4).

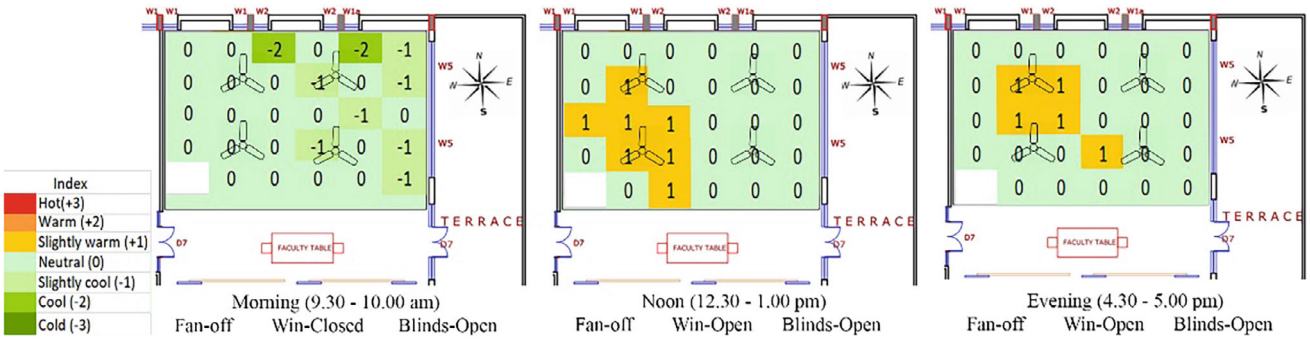


Fig. 3 Studio 01 plan showing mapping of thermal sensation votes (TSV) based on student seating position on December 16, 2021

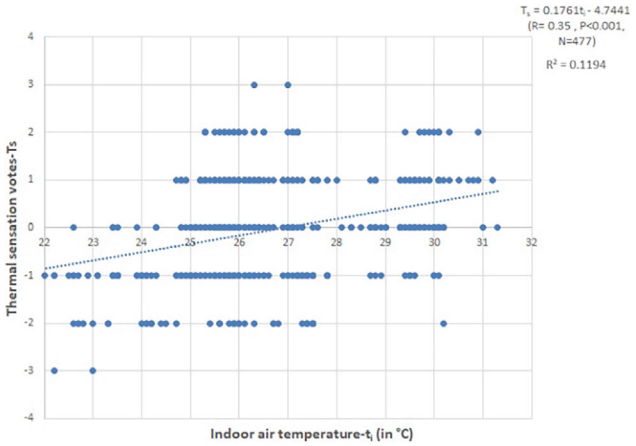


Fig. 4 Linear regression of thermal sensation-T_s with indoor air temperature-t_i (°C)

5 Conclusions

This study assessed the winter thermal comfort of students in studio environments in an institutional building in a moderately warm climate of Tumkur, Karnataka, India. The results of this study are significant because of two main reasons. Firstly, this study provides useful thermal comfort data which will bear significance in terms of creating a thermal comfort database for the purpose of developing an adaptive thermal comfort standard specific for this climatic region of India for inclusion in the Indian standard codes like the National Building Code of India (NBC 2016). Secondly, the data from this study can be used by architects to design classrooms and institutional buildings which are climate responsive for the dual objective of reducing mechanical cooling and simultaneously providing comfortable indoor environments. About 47% of India's population is below the age of 25 years. This is important considering the fast economic growth of India and its high priority to higher education, leading to a high demand in quality institutional infrastructure and education.

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How Can Public Data Be Used to Map and Monitor Exposure to Urban Energy Poverty? Evaluation of the Energy Vulnerability in Mediterranean Regions

Iker González-Pino, Jon Terés-Zubiaga, Cristina Villanueva-Díaz, Irantzu Alvarez-González, and Aitor Urresti-González

Abstract

Energy poverty is the result of the combination of the household incomes, the raising energy prices and the inefficient performance of the building stock. It is estimated that between 50 and 125 million people cannot afford maintaining adequate indoor temperatures at home, so energy poverty is one of the biggest challenges facing the European Union, and tackling it has become a policy priority. Thus, identifying the number of households in situation of energy vulnerability and taking the necessary measures to protect vulnerable and energy poor customers are considered to be essential. In this paper, a simple method for identifying and monitoring areas with high exposure to energy poverty based on information available in public databases in Spain is evaluated. The method allows exposure to energy poverty to be mapped and diagnosed, at the census-section level, by means of a multi-dimensional index that considers building features and energy expenses, as well as two socio-economic parameters. In order to assess the potential and limitations of the method, it is demonstrated through its implementation to the evaluation of the energy vulnerability of three different urban areas in Spain. Due to its simplicity, the evaluation procedure can be easily adapted to the contexts of other Mediterranean regions and countries and thus constitutes a general basis for guiding efforts in tackling energy poverty. Nevertheless, despite the potential the method possesses, the way it is approached can make comparison between different regions unfair and the lack of information can distort the vulnerability level, so defining additional indicators is needed.

Keywords

Energy vulnerability · Energy poverty · Open data · Energy performance certificates · Cadastral data

1 Introduction

Energy poverty is the outcome of the unbalance between household income and energy expenses allocated to cover the energy needs of the household. As it is a widespread problem in Europe, there is a commitment to tackle it, and Member States should protect vulnerable and energy poor customers and evaluate and monitor the number of households in energy poverty (European Commission, Directorate General for Energy 2019). Energy poverty can be evaluated through different indicators, methods and pathways (Heindl 2015). In this work, a multi-dimensional method that addresses energy vulnerability focused on the affordability of energy expenditure is evaluated. The main objective of the work is to apply this method in different regions, under different constraints, so that its potential and weaknesses can be identified.

2 Materials and Methods

As graphically described in Fig. 1, the method proposes five vulnerability parameters, divided into three main dimensions: building features, energy costs and socio-economic factors. The main feature of this method is that the three dimensions are composed of indicators calculated with data available through public databases that are updated peri-

I. González-Pino (✉) · J. Terés-Zubiaga · C. Villanueva-Díaz · A. Urresti-González
ENEDI Research Group, Energy Engineering Department, University of the Basque Country UPV/EHU, Bilbao, Spain
e-mail: iker.gonzalezp@ehu.eus

I. Alvarez-González
SAREN Research Group, Department of Graphical Expression and Engineering Projects, University of the Basque Country UPV/EHU, Bilbao, Spain

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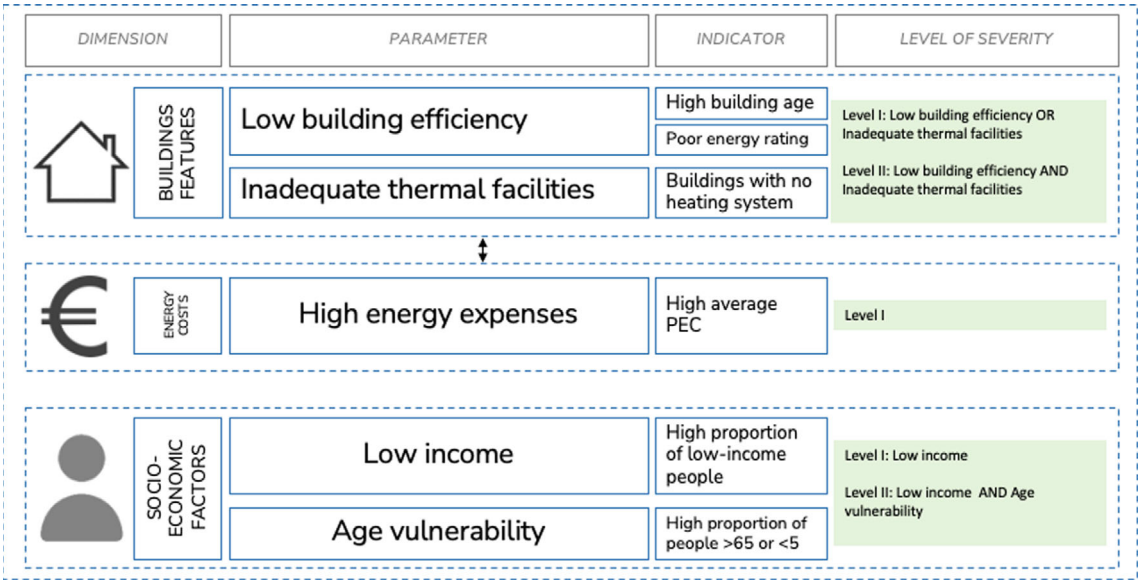


Fig. 1 Dimensions, parameters, indicators and vulnerability levels proposed

odically. The general procedure evaluates the vulnerability of census section by analysing, for each indicator, the percentage of dwellings with a value higher or below a threshold defined for the indicator, with respect to the total amount of dwellings in each census section. The census sections considered as vulnerable are those that exceed the mean value of the entire region evaluated by 50% (i.e. 1.5 times the mean value of the entire region).

Thus, building energy efficiency is evaluated using as indicators the building age (obtained from the cadastre) and the energy rating provided by the EPCs, and the exposure to inadequate thermal facilities of census regions is evaluated considering the percentage of dwellings with no heating system. Similarly, the percentage of dwellings with a high average value of primary energy consumption is assumed as indicator to evaluate the exposure to high-energy expenses. Finally, socio-economic factors are included in the analysis evaluating two indicators: the proportion of low-income people and the age vulnerability. The proportion of low-income individuals in each census section is calculated by assuming the poverty threshold at 60% of the median income per consumption unit, as established by EUROSTAT. Additionally, population age is considered as complementary socio-economic indicator, focusing on the weight of two cohorts in the total population of each census section: population over 65 years and an infant cohort (from 0 to 5 years). The procedure analysed in this work is defined in detail in Terés-Zubiaga et al. (2023).

Based on the evaluation of the five parameters, different exposure levels according to the three defined dimensions are firstly set and, secondly, a colour-coded global vulnerability index for categorising and prioritising the evaluated census areas is defined: severe (red), moderate (orange) and mild (yellow).

For analysing the applicability of this method, as well as its strong points and weaknesses, it must be submitted to different evaluation conditions by means of its application to regions with different constraints and data availability. For that purpose, the following criteria for choosing regions to be evaluated are proposed in this work: population level, both totally and in density terms, building typology, climatic severity, and data sources and availability. Besides, it was considered that, in order to have a wider insight of the behaviour of the method, all the regions where the analysis is to be applied should have a different amount of municipalities.

3 Case Studies

Following the criteria defined, three Spanish regions were evaluated: Bilbao Metropolitan Area (Basque Country), Saragossa Metropolitan Area (Aragon) and Tarragona Metropolitan Area (Catalonia). The main features of the regions are included in Table 1.

Table 1 Features of the three evaluated regions

Region	Number of municipalities	Population		Climatic conditions (winter/summer)
		(inhab.)	(inhab./km^2)	
Bilbao	35	904,423	1794.5	Mild/Mild
Saragossa	21	766,380	338.5	Cold/Warm
Tarragona	40	485,314	584.2	Soft/Hot

Additionally, Bilbao includes almost 458,000 dwellings located in 49,600 residential buildings (9.23 dwellings/building), Saragossa, more than 370,000 dwellings distributed amongst almost 43,000 buildings (8.64 dwellings/building), while 316,000 dwellings and 78,000 buildings are in Tarragona (4.03 dwellings/building).

Different public databases were used to collect the input data required for the analysis: National Statistics Institute of Spain—INE (cartography of the census sections and socio-economic indicators); Spatial Data Infrastructure of the Basque Country—GeoEuskadi—and National Geographic Institute of Spain—IGN (limits of municipalities and regions of Bilbao and Saragossa and Tarragona, respectively); Cadastres of Bizkaia and Spain (building-related information for Bilbao and Saragossa and Tarragona, respectively); Autonomous Governments of the Basque Country, Aragon and Catalonia (EPC-related information); Basque Statistics Institute—EUSTAT (inadequate thermal facilities for Bilbao); and Atlas of Vulnerability (deprived neighbourhoods in Spain).

It must be pointed out that information relative to inadequate thermal facilities is not available for the cases of Saragossa and Tarragona, so the corresponding indicator could not be evaluated. This issue involves that the first dimension evaluated ("Buildings' features") will be only based on the parameters related to inefficient buildings, which is a limit in the data analysed, and, in consequence, it should be taking into account as a limitation when the results are analysed.

4 Results and Discussion

Following the method described, the results depicted in Figs. 2 and 3 were obtained for the cases of Bilbao and Saragossa, respectively, while only 6 vulnerable census Sections (1 moderate, 5 mild) were detected in Tarragona.

Results evidence that a much higher number of vulnerable areas have been identified in Bilbao than for the cases of Saragossa and Tarragona. Nevertheless, since the method estimates vulnerability levels compared to the situation within the region, this fact does not mean that lower vulnerability levels exist in the last two regions in global terms, but that the vulnerability in these regions is more distributed,

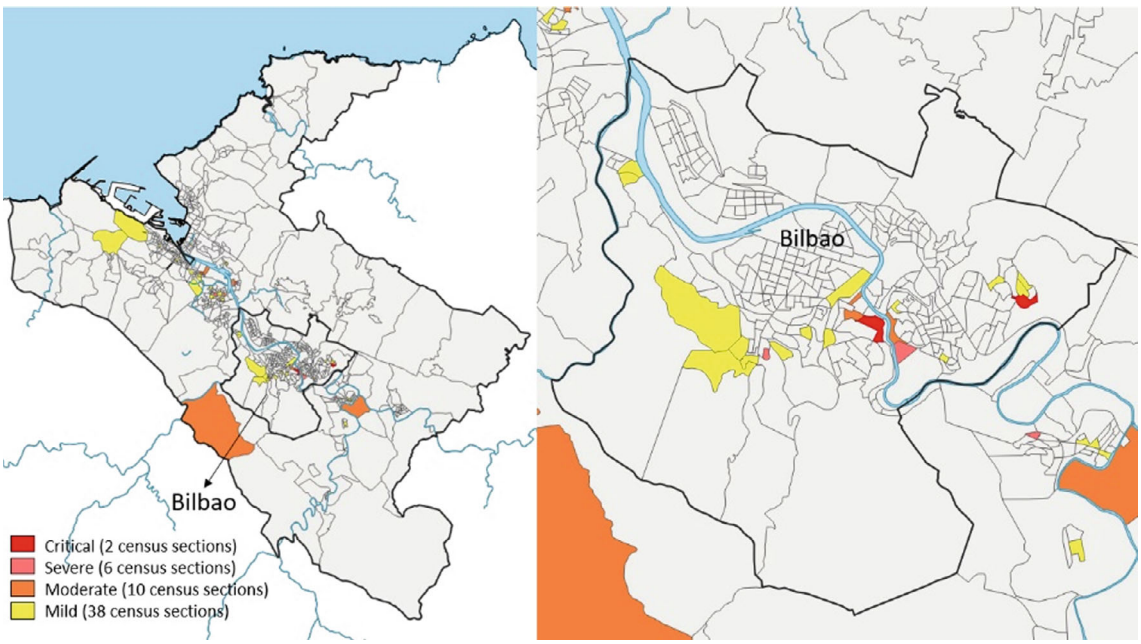


Fig. 2 Global energy vulnerability results for Bilbao Metropolitan Area: region (left) and the city of Bilbao in detail (right)

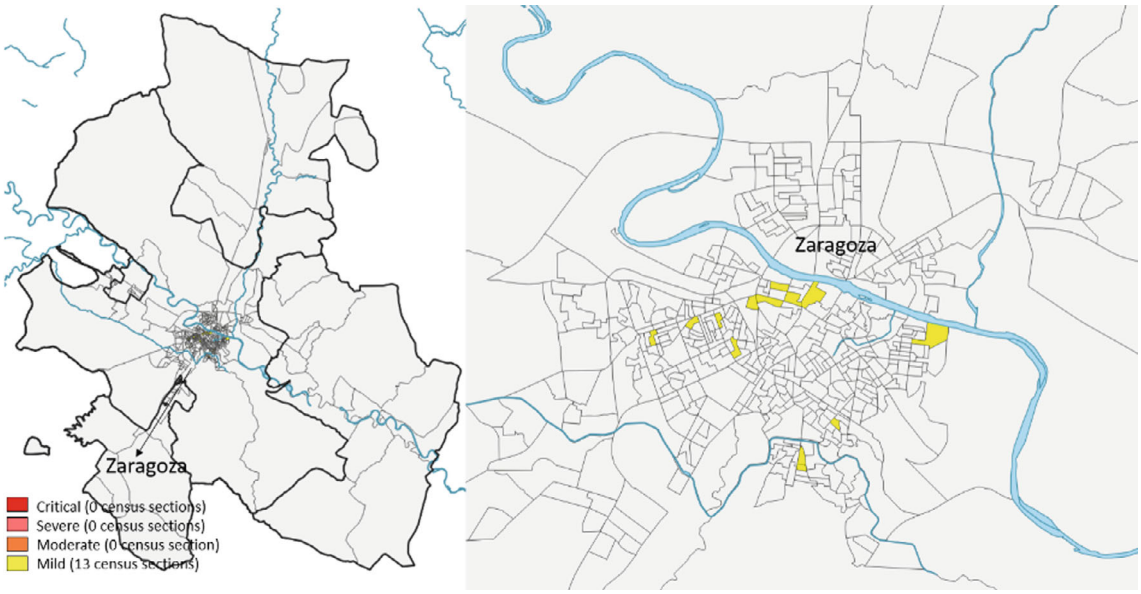


Fig. 3 Global energy vulnerability results for Saragossa Metropolitan Area: region (left) and the city of Saragossa in detail (right)

that is, there are fewer inequalities within Saragossa and Tarragona. Besides, in the case of Tarragona, the softer climatic severity in winter can also cause lower vulnerability levels, since space heating requirements in the residential sector are low. Additionally, it must be remarked that the vulnerability due to building features did not include information of the thermal facilities for the cases of Saragossa and Tarragona, so vulnerability due to this dimension can be underestimated. To evaluate this fact, a sensibility analysis was carried out.

4.1 Limitations and Sensibility Analysis

In order to analyse the robustness of the method, the energy vulnerability or Bilbao was also evaluated excluding the heating system availability indicator, as it happens in the cases of Saragossa and Tarragona. This way, the results can be compared, and the sensibility of the method to this lacking information can be determined.

As depicted in Fig. 4, in case the afore-said indicator is omitted, vulnerability levels of the region of Bilbao decrease

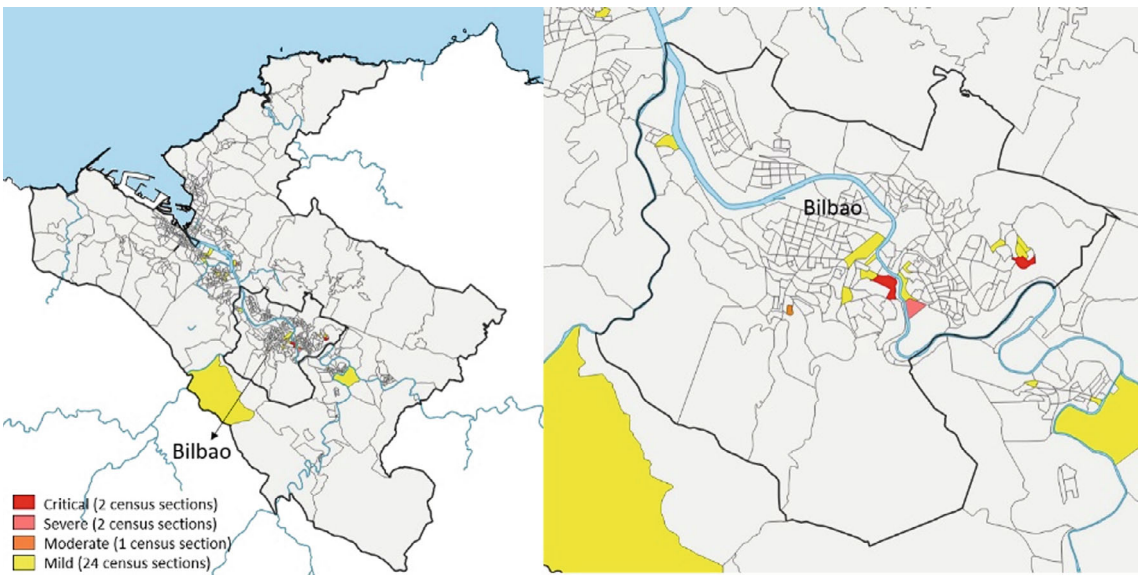


Fig. 4 Global energy vulnerability results for Bilbao Metropolitan Area excluding the heating system availability indicator: region (left) and the city of Bilbao in detail (right)

and, in consequence, so happen to the number of vulnerable census sections (from 56 to 29).

5 Conclusions

This work evaluates the robustness of a simple three-dimensional method that identifies energy vulnerable areas based on information available in public databases. For that purpose, the method is applied to three Mediterranean regions with different features and constraints. Results show different amounts of vulnerable areas in each region, which evinces different inequality levels within each region. In addition, the analysis brings to light the sensibility of the results to the absence of any indicator, which can substantially distort the final results. This way, the definition of additional indicators whose information is publicly available is necessary to improve the method.

Finally, it must be pointed out that, due to the approach of the method, whenever the analysis is carried out independently for different regions, the results must be analysed individually for each region and not compared to others. In order to get a comparative analysis between different regions, the limits of the evaluated area should be extended in order to include all the regions to be considered.

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Occupancy Modelling Using Machine Learning for Building System Control

Ajith N. Nair, Harshwardhan Tanwar, and Prashant Anand

Abstract

Buildings frequently depend on static occupancy profiles derived from building types and standard working hours, resulting in unwarranted energy consumption. Precisely predicting occupancy information is crucial for effective building system control and optimising indoor environmental quality. Conventional approaches for gathering occupancy data, including occupancy cameras, thermal imagers, Passive Infrared Sensors (PIR), and Radio-Frequency Identification (RFID) techniques, exhibit multiple constraints such as high costs, the need for specialised expertise during implementation, accuracy challenges, and concerns related to privacy issues. To address these limitations, the proposed solution in this study involves utilising machine learning and data-driven approaches to predict occupancy states using indoor air quality (IAQ) data, which includes parameters such as temperature, humidity, and indoor CO_2 concentration. These data were collected using cloud-based IAQ sensors for 60 days. Ground truth occupancy information was collected for analysis using an occupancy camera. Using machine learning algorithms' predictive capabilities and IAQ data, occupancy was inferred without additional sensors or equipment. Machine learning algorithms, such as k-Nearest Neighbour's Algorithm (k-NN), Support Vector Machines (SVMs), Decision Tree (DT), XGBoost Classifier, and Random Forest classifier (RF), were evaluated based on their accuracy, precision, recall, F1-score, AUROC values, and computational time. The study utilised packages such as XGBoost library and Scikit-Learn to implement the models. Among the tested algorithms, the Random Forest algorithm demonstrated the highest performance in predicting occupancy states, followed by the XGBoost Classifier and DT. The Random Forest algorithm performed best, achieving 86% accuracy on the test dataset for occupancy state prediction. By employing data-driven methods and machine learning algorithms, the proposed solution offers a more cost-effective and non-intrusive approach to occupancy detection, allowing for improved control and optimisation of various building systems.

Keywords

Occupancy prediction · IAQ · Data-driven modelling · Machine learning · HVAC control

1 Introduction

The building and construction sector contributes to about one-third of the global final energy use and 15% of the direct CO_2 emissions (IEA 2021). Rooms are frequently over-conditioned without a need, leading to significant energy wastage. Researchers suggest that occupancy-based HVAC and lighting controls can enhance energy efficiency in building systems (Wang and Shao 2017; Dong and Lam 2014). Moreover, real-time HVAC control necessitates the real-time collection of data related to indoor environmental quality (IEQ) and occupancy data. This dependence is progressively growing on precise and reliable occupancy predictions (Taheri and Razban 2021). Also, HVAC control systems should preferably incorporate predictive capabilities to manage the complex and dynamic interactions of a building's heating and cooling loads effectively (Dobbs and Hencey 2014). Centralised and decentralised building systems can be fine-tuned by utilising occupancy data to enhance efficiency and prevent unnecessary energy usage (Zhou et al. 2013). Furthermore, the COVID-19 pandemic has reiterated the need for better fresh air ventilation and

A. N. Nair (✉) · H. Tanwar · P. Anand
Department of Architecture and Regional Planning, Indian Institute of Technology Kharagpur, Kharagpur, India
e-mail: ajithn10@kgpian.iitkgp.ac.in

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real-time management of IAQ parameters through optimised building controls to curb disease spread (Nair et al. 2022). Accurate occupancy information is crucial in addressing this requirement.

In many applications, such as lighting control, it is adequate to determine the current occupancy state; however, a longer forecasting horizon may be necessary in some cases, such as optimum thermal environment control (Huchuk et al. 2019). Traditional methods of collecting real-time occupancy information, such as occupancy cameras, thermal imagers, Passive Infrared Sensors (PIR) sensors, and Radio-Frequency Identification (RFID) techniques, are fraught with several limitations, including high cost, the need for specialised expertise for implementation, accuracy issues, and privacy concerns (Ding et al. 2022).

Real-time IAQ monitoring is essential, but it is insufficient on its own. A channel for IAQ information interaction with building system controls, such as HVAC system control, should also be made available. The study's novelty is utilising IAQ data and machine learning algorithms for occupancy prediction. Using the collected IAQ data, this study examines the performance of various algorithms, such as the k-Nearest Neighbour's Algorithm (k-NN), Support Vector Machines (SVMs), Decision Tree (DT), XGBoost Classifier, and Random Forest classifier (RF). A thorough analysis of these algorithms in the context of IAQ data also clarifies their effectiveness and adaptability in indoor environmental quality and building system control. By utilising data-driven modelling, this method goes beyond traditional occupancy information collection using sensors. It offers a more nuanced understanding of the complex interactions between IAQ dynamics and occupancy patterns.

2 Experimental Setup and Methodology

2.1 Data Collection

The data were collected from the AI-HBI laboratory, Department of Architecture and Regional Planning at the IIT Kharagpur campus, India (see Fig. 1). The area of the lab is 31.7 m^2 and has a small occupancy change pattern (1–6 occupants) throughout the day. Research scholars are occupying the lab during the data collection period. The space is conditioned by a manually operated split AC system that works in response to user-defined set point temperature. This manual control mechanism allows occupants to customise and manage the temperature within the space according to their comfort preferences.

Testo 160 indoor air quality measuring module was used to collect IAQ data. The lab sketch and the location of the Testo 160 IAQ sensor modules in the lab for data collection are shown in Fig. 1. The sensors were strategically positioned within the laboratory to ensure that they are situated at a considerable distance from openings and other sources of air circulation, such as windows and air conditioner units. This placement was deliberate to minimise potential biases (due to infiltration) in the collected data and provide a more accurate representation of the overall IAQ within the lab. Time series IAQ data for 60 days, starting from 01/04/2023 to 01/06/2023, was collected at 15-min intervals. The ground truth occupancy profiles were collected using an occupancy camera mounted on the entry/exit door (see Fig. 1).

2.2 Data Types and Selected ML Algorithms

The study utilised data presented in a time series format, encompassing key parameters such as temperature (°C), relative humidity (%), and indoor carbon dioxide concentration (CO_2) in parts per million (PPM). The timestamp associated with the collected dataset was leveraged to derive two additional features: timestamp-numeric, representing the numeric value of the hour, and week status, indicating whether it corresponds to a weekday or not. After thorough data cleaning and preprocessing, the dataset was partitioned into training and testing sets, with 80% of the data allocated for training purposes and the remaining 20% reserved for testing. Five distinct machine learning models were employed in the study: k-NN, SVM, DT, XGBoost, and RF. The implementation of these models was carried out using popular libraries such as XGBoost library and Scikit-Learn.

2.3 Evaluation Metrics

The efficacy of machine learning models is evaluated in the study using a thorough set of six evaluation metrics, including accuracy, precision, recall, F1-score, AUROC values, and computational time. The true positives, true negatives, false positives, and false negatives were calculated based on the actual occupancy state and the predictions, which were used to calculate the precision, accuracy, recall, and F1-score. Computation time is also assessed for each algorithm to determine how effectively a model processes data. Additionally, anomaly detection precision is evaluated using the Area Under the Receiver Operating Characteristic Curve (AUROC), which enables valuable model comparisons.

3 Results and Discussion

RF is an ensemble learning technique, constructing numerous Decision Trees in the training phase and combining their predictions to enhance the accuracy of classifications. In this table, RF achieved the highest precision, recall, F1-score,

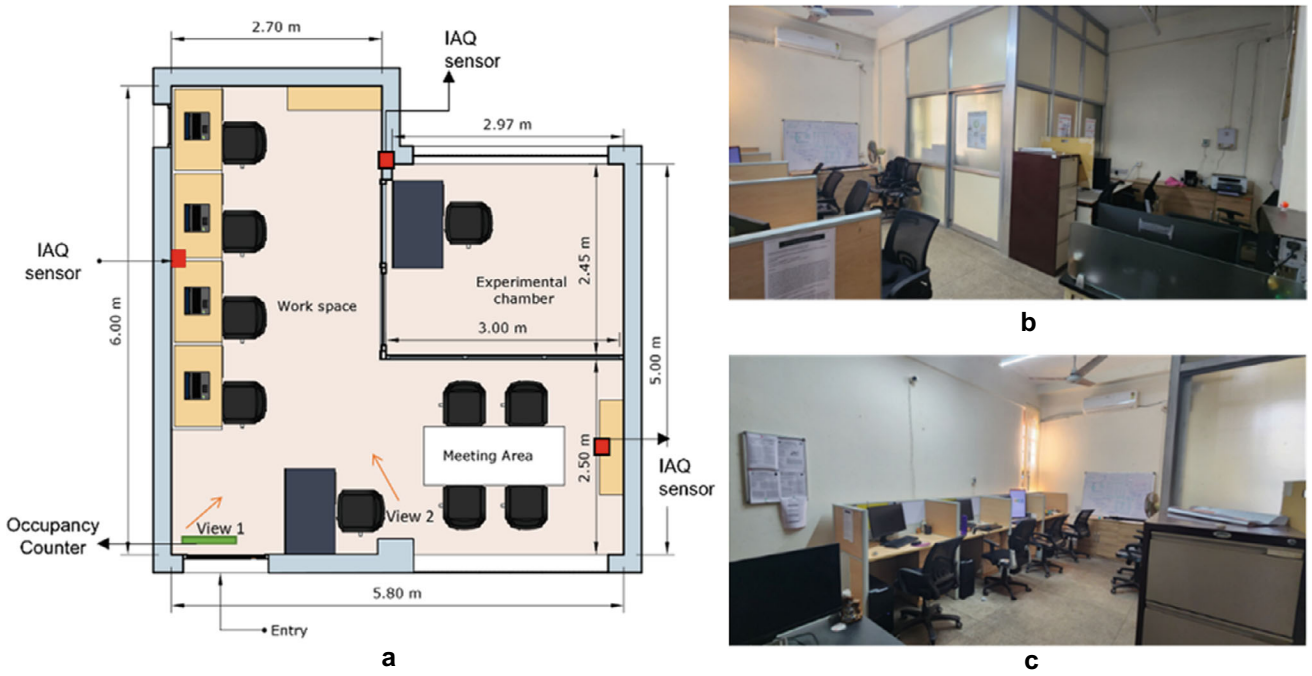


Fig. 1 **a** Plan of the laboratory **b** view from the entry **c** view of the researcher desks

Table 1 Performance of algorithms for various performance matrices

Algorithm	Precision	Recall	F1-score	Accuracy	AUROC	Time(s)
k-NN	0.8259	0.8215	0.8196	0.8215	0.8130	0.87
SVM	0.8352	0.8291	0.8271	0.8291	0.8203	6.59
DT	0.8518	0.8469	0.8469	0.8469	0.8460	0.02
XGBoost	0.8529	0.8473	0.8474	0.8473	0.8468	0.08
RF	0.8654	0.8594	0.8593	0.8594	0.8591	0.23

and accuracy among the algorithms, indicating its strong performance in occupancy detection. However, RF took more time (0.23 s) for both training and prediction in comparison to specific other algorithms, such as XGBoost (0.08) and DT (0.02), which exhibited comparable performance to RF in various evaluation metrics. Regarding testing accuracy, the RF classifier showed the highest performance of 86%, followed by XGBoost, DT, SVM, and k-NN refer to Table 1. All algorithms performed well in occupancy detection; however, some differences can be seen in computation time. This can be a deciding factor when we choose an algorithm for real-time building system control.

The AUROC and F1-score are essential metrics for evaluating the performance of classification algorithms in terms of their ability to discriminate between classes and the balance between precision and recall. All the algorithms exhibit good AUROC scores, ranging from 0.8130 for k-NN to 0.8591 for RF. These values suggest that all algorithms are reasonably good at distinguishing the positive (occupant presence) and negative classes (occupant absence). Regarding the F1-score, all the algorithms also perform well, ranging from 0.8196 for k-NN to 0.8593 for RF. This indicates that they achieve a good balance between precision and recall, making them suitable for applications that should minimise false positives and false negatives, such as HVAC system control.

Even though the ML models perform well with high accuracy in prediction and classification tasks, most models lack interpretability and generalizability. There is a need to explore more explainable ML models for this kind of prediction and classification task in the building system domain so that the user can make more informed decisions for building optimisation tasks.

4 Conclusions

In this study, we have assessed the performance of selected machine learning algorithms for occupancy detection using indoor air quality sensor data. The study demonstrates that IAQ data are efficient enough to predict the occupancy state, and it can be used for occupancy-based building system control, energy efficiency, and IAQ improvement. Among the

algorithms tested, it was found that the Random Forest classifier (RF) achieves the best performance in terms of all evaluation metrics compared to other algorithms (SVM, k-NN, XGBoost, and DT). The Random Forest classifier reported an accuracy of 86%, followed by XGBoost at 85%. The SVM algorithm took a maximum time of 6.59 s to classify the problem. DT performed the best in terms of computation time. Future studies should test these ML models for their occupancy prediction (count) capability and how effectively they can be integrated into various building and real-time control systems. Furthermore, studies should focus on developing more interpretable and explainable ML models to enhance decision-making in building system optimisation problems.

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Enhancing Work-From-Home Comfort and Sustainability: Investigating Occupant Behavior and Thermal/Visual Comfort in Brazil

Lumy Noda, Amanda V. P. Lima, Solange Leder, and Celina Pinto Leão

Abstract

The actual energy consumption in buildings often does not align with predictions or designs, leading to a knowledge gap regarding building energy performance. This uncertainty is frequently attributed to interactions between occupants and the built environment. One of the main reasons for these interventions is to enhance user satisfaction with comfort, as users actively play a role in improving their comfort. This study investigated the control measures adopted by occupants working remotely and how they affect their perception of the thermal and lighting environment. Field research was conducted in homes in a city with a hot and humid climate in Brazil, involving measurements of indoor environmental variables and the simultaneous administration of questionnaires (quantitative and qualitative data). The focus was on comfort perception and understanding occupants' adaptive behavior. Concerning actions in response to the thermal environment, among eight options of adaptive strategies that were suggested, the most frequently adopted were "wearing lightweight clothing" (86.23%) and "opening doors/windows" (76.09%), indicating a preference for and predominance of natural ventilation. In response to the lighting environment, among five actions suggested, the main measures were the activation of artificial lighting (38.41%) and the opening of curtains/blinds (36.96%). Even under internal conditions with a high air temperature (average 27.5 °C) and low illuminance (average 169 lx; median 43.4 lx), high satisfaction rates were observed with the thermal and visual environment compared to typical findings in research on office buildings. The heat-related thermal sensation and the preference for a brighter environment influenced the increased occurrence of simultaneous actions, both thermal and visual related (p-value < 0.05), suggesting that the increased availability of adaptive control measures in the residential context favored better adaptation by occupants and led to gains in the perception of comfort. By promoting adaptive behavior and enhancing personal comfort, the built environment can become more sustainable through reduced energy consumption, resource conservation, and the cultivation of sustainable habits. In the global scenario where remote work has become widely established and adopted, understanding comfort conditions for workers in residential contexts becomes relevant and conducive to investigations as occupants work in environments that provide more opportunities for adaptations.

Keywords

Occupant behavior · Thermal comfort · Visual comfort · Work-from-home · Hot and humid climate

1 Introduction

In the past two decades, studies on the quality of the built environment and occupant behavior have garnered significant attention due to their substantial impact on building sustainability. The actual energy consumption in buildings often does not align with what is predicted or designed, creating a knowledge gap regarding the energy performance of buildings (IEA 2020). This uncertainty is frequently attributed to the interactions between occupants and the built environment.

Occupant behavior plays a crucial role in adjusting the building's energy system to adapt to the indoor environment, directly affecting energy consumption and deviations from estimated or projected energy use in buildings. One

L. Noda (✉) · A. V. P. Lima · S. Leder
Federal University of Paraíba, João Pessoa, Brazil
e-mail: barbara.lumy@academico.ufpb.br

C. P. Leão
University of Minho, Guimarães, Portugal

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of the main reasons for these interventions is to enhance user satisfaction with comfort since users actively play a role in improving their comfort (O'Brien and Gunay 2014). At the same time, modeling occupant behavior is challenging due to its stochastic nature and variability among occupants (Ebuy et al. 2023).

The ability to control the environment (personal or individual control) is crucial for the success of a project that values indoor environment quality (Burkee and Keeler 2010). Adaptive behaviors are significantly shaped by the building's design and intended use (Mishra and Ramgopal 2013). Users have different adaptive opportunities in various building types. Consequently, research often distinguishes between work environments and residential settings. In office spaces, occupants frequently must adhere to norms or social standards, leading to more limited adaptive options (Sekhar 2016). In contrast, user preferences play a significant role in the adaptation process in residential buildings, granting greater freedom to adjust the thermal environment for personal satisfaction, resulting in various adaptive behaviors (Rijal et al. 2019).

In light of these findings, this study aims to investigate the behavior of occupants performing office work activity from residences and how these measures affect their perception of the thermal and lighting environment.

2 Methods

This study was conducted in João Pessoa, Brazil, a coastal city characterized by a hot and humid climate, and was carried out during the 2020 COVID-19 pandemic when remote work, also known as work-from-home, became widespread. A convenience sample of participants engaged in remote work volunteered to participate in the study conducted in their respective homes.

During the field surveys, indoor environmental variables (air temperature, relative humidity, and illuminance) were measured using small data loggers (HOBO U10 and HOBO U12) manufactured by Onset. For 2 months (May to June 2020), 138 participants were involved in the study. Alternate weeks were chosen, during which each participant kept the monitoring equipment installed in their work environment for 6 days.

Data collection followed the Class III protocol (Brager and Dear 1998) for thermal comfort measurements, encompassing synchronized monitoring of environmental variables and administering questionnaires. The equipment was positioned at a height of 1.10m from the floor, placed near where participants carried out their typical office activities. For analysis purposes, the value assigned to the time of questionnaire completion was considered for each occupant. They were asked to answer the questions twice. To gain insights into occupant behavior, participants indicated the adaptive control measures (actions) implemented when responding to the online questionnaire. Their goal was to enhance their personal thermal and visual comfort. The collected data were processed and organized in a spreadsheet, with each result linked to a corresponding user for analysis. Beyond descriptive statistical analysis, Pearson's correlation was employed to examine relationships between variables.

3 Results and Discussion

3.1 Indoor Environmental Variables and the Occupant Opinion

Regarding thermal conditions, under the average air temperature of 27.5 °C and average relative humidity of 73.1% (Table 1 and Fig. 1), a significant number of respondents reported feeling thermally neutral (66.8%). In contrast, 26.2% mentioned experiencing heat-related sensations, while 7.0% reported cold-related sensations (Table 2). Interestingly, despite 57.03% of respondents expressing a preference for maintaining the current thermal environment, the majority rated their home workspace as comfortable (93.20%). This comfort perception holds even when the temperature conditions were notably higher than the indoor air temperature usually observed in air-conditioned office environments (Sekhar 2016). The illuminance results exhibited a wide range, spanning from 11.80 lx to 2140.40 lx (Table 1).

Nevertheless, approximately 55% of the occurrences fluctuated around 50 lux. Most occupants perceived the environments as adequately lit despite predominantly falling well below the illumination level recommended by Brazilian standards for office activities (a table-plane illuminance of 500 lux). They expressed no desire for alterations (Table 2). These findings suggest that other contextual factors, besides the individual environmental variables of air temperature, relative humidity, and illuminance, can influence occupants' comfort perception.

Table 1 Result of recording internal environmental variables

Results	Min.	Max.	Mean	Median	S.D
Indoor air temperature (°C) ($n = 256$)	23.40	31.80	27.50	27.47	1.23
Relative humidity (%) ($n = 256$)	43.20	87.60	73.10	73.77	7.79
Illuminance (lux) ($n = 138$)	11.80	2140.40	169.28	43.40	330.94

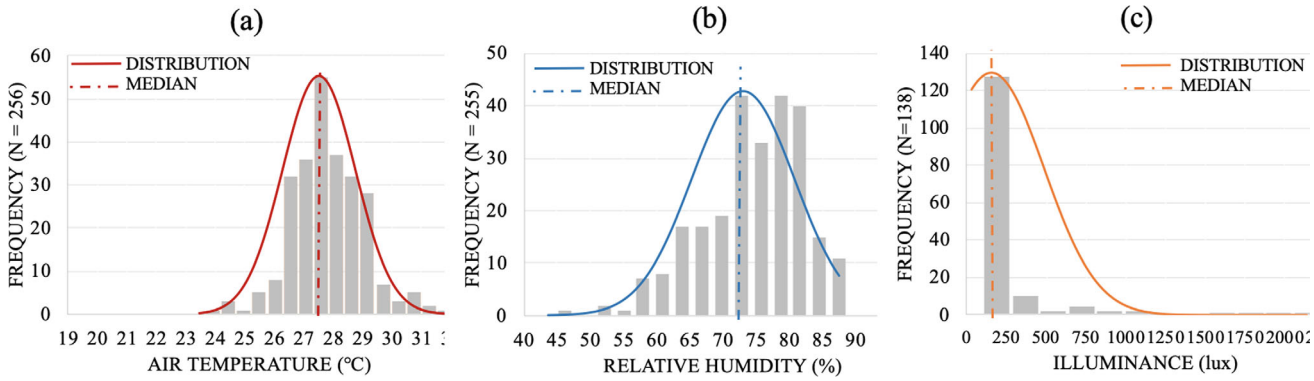


Fig. 1 Distribution of records in indoor environments **a** air temperature, **b** relative humidity, and **c** illuminance

Table 2 Results about occupant's opinion

Parameters	Scale votes (%)		
Thermal sensation	Cold: 7.03	Neutral: 66.80	Warm/hot: 26.17
Thermal preference	Warmer: 1.95	No change: 57.03	Cooler: 41.01
Thermal comfort	Discomfort by cold: 0.00	Comfort: 90.23	Discomfort by heat: 9.77
Light sensation	Dark: 9.41	Neutral: 33.33	Bright: 57.97
Light preference	Darker: 3.62	No change: 73.19	Brighter:23.18

3.2 Occupant Behavior

To enhance personal thermal comfort, occupants predominantly adapted their clothing by *utilizing lightweight*, low-thermal-resistance clothing ensembles (85.94%) and embracing the *opening of doors and windows* to facilitate cross-ventilation (76.60%). These actions align with previous research suggesting a preference for natural ventilation in residential contexts. This inclination remains significant, even considering the prolonged periods spent within the environment due to daily remote work schedules, as observed in this study. Regarding visual comfort, the most recurrent strategies aim to enhance indoor lighting: *switching on artificial lighting* and *opening the curtains/blinds* (Table 3), recognizing that these measures correspond to the types of lighting sources, artificial and natural, when activated individually, approximately 25% of the occupants associated improved lighting with artificial sources, and about 25% daylighting control. Only 15% of the occupants utilized both sources concurrently for lighting control.

The degree of association between the occurrence of simultaneous thermal-related actions and the corresponding thermal sensation associated with heat shows a significant positive correlation ($R = 0.20$, p-value < 0.005, Fig. 2a). Likewise, a similar connection is established between the heightened frequency of concurrent illuminance-related actions and the expressed preference for a brighter environment ($R = 0.17$, p-value < 0.05) (Fig. 2b).

Table 3 Adaptive control measures

Thermal-related actions	%*	Illuminance-related actions	%*
Uses light clothing	85.94	Switched on artificial lighting	38.41
Open doors and windows to ventilate	76.60	Opened the curtains and blinds	36.96
Use a fan	43.36	Adjusted monitor position	34.78
Have a cold drink	25	Closed curtains and blinds	7.25
Take a bath	25	Using a table lamp	6.52
Use air-conditioning	7.03		
Have a hot drink	5.08		
Adds another layer of clothing	1.20		
None of the actions	2.73	None of the actions	24.64

*Percentage of occupants who cited the action, understanding that more than one can co-occur

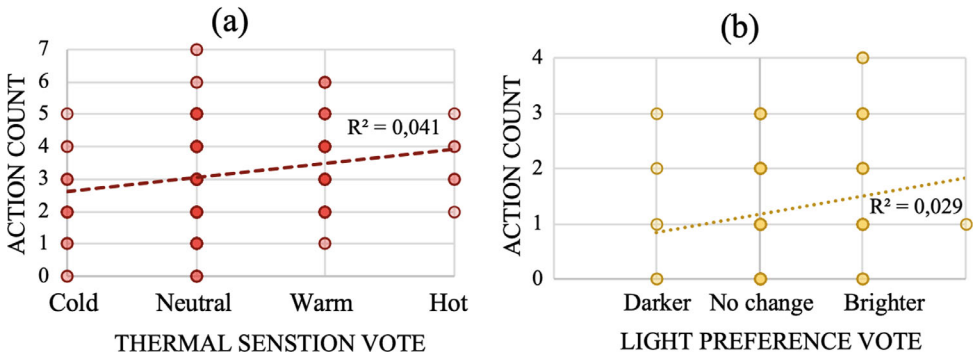


Fig. 2 Correlation of the number of simultaneous actions related to **a** thermal comfort and thermal sensation votes, $n = 255$, and **b** visual comfort and illuminance preference votes

4 Conclusions

The study revealed that satisfaction rates were high even under conditions of higher temperature and lower illuminance than recommended for office work activities, which differs from conventional conclusions in office building research. In remote work within residential environments, where the impact of user behavior is more significant, the increased availability of adaptive control measures promoted enhanced occupant adaptation, resulting in an improved perception of comfort. This dynamic can encourage adaptive behaviors, thus contributing to personal comfort enhancements. Furthermore, this approach can make the built environment more sustainable by reducing energy consumption, conserving resources, and fostering sustainable practices.

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Successful Phytoremediation Implementation Through a Detailed Case Study

Nikolai Dinev, Mariana Hristova, Ivona Nikova, and Ana Katsarova

Abstract

Phytoremediation is an innovative technology that uses the distinctive features of various plant genotypes to combat soil stress factors. This method has demonstrated remarkable success in areas polluted with heavy metals and organic pollutants. A step-by-step plan has been proposed for remediation actions as part of the research strategy. An experiment was conducted to improve the phytostability of an area near the copper plant in Pirdop Municipality, Bulgaria. The soil in the area was heavily polluted, with a highly acidic pH of 4.0 and toxic levels of copper reaching up to 1900 mg.kg-1. The experiment aimed to restore the practically barren soil by testing various combinations of ameliorants through a series of trials, including greenhouse, mesocosm and field experiments. A group of experiments was conducted to select the optimal meliorates and assess the transfer of pollutants, mainly copper, in plant production. In greenhouse experiments, treatments with lime material and Fe_2O_3, Fe_2O_3 + lime material + peat and zeolite + lime material were used to test plants such as lettuce and alfalfa. In mesocosm, vessels were tracked to evaluate the distribution of pollutants by substrate depth—65 kg—"artificial roots" at 15 and 30 cm and washing from the vessel. The optimal options were a combination of CaO + peat. These variants were applied in field conditions, and the resulting production was analysed. The most optimal variants were peat + CaO + zeolite, CaO + Fe_2O_3 and peat + CaO + Fe_2O_3. The knowledge accumulated through such experiments can be used for application in a streamlined system for the remediation of contaminated lands. A proposed methodology leads to selecting a scheme for the phytoremediation of heavy metal-laden lands. It includes several steps, with the main optimisation element being applying conventional and alternative plant production.

Keywords

Copper contamination · Acid soils · Management · Remediation scheme · Mesocosm

1 Introduction

Phytoremediation emerges as a progressive and promising technology for addressing the challenges of contaminated agricultural land and highly polluted urban or industrial areas caused by anthropogenic activities (McGrath et al. 2002). The evolution of this technology encompasses significant strides in comprehending the physiological and biochemical aspects of metal uptake, transport and sequestration by hyperaccumulator plants. It also involves delving into the intricate processes unfolding within soil and plant systems, with a focus on the chemical enhancement approach (Adriano et al. 2004). Despite substantial research conducted over the past decade, it is evident that there remains a substantial gap in knowledge.

Phytostabilization aims to confine contaminants through mechanisms such as root accumulation or sedimentation within the rhizosphere, effectively restraining their mobility and mitigating risks related to migration, wind and water erosion, soil leaching and dispersion. This term also encompasses the establishment of vegetative cover on contaminated soil surfaces, reducing exposure to wind, water and direct contact for humans and animals. Employing soil amendments capable of efficiently immobilizing metals in plant species resilient to high contamination levels holds the potential to enhance phytostabilization techniques.

N. Dinev (✉) · M. Hristova · I. Nikova · A. Katsarova
Institute of Soil Science, Agrotechnology and Plant Protection "Nikola Poushkarov", Agricultural Academy, Sofia, Bulgaria
e-mail: ndinev@itp.bg

A. Katsarova
Forestry University, Sofia, Bulgaria

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The selection criteria were based on unfavourable properties of the selected soil, including its very strongly acidic pH of approximately 4.0 in H_2O, superficially destructured and limited profile depth, poorly defined genetic horizons, susceptibility to erosion and deficiency in humus content. The significant acidification of the soil, attributed to sulphur compound deposition from mining operations, disrupts natural conditions and alters the mobility of heavy metals (Vangronsveld et al. 1996). This phenomenon underscores the substantial impact of environmental pollution in this context, highlighting the need for robust strategies to achieve successful phytostabilization and the practical resolution of heavy metal contamination.

The primary objective of the experiment was to compare the effectiveness of various soil amendments in immobilizing copper within contaminated soils and perennial grass mixtures.

2 Materials and Methods

This study focuses on soils situated near a copper mining facility in Pirdop town (Bugaria). Owing to the extended operation of the plant, the surrounding areas have become consistently contaminated. The experimentation involved alluvial soil containing 1700 ppm of copper, exhibiting a strongly acidic pH of approximately 4. This soil type supported only minimal natural vegetation. The analyses were conducted employing established techniques for soil decomposition and the determination of overall heavy metal content (ISO 11466 1995), as well as through ICP-AES (ISO 22036 2008) and AAS (ISO 11047 1998) methodologies, with measurements carried out using a Perkin-Elmer 2100 instrument.

3 Results and Discussion

A series of meticulously designed experiments were executed, categorized into three distinct groups: initial vegetation trials employing lettuce as the experimental crop, mesocosm trials employing diverse grass mixtures, and comprehensive field experiments encompassing both grass and tree species. The controlled environment of the greenhouse served as the testing arena for a comprehensive 50-variant scheme meticulously crafted to evaluate the diverse impacts of different soil modifications and their intricate combinations. The trials encompassed a range of variants: powdered coal and calcium (Ca), iron hydroxide (Fe_2O_3) in combination with Ca, Fe_2O_3 combined with peat, Fe_2O_3 along with both Ca and peat, Fe_2O paired with Ca and coal powder, zeolite in conjunction with Ca and peat, and lastly, zeolite combined with Ca and coal powder.

The findings unequivocally underscore the swift efficacy of lime material in optimizing soil pH. Variations incorporating lime (leading to a pH level of 7) and Fe_2O_3 consistently maintained pH levels proximate to 6. This reaffirms the pivotal role of lime material in pH optimization within the soil (Fig. 1).

The incorporation of amendments into the soil leads to reduced concentrations of available copper and zinc. However, there is an exception observed in variants involving solely peat application and peat combined with iron hydroxide, where the mobility of copper and zinc remains similar to that of the control variant.

For this purpose, specialized containers were utilized, each capable of holding 65 kg of soil. These containers were equipped with "artificial roots" known as Rhizon soil moisture samplers, manufactured by Rhizosphere Research Products in the Netherlands (Fig. 2).

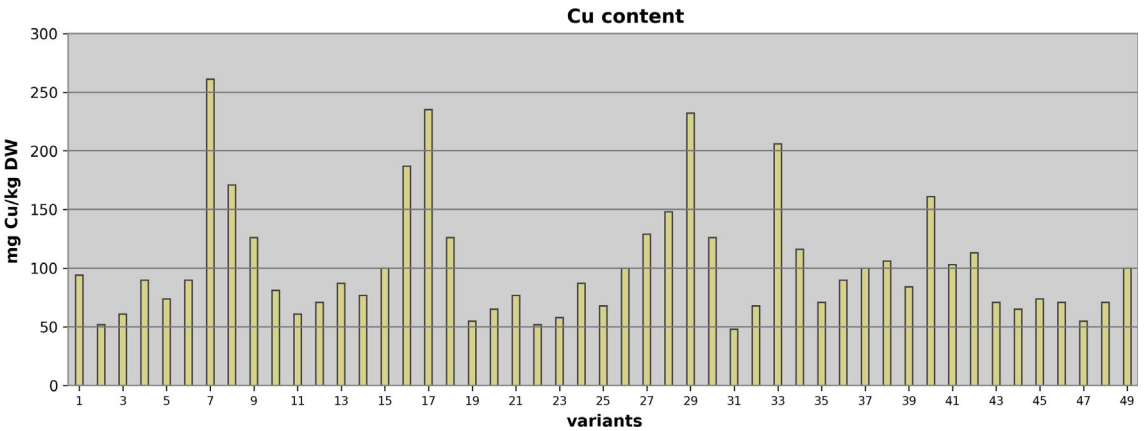


Fig. 1 Preliminary greenhouse experiment in pots for selection of promising variants

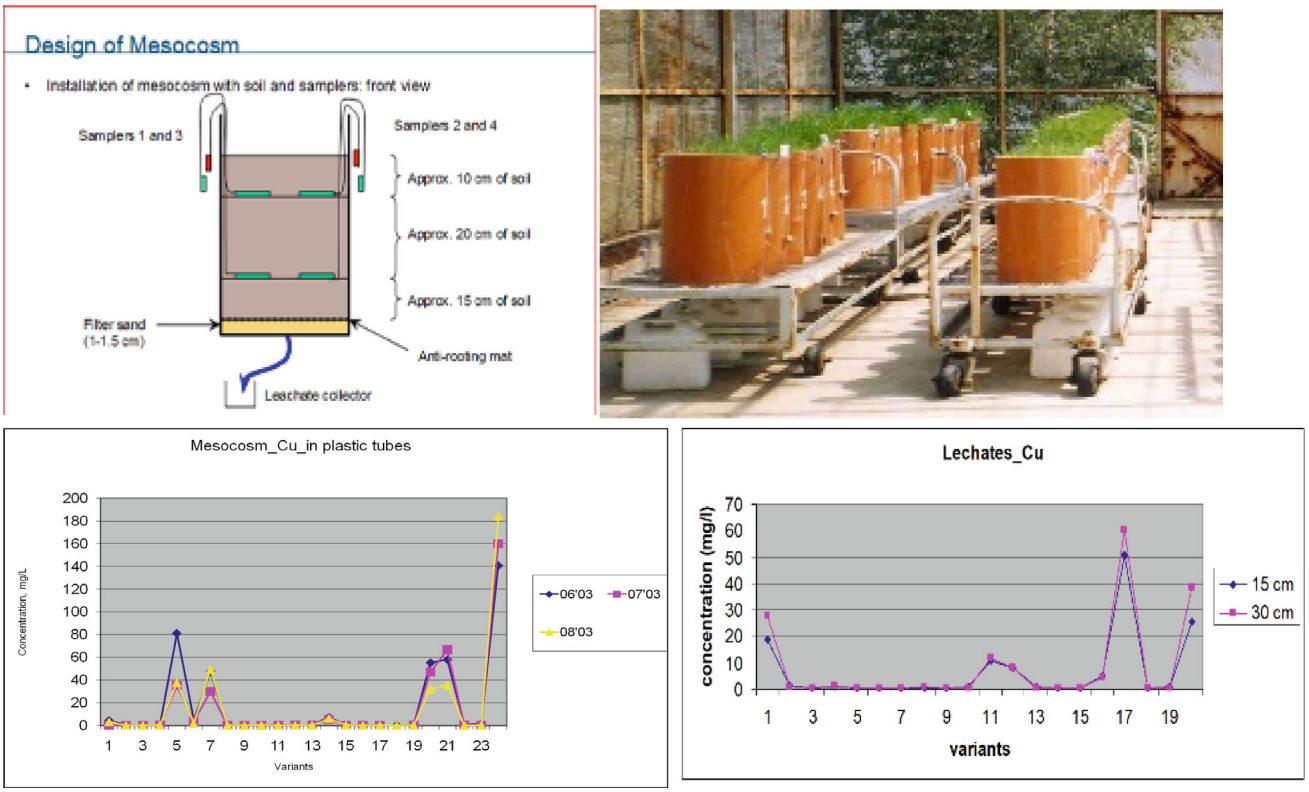


Fig. 2 Concentration of copper in different depths and time in mesocosm pot



Fig. 3 Implementation of best variants in field remediation

Concerning the impacts of the implemented amendments, it's evident that variants 5 and 7, characterized by medium levels of limestone material and coal dust, exhibited notably elevated copper concentrations at depth across all containers. A comparable trend materialized in variants 20, 21 and 24, where zeolite and pearlite were self-applied.

Furthermore, the behaviour of copper within the simulated root structures displayed a harmonized pattern at both 15 and 30-cm depths. Notably, reduced copper blocking was discernible in specific variations, such as peat variants 11 and 12, and those involving zeolite, either alone in variant 17 or combined with iron hydroxide in variant 20. It's worth noting that the designated notations used in this text include Var. 1 for the control, Var. 11 for peat (at 1000 g per pot), Var. 17 for zeolite (at 400 g per pot) and Var. 20 for the combination of peat (400 g per pot) with zeolite (400 g per pot).

An imperative metric lies in quantifying copper content within the surface biomass of the "grass mixture" plants. Among the different approaches, variant 11, characterized by the self-application of peat and lime, and variant 20, incorporating zeolite and iron hydroxide, showcased the most noteworthy copper content. In contrast, variants 13, 15 and 19, involving combinations of lime and peat materials with iron hydroxide and zeolites, exhibited the lowest copper content (Fig. 3).

The field experiment encompassed the meticulous application of variations that had undergone rigorous testing within controlled environments. The precise composition and quantities of the ameliorants were incorporated following the outlined scheme. Many test plants were involved, spanning species such as wheat, alfalfa, amarantys, festuca spp., dactylis, onobrychis sativa, ryegrass and poa spp. Moreover,

the study also encompassed tree species, including apple, plum, acacia and sour cherry. The experiment commenced in the autumn, with the progress of plant species carefully monitored through the ensuing spring season. Notably, among the tree species, apple and acacia seedlings displayed the highest levels of adaptability.

Each distinctive variation exhibited specific behaviours. Particularly notable were the outcomes derived from the application of peat sourced from Bulgaria with a pH level of 7, which yielded the most favourable results. Although comparatively less potent, adding calcium oxide and zeolite still induced discernible positive effects. Calcium oxide, a conventional ameliorative agent, was employed to counteract soil acidity. The utilized Bulgarian zeolite showcased impressive blocking capabilities, opening avenues for deeper exploration of its potential in experimental remediation practices.

4 Conclusions

Experiments conducted in greenhouse, mesocosm and field soil showed that remediation of polluted and contaminated soil is possible. Lime was found to be the most effective enhancer, with a fast effect on soil properties and plant growth. Other amendments in combination improved soil properties, but peat and ferric oxide had negative effects. Organic amendments play a crucial role in facilitating the re-vegetation of metal-contaminated soils, with immobilizing effects in the initial post-application stage. A remedial blend comprising lime material or zeolite is imperative for exceedingly acidic soils, with the attained favourable outcome enduring and enabling replication in comparable soil degradation scenarios.

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Testing Graphene Filters for a New Approach to Improve Air Quality in an Indoor Environment

Federico Stirano, Fabrizio Bertone, Giuseppe Caragnano, Olivier Terzo, Giò Deodato, and Jacques Roland

Abstract

Air pollution is nowadays one of the major threats to human health. Particulate matter and very small particles (PM_1) can have a major impact on the respiratory system of people, as they can pass through the natural body defenses and induce health issues like stroke, heart disease, lung cancer, and both chronic and acute respiratory diseases. Indoor environments are prone to pollutant accumulation, and their air quality can also be worsened by spores, bacteria, and viruses. Each year, at least 3.2 million people die prematurely from illnesses attributable to household air pollution, according to the WHO. It is thus important to study and develop new ways to reduce the concentration of such pollutants. This paper describes a set of experiments made with a laser-induced graphene filter with the aim to build a confined environment with a reduced concentration of particulate matter and an overall healthier quality of air. Beyond the typical filter behavior, graphene filters can be powered up to reach high surface temperatures and thus self-sterilize. In the preliminary experimental setup, two boxes connected by the filter simulate respectively the outside environment and the inside environment. A smoke generator has been used to simulate the polluted air in the "outside" box. Specific sensors were used to monitor the concentration of air pollutants in both boxes and data were transferred to a cloud recipient. Experimental results show that graphene-based filters have an efficiency comparable to high-level HEPA filters. Even fine particulate matter such as PM_1 was for the most part successfully blocked by the filter, effectively enhancing the air quality. The overall PM concentration is highly reduced (about two orders of magnitude) at room temperature. The filtering capacity is even further improved when increasing the temperature of graphene. The capability to reach high temperatures in a very short time can make these filters also suitable to reduce biological hazards. Even if further tests are required to confirm the preliminary results, graphene can be already considered a promising solution to create a healthier indoor environment, providing a valuable benefit for people spending the most time in it.

Keywords

Indoor air environment · Indoor air quality · Graphene filters

1 Introduction

Air pollution is nowadays one of the major threats to human health (Suess 1992; Mølhave and Krzyzanowski 2003; Braubach and Krzyzanowski 2009). Particulate matter, and very small particles (PM_1) can have a major impact on the respiratory system of people, as they can pass through the natural body defenses and pave the way for health issues like stroke, heart disease, lung cancer, and both chronic and acute respiratory diseases. This is particularly true in an urban context where the concentration of particulate matter can be quite high due to road traffic and building heating systems. Several other chemical pollutants are also responsible of various health issues. According to the WHO, ambient (outdoor) air pollution is estimated to have caused 4.2 million premature deaths worldwide in 2016 (World Health Organization 2022). Moreover, indoor environments are prone to pollutants accumulation, and the air quality can also be worsened by spores, bacteria and viruses. Each year, 3.2 million people die prematurely from illnesses

F. Stirano (✉) · F. Bertone · G. Caragnano · O. Terzo
Fondazione LINKS, Torino, Italy
e-mail: federico.stirano@linksfoundation.com

G. Deodato · J. Roland
Videro Srl, Torre Pellice, Italy

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attributable to the household air pollution caused by the incomplete combustion of solid fuels and kerosene used for cooking alone, according to the WHO.[1]

Furthermore, air pollution is a very complex matter, as there are a lot of noxious substances that are discharged in the atmosphere, mainly coming, but not limited to, from the combustion of fossil fuels. Monitoring and controlling air pollution is thus an extremely complex process, as it also depends on the climatic conditions (temperature, wind speed, atmospheric pressure, etc.). Outdoor pollution penetrates in indoor environments, summing up to the locally generated pollutants coming from cleaning products, heating, and so on.

Based on these considerations, approaches to filter out particles in indoor environments are a necessity, to provide a clean place where people can have a rest or perform daily activities, improving quality of life (Mitova et al. 2020). This paper discusses a different approach based on graphene filters to provide a viable solution to improve air quality in residential or office environments, with a positive effect on quality of life and productivity. The aim of the research was to test the filtration characteristics and the applicability of these newly developed graphene filters within an environment simulating a lifelike confined space, where a limited number of individuals could engage in activities.

2 Materials and Methods

2.1 Graphene Filters

Graphene (Novoselov et al. 2004) is a bidimensional nanomaterial composed by carbon. Pure graphene is composed by a single layer of atoms, representing the thinnest known material. However, this kind of material is still complex and expensive to produce. In addition to pure monolayer graphene, there are some derivate materials, like graphene oxide (considerably easier to produce) with interesting properties. For example, membranes made of graphene oxide appear to be particularly able to filter very small particles (Joshi et al. 2015).

Laser is currently one of the main production technologies to synthesize graphene oxide. The filters used in the set of experiments described in this paper were manufactured by LIGC Ltd., an Israeli company specialized in air filtering systems using the laser-induced graphene (LIG) technology (Lin et al. 2014) that creates a 3D porous structure like *foam.*

These filters have a graphene surface of 200 × 200 mm and contain copper bars on two opposite sides to apply an electric potential difference and produce a current flow inside the whole filter. A peculiar characteristic of this kind of filters is that they can reach temperatures of hundreds of Celsius degrees in a very short time. Previous research done on smaller samples of LIG filters shown the capacity to reach up to 380 degrees within five seconds. Such high temperature decomposes the organic substances trapped on the surface of the filter, effectively enabling self-sterilization of the filter (Stanford et al. 2019).

2.2 Experimental Setup

The experimental setup (Fig. 1), fully described in Stirano et al. (2022), is composed by two boxes: a *clean* box representing the indoor environment, and a *dirty* box representing the outdoor environment. The two boxes are connected through an element hosting the graphene filter, and air can flow between the two boxes only through the filter. An axial fan is used to force the air flow between the two boxes. Each box is equipped with a sensor board, able to measure the main pollutants, including a Sensirion SPS30 optical sensor to evaluate the concentration of fine dust (PM_1, $PM_{2.5}$, and PM_{10}).

Smoke is generated in the *dirty* room and forced to flow through the filter. Different power supply voltages were tested to understand how the filtering properties vary when the system conditions change. Sensor boards collect data and send it to an external gateway where data can be monitored in real time as well as stored in a database for further analysis.

3 Results

Figure 2 shows how the PM_1 values in the *dirty* room (orange line) and in the *clean* room (blue line), when applying a voltage of 0 V (left) or 40 V (right). Logarithmic scale is used in both charts for the PM_1 concentration, due to the large difference between the maximum concentration in clean room and dirty room. According to the data shown in the graphs in Fig. 2, graphene filters block the majority of the PM_1 particles generated in the *dirty* room. Starting from a concentration of over 10,000 $\mu g/m^3$, in the first graph (no voltage applied to the filter) the PM_1 concentration in the *clean* room is in the order of 100 $\mu g/m^3$, while in the second graph (40V voltage applied to the filter), the maximum concentration is in the range of 20–30 $\mu g/m^3$.

Results for $PM_{2.5}$ and PM_{10} follow the same trend as PM_1, with the maximum value in the clean room in the same order of magnitude for each PM_x.

[1] https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health.

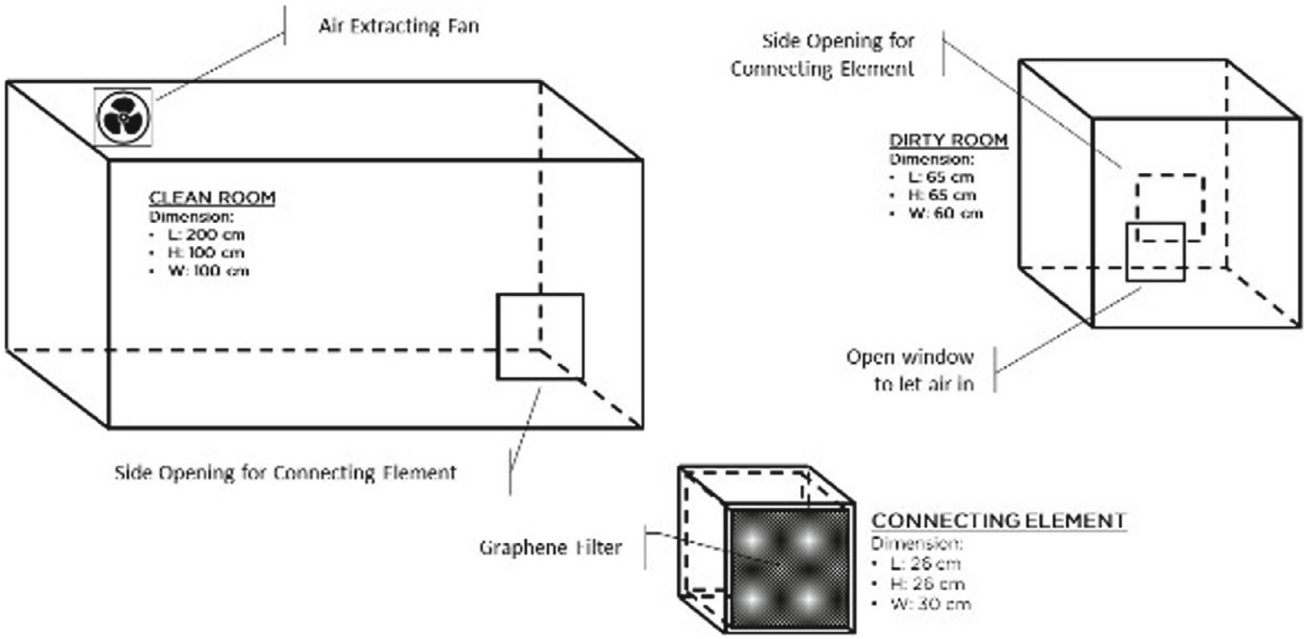


Fig. 1 Test bed configuration

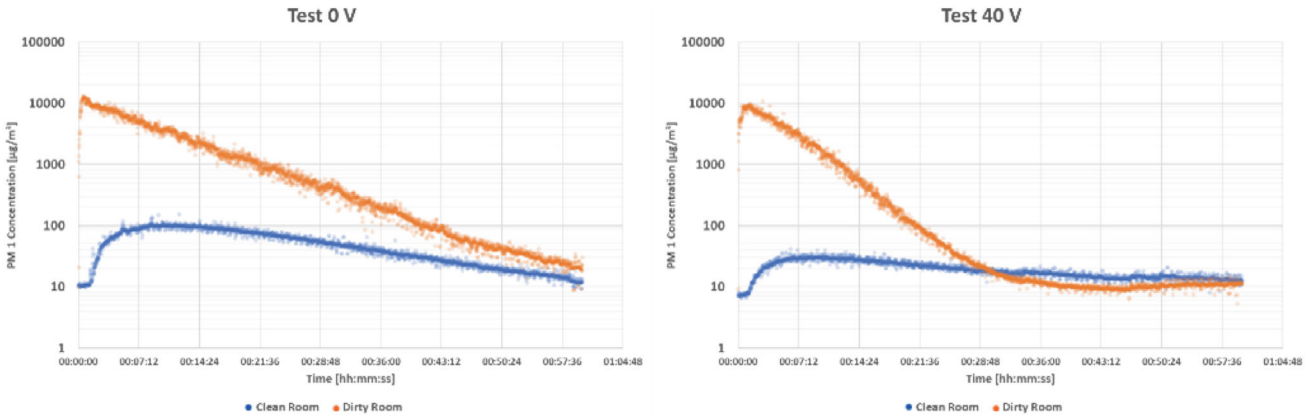


Fig. 2 Filtering test at 0 V (left) and 40 V (right)

4 Discussion

These data shows that LIG graphene filters can be effective for the most part of activities even when they're not powered up. If a higher filtering capacity is required, applying a voltage of 40 V to the filter greatly increases the performance, with a minimum increase in power consumption (lower than 100W).

Thus, the filter can be managed in a dynamic mode to optimize performance and energy consumption while guaranteeing at the same time a clean indoor environment.

Even if these preliminary tests shows that graphene filters can be a promising solution to filter micro particles, additional research is required. Further tests related to how the air flows in both the rooms are necessary to fully characterize the filters, even in terms of pressure drop. In the tests presented in this paper, a specific sensor measured the pressure drop between the two rooms (in these preliminary tests, the pressure drop is 2.7 Pa). Furthermore, the sensor board in the *clean* is located where it is expected that a person will be located. Additional tests are required to confirm that the design choices are correct as well as the preliminary results on filtering capacity.

5 Conclusions

This paper considers LIG graphene filters as an innovative approach to provide a clean and healthy indoor environment, thanks to their capability to filter out microparticles like fine particulate matter. A healthy environment where people can rest or spend their leisure time increases the quality of life

and helps to reduce chronic illness related to the respiratory system.

Further tests are required to better characterize the filters, but preliminary results indicate that graphene filters can represent a valid alternative to standard HEPA filters, with some additional interesting features, like a self-cleaning capacity that increases the life of the single filter.

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Particle-Bound PAHs in Algeria Home Dust: Spatial Distribution, Source, and Health Risk Assessment

Lyes Rabhi, Abdelkader Lemou, Angelo Cecinato, Catia Balducci, Nabila Cherifi, and Riad Ladji

Abstract

The dust in the interior environment was analysed for particulate polycyclic aromatic hydrocarbons (PAHs). Household dust is hazardous, affecting human health. We examined PAH levels, sources and carcinogenic risk in 15 residential dust samples from four regions in Algiers. The procedure for collecting dust consisted of pre-cleaning the surface (horizontal, at 1.8–2.2 m above ground, 1 m^2), allowing free exposure to particle settling, and recovering dust 15 days later using two white filter sheets. Ultrasonic bath extraction, using mixtures of solvent (Dichloromethane-acetone, 4:1, v: v), column chromatography using silica gel and gas chromatography–mass spectrometry were used for analysis. Concentrations of total aromatic hydrocarbons (PAHs) in household dust (TPAH) ranged from 3.27–103.06 ng.m^{-2}. However, 2-ring and 3-ring compounds represent almost three-quarters of the total PAHs. While the 5-ring compounds represent 17%, with a contribution from benzo (a) pyrene (3.6%). According to the model of principal component analysis (PCA), the key sources are the combustion of fossil fuels (62.7%), combustion of biomass, and exhaust from vehicles (14.7%). The total toxic equivalent concentrations (TEQs) of 21 PAHs were 0.20–8.26 ng m^{-2}. Of the 21 PAHs, 7 of the 5 PAHs rings caused 74.1–96.2% of the total TEQs. This research records extensive data on PAHs in home dust exposure among Algerians in the region. Finally, inhalation exposure to all 21 PAHs, including the priority PAHs and the associated risk of cancer was investigated.

Keywords

Aerosols · Dust · PAHs

1 Introduction

Indoor air pollution causes respiratory, cardiovascular and other ailments, leading to huge amounts of morbidity and death globally (Yang et al. 2023). The most common source of pollution in residential areas is the use of inadequate heating methods and polluting fuels and technology (WHO 2023).

Polycyclic aromatic hydrocarbons (PAHs) have garnered a lot of interest over the last half century due to their persistence in the environment, bioaccumulation, long-range transport and toxicity (Patel et al. 2020). More than a hundred PAHs have been discovered in various matrices all over the world. Toxic compounds found in the average home may have serious effects on human health. Benzo (a) pyrene (B[a] P) is a recognized human carcinogen and is a proxy for other carcinogenic PAHs to evaluate human cancer risks. EU limits B[a] P to 1 ng m^{-3} annually (Pateraki et al. 2020). Health risk evaluations of PAH exposure are now the subject of a large number of research (He et al. 2023; Jung et al. 2010).

This research examined the association between polycyclic aromatic hydrocarbon exposures in an indoor area of Algiers, Algeria.

L. Rabhi · A. Lemou · N. Cherifi · R. Ladji (✉)
Unité de Recherche en Analyses Physico-Chimiques Des Milieux Fluides Et Sols/Centre de Recherche Scientifique Et Technique en Analyses Physico-Chimiques (URAPC-MFS/CRAPC), Tipaza, Algeria
e-mail: riad.ladji@crapc.dz

A. Cecinato · C. Balducci
Institute of Atmospheric Pollution Research (CNR-IIA), National Research Council of Italy, Monterotondo, Italy

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2 Materials and Method

The procedures for sample collection and analysis followed those of published research (Rabhi et al. 2018). Briefly, dust was collected by first cleaning the surface (horizontally at 1.8–2.2 m above ground, 1 m^2) (Rabhi et al. 2018), then allowing 15 days for particle settling, and then recovering the dust using two white filter sheets. Surrogate standards (naphthalene-d_8, acenaphthylene-d_{10}, phenanthrene-d_{10}, chrysene-d_{12} and perylene-d_{12}) were added to all samples before ultrasonically extracting PAHs from filters for 1 h with 20 mL of dichloromethane-acetone (4:1) (Rabhi et al. 2018), and then cleaned up on a silica gel column. The effluents were concentrated using a nitrogen evaporator. These final extracts were carried to a gas chromatography (GC) vial for instrumental analysis. Statistical analysis has been used for the analysis and interpretation of the data. PCA extraction employed eigenvalues higher than one and varimax rotation. Jamovi software was used for Pearson correlation analysis (PCA).

3 Results

3.1 Overview of PAH Concentrations, Species and Possible Influencing Factors Results

In this study, 21 PAHs were detected, with values ranging from 3.27 to 103.06 ng m^{-2}. Urban areas have elevated levels of 21 PAHs. 46.4–88.3% were found to contain 16 PAHs (Table 1). The highest detection rate was observed in M-PHA (31.4%), followed by FLU, CHR, PHE and PYR (14.7, 11.6, 9.7 and 7.7%, respectively, see Fig. 1). These five substances were responsible for the accumulation of 75% of the total PAHs. Whereas, 6-ring compounds were the lowest ones (<0.2%). The phenomena observed in this study can be attributed to the following factors:

First, there is a wide range of pollution sources for low-molecular-weight PAHs. Besides the pollution caused by incomplete combustion, low-molecular-weight PAHs such as NAP, Fla, PHE and PYR are also used in the manufacture of pesticides, medicines, resins and pigments or as intermediates in chemicals.

This has resulted in a wider range of sources for low-molecular-weight PAHs (LMW < 220) compared to those with high molecular weight (HMW > 220).

Second, LMW-PAHs had a higher transfer potential. According to the transport theory, amphiphilic pollutants (which have certain lipid-soluble and water-soluble properties) are easy to transport into the human body. Because of their high vapour pressure, the polycyclic aromatic hydrocarbons (PAHs) with LMW prefer to exist in the gaseous phase. Still, the PAHs with HMW, which include 5- or 6-rings, adhere to particles in the atmosphere. Sources may be classified as petrogenic or pyrogenic based on their LMW/HMW ratio (sum of two/three-ring PAHs vs. sum of 4/5-ring). LMW/HMW rates are represented in the Table 1. Incomplete combustion of fossil fuels and wood are examples of pyrogenic sources (>1), whereas low rates (<1) point to petrogenic sources like oil split and oil petroleum products usage (Rabhi et al. 2018).

Table 1 PAHs concentrations (ng.m^{-2}) and ratios

	2 + 3-rings	4-rings	5-rings	6-rings	TPAHs	∑ 16PAHs	LMW	HMW	LMW/HMW
H-01	2.9	2.2	1.3	0.0	6.4	3.9	2.9	3.4	0.9
H-02	3.6	4.7	1.7	0.0	10.0	8.9	3.6	6.4	0.6
H-03	5.7	2.1	0.5	0.0	8.3	5.9	5.7	2.7	2.1
H-04	3.1	0.1	0.0	0.0	3.3	2.7	3.1	0.1	21.2
H-05	1.9	1.1	0.3	0.0	3.4	2.1	1.9	1.4	1.3
H-06	3.1	1.9	0.7	0.0	5.7	3.1	3.1	2.6	1.2
H-07	4.3	3.9	1.2	0.0	9.4	5.2	4.3	5.1	0.8
H-08	1.1	0.6	0.4	0.0	2.2	1.3	1.1	1.0	1.1
H-09	5.8	5.8	3.8	0.0	15.5	9.7	5.8	9.6	0.6
H-10	6.2	5.1	2.8	0.0	14.0	7.7	6.2	7.8	0.8
H-11	12.5	9.1	5.5	0.1	27.1	14.8	12.5	14.5	0.9
H-12	13.2	7.7	3.3	0.0	24.2	11.2	13.2	11.0	1.2
H-13	30.9	17.8	2.4	0.0	51.1	26.3	30.9	20.2	1.5
H-14	31.4	14.6	3.9	0.0	49.9	26.9	31.4	18.5	1.7
H-15	27.2	46.4	29.1	0.4	103.1	71.1	27.2	75.4	0.4

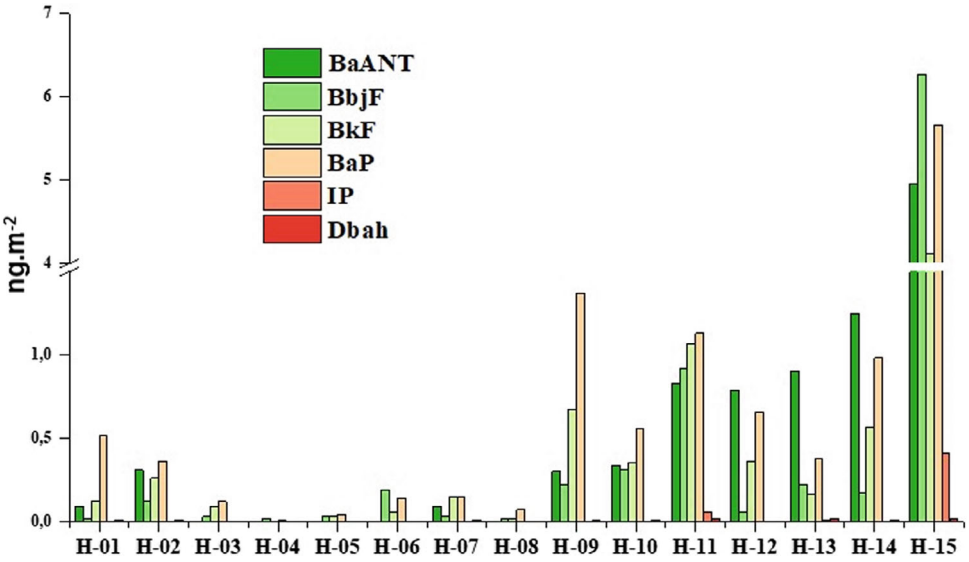


Fig. 1 Highest PAH components in the household

3.2 Principal Component Analysis (PCA)

PCA was used to identify the species with the highest factor loadings and shed light on the possible PAH emission sources associated with each factor. Eigenvalues > 1 and factor loadings > 0.8 on the principal components were considered.

The proportion of variation for the first major component was 62.65% (Fig. 2). The Table 2 displays the component matrix, which revealed that the biggest contribution rates were from the 4-, 5-, and 6-ring components, respectively. As a result, PC1 was heavily loaded with most petrogenic and pyrogenic PAHs (Fig. 2). Two PAH with 4 ring in BaANT and CHR in PC1, is generated by the combustion of coal and biomass. The rest of PAH depict sources associated with the partial combustion of petroleum. Pyrolysis and incomplete fuel combustion are the usual methods of producing these high-molecular-weight PAHs with 4–6 rings (Younis et al. 2023).

The Factor 2, PHE and ANT are thermodynamically stable PAH with 3- ring structures, suggesting they likely originate from petroleum sources. NAP and FLU pollutant loadings are greatest in Factor 3. NAP found that residential garbage combustion produces low-molecular-weight PAHs. Other sources of FLU include braking and tyre wear. Factor 4 contains only the BghiP with 5% of the variance. It is found in fossil fuels and enters the environment via incomplete combustion in coke ovens, motor vehicles, cigarette smoke and small-scale wood burning.

3.3 Health Risk Assessment

Inhalation of PAHs was studied to see whether they pose a possible cancer risk. To represent PAHs and as a measure of exposure to particle carcinogenicity, benzo(a)pyrene is often used as a single indication (Rabhi et al. 2018). Carcinogenic equivalents are determined using the cancer potency relative to BaP (TEF) multiplied by the concentration of PAH in a sample. These equivalents are called BaP-TEQ (Eq. 1) (Jung et al. 2010) and are based specifically on the report by Nisbet and Lagoy (Nisbet and LaGoy 1992).

Table 2 PCA results of PAH levels

Factor	Factor 1	Factor 2	Factor 3	Factor 4
Components	BaANT (0.89), CHR, Baf, and BaP (0.94), CCP and BkF (0.95), BjF (0.96) and IP (0.97)	PE (0.80), ANT (0.84), PHE (0.89), M-PHE (0.94)	FL (0.86), NAP (0.87)	Bghip (-0.88)
Eigenvalues	13.16	3.09	2.01	1.06
% variance	62.7	14.7	9.6	5.0
% cumul. variance	62.7	77.4	87.0	92.0

NAP: Naphthalene; PHE: Phenanthrene; ANT: Anthracene; FL: Fluoranthene; PYR: Pyrene; M-PHA: Methyl-Phenanthrene;; BaANT: Benzo(a)anthracene; CHR: Chrysene; CCP: Cyclopent(cd)pyrene; BaF: Benzo(a)fluorene; BjF: Benzo(j)fluoranthene; BkF: Benzo(k)fluoranthene; PE: Perylene; BaP: Benzo(a)pyrene; IP, Indeno (1,2,3-cd) pyrene; BghiP: Benzo(ghi)pyrene

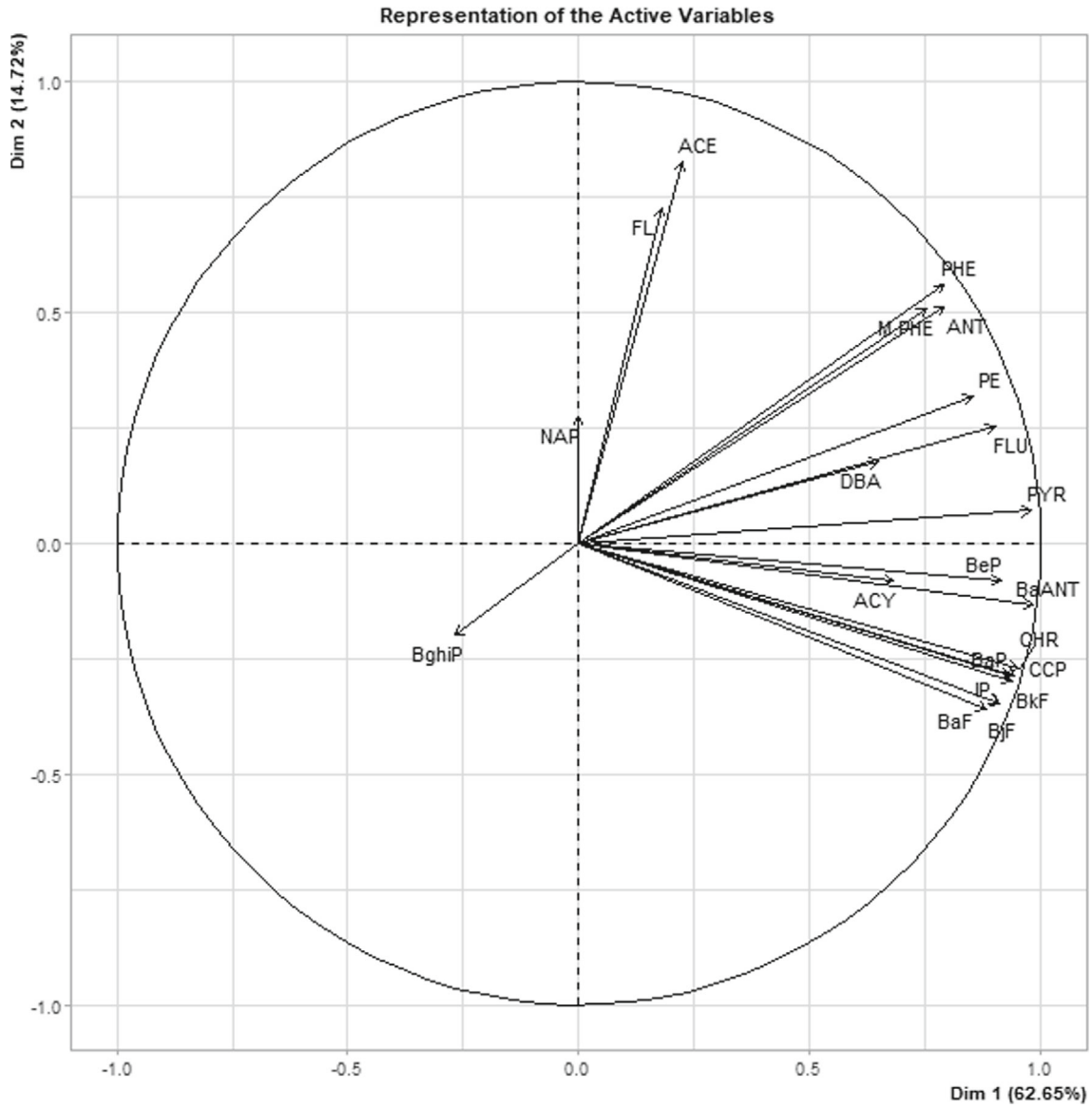


Fig. 2 Component plot of PAHs in the investigated in home dust samples

$$\mathrm{BaP-TEQ} = \sum(\mathrm{PAHi} * \mathrm{TEFi}) \quad (1)$$

where PAHi is the PAH congener i concentration, TEFi is the toxic equivalent factor for PAH congener i, and TEQ is the reference compound's toxic equivalent.

The total toxic equivalents (TEQs) of all 21 PAHs were between 0.15 and 8.26 ng m^{-2}, with 74.1–96.2% of the TEQs coming from only 7 of the 5 PAH rings. Dust in rural regions has a lower benzo[a] pyrene equivalent than dust in metropolitan areas. The levels of danger posed by TEQ are determined not only by the concentrations of each PAH but also by the make-up of PAH mixes, which are influenced by a variety of emission sources. The TEQ levels found in house dust were lower than the US EPA threshold of 10 ng m^{-3} but much greater than the World Health Organization (1 ng m^{-3}, WHO 1987) limit (Zhu et al. 2015). However, expressing that the PAH loads, at least in some dust, seem to merit consideration in terms of possible risk due to non-dietary intake of compounds.

4 Conclusions

Particulate polycyclic aromatic hydrocarbons (PAHs) in interior dust were investigated. We evaluated PAH levels, sources and carcinogenic risk in 15 household dust samples from four Algiers areas. There were 21 distinct PAHs found, and their concentrations ranged from 3.27 to 103.06 ng m^{-2}. The

main component analysis indicated that fossil fuels, biomass and cars produce the most PAHs. The total toxic equivalents (TEQs) of different PAHs ranged from 0.20 to 8.26 ng m^{-2}. The benzo[a] pyrene equivalent content of the dust found in rural areas is lower than that found in dust from urban areas. This study used PCA to show that incomplete fuel combustion and pyrolysis, coal and fossil fuel burning, coke ovens, motor vehicles, cigarette smoke and small-scale wood burning are indoor sources of PAHs in rural areas.

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Dynamics of Thermal Inversion in Cergy-Pontoise Agglomeration (Valley Zone)

Souad Lagmiri and Salem Dahech

Abstract

Balloon-tethered soundings and ground temperature measurements were carried out to elucidate the thermal inversion in Cergy-Pontoise, situated in a hilly plain. During stable weather, ground measurements provided cost-effective profiles, revealing areas of cold air accumulation. The inversions observed in the valley at the center of the agglomeration are considered more accurate and sensitive to local altitude variations (19–200 m). The results also indicate the presence of three wind circulation mechanisms in the basin during the nighttime. These include downslope flow and free wind, circulation influenced by the urban heat island effect, and mechanical air removal beneath an inversion layer toward the eastern side of the basin.

Keywords

Thermal inversion · Fixed sensors · Tethered balloon

1 Introduction

Several studies have analyzed thermal inversion on rugged terrain, particularly at small scales (Niedźwiedź et al. 2021; Joly 2018; Yoshino 1984; Rendón et al. 2014). Nevertheless, our comprehension is still incomplete regarding the collection of cool air in less rugged terrain, like valleys located less than 200 m above sea level.

In addition, the mixed layer in uneven terrain differs from that in flat areas. Indeed, a slightly undulating topography can create local winds which have an impact on the boundary layer.

In the Paris region, a single radiosonde station, that of Trappes, studies the vertical variation of meteorological parameters in the boundary layer on a regional scale. No measurement specifically explores an area with irregular topography, including semi-closed low valleys like the Cergy-Pontoise agglomeration. This study aims to analyze how topographical characteristics influence thermal inversions in the first 200 m of the troposphere.

2 Materials and Methods

Temperature surveys using a tethered balloon were carried out on March 2, 2023, from 7:10 a.m. to 8:06 a.m., to determine the vertical profile of the atmosphere over the hilly area of Cergy-Pontoise. Temperatures were measured at various altitudes: 110, 90, 45, 35, and 25 m, with a thermal sensor attached to the balloon. Simultaneously, sensors positioned on the ground at 2 and 0.5 m heights provided continuous temperature measurements. The study also uses temperatures collected from five meteorological sensors located at different altitudes (from 0 to 89 m; relative to the bottom of the valley) and measuring the temperature at 3 m from the ground. Additional meteorological investigations were conducted using two "Davis" weather stations to elucidate questions about the thermal profile. The first station is situated on the basin floor (Idl), while the second is positioned 42 m above the valley floor on the rooftop of a building (Mgen) on the eastern side. These stations record average temperature, relative humidity, wind direction, and speed every hour (Fig. 1).

S. Lagmiri (✉) · S. Dahech
Research Center for the Organization and Dissemination of Geographic Information (PRODIG), UMR 8586 (CNRS), Paris City University, Paris, France
e-mail: souad.lagmiri@gmail.com

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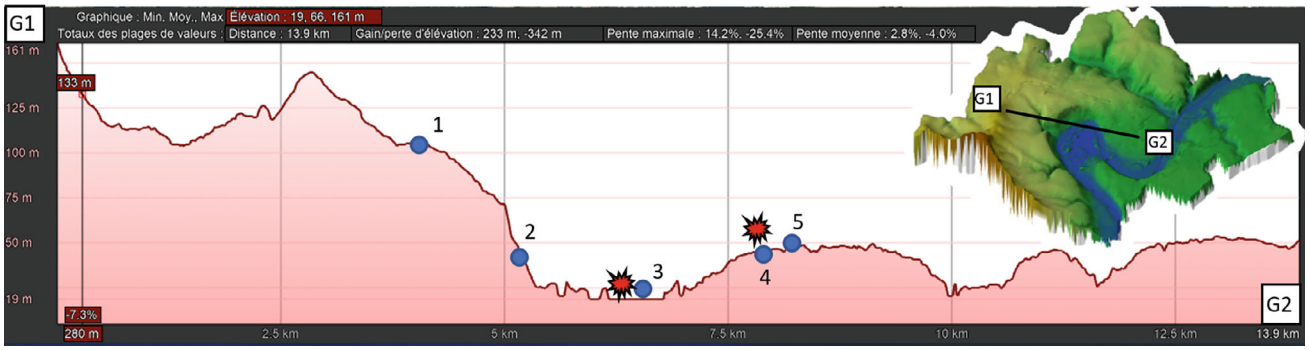


Fig. 1 Topographical features of the study area and sensor locations for measuring climate parameters (the numbers indicate the number of each sensor). Red stars represent Davis stations

3 Results

3.1 Correspondence Between Vertical Surveys and Ground Measurements

The vertical air temperature variation at three altitude levels (110 m, 2 m, and 0.5 cm) at 7:20 a.m. shows a strong thermal inversion ($\Delta T = 0.45 + 2.32$). Between 45 and 25 m, temperatures are cooler on higher floors compared to lower ones. La dissipation de cette inversion est provoquée par l'élimination de l'air à travers des flux horizontaux, se déplaçant à environ 1,3 m/s dans une direction nord-ouest. Observing the balloon's path and the wind direction data captured by the Davis station atop the Mgen building validated this air movement.

Figure 2 illustrates the comparison between sounding temperatures (from 7:35 to 8:06) and those of the slope line. The findings indicate that temperatures along both sides below 25 m serve as reliable indicators of free air temperature soundings in the basin center, with a standard deviation of 0.35 °C on the eastern flank and 0.38 °C on the western flank. This zone represents the cool air subsidence zone. The elevated temperatures noted on the eastern slope result from the influence of the urban heat island effect.

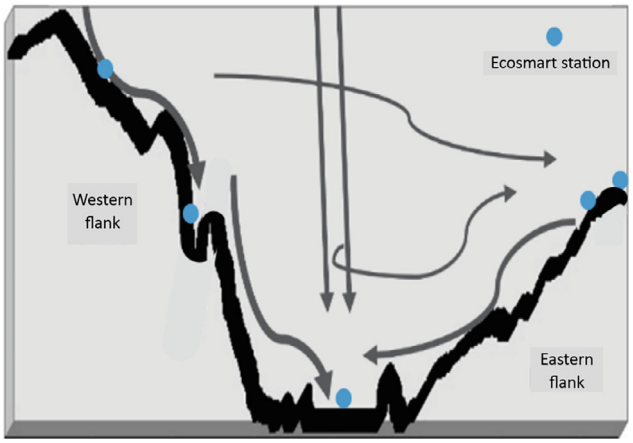


Fig. 3 The diagram illustrates the currents generated in the basin under stable weather conditions

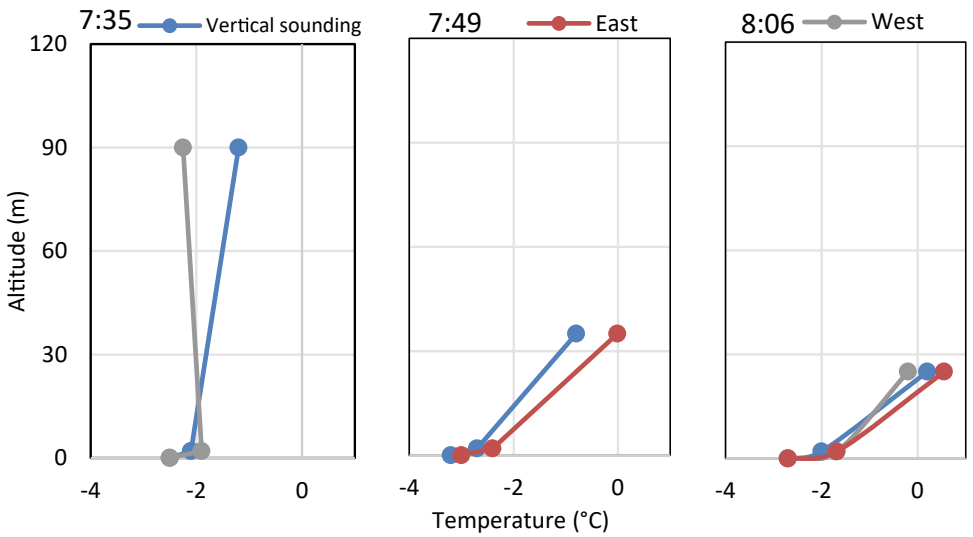


Fig. 2 Temperature differences between the free air and the air mass in contact with the ground on the lateral slopes calculated on March 2, 2023

The most significant deviations are observed on the western slope at 90 m where the air is relatively cooler. This difference is due to the radiative conditions affecting the near-surface atmosphere where the sensors are placed, compared to the measurements taken in the free atmosphere of the valley. Cooling of the air near the ground initiates a downslope wind that carries cold air masses down the slopes. As a result, temperatures on the slope are lower compared to those in the free atmosphere of the valley at the same altitude (Whiteman 2000; Whiteman et al. 2004). Clements et al. (2003) noted that these downward flows are typically most vigorous in the early evening and diminish in strength once the inversion settles over the valley. Figure 3 illustrates a simplified diagram depicting the process of fresh air accumulation and the resulting flows in the study area on March 2, 2023, from 7 a.m. to 8 a.m.

3.2 Accumulation of Cool Air During Stable Weather

To assess the cold air accumulation process during stable weather, we selected the date of October 20, 2022, which corresponded to a situation of surface barometric stagnation and high geopotential at higher altitudes. Figure 4 presents the time series of climatic variables observed at the Davis meteorological stations, one located at the bottom of the basin (Idl) and the other at an altitude of 42 m on top of a building (Mgen) situated on the eastern side of the lateral flank, from October 19 at 2:00 p.m. to October 20 at 1:00 p.m.

Temperature recordings reveal a contrast between the bottom of the basin, which was colder, and the 42-m altitude. At the bottom of the basin, the temperature, which was around 23 °C at 2:00 p.m., dropped to 13.7 °C in the middle of the night. At 42 m altitude, the diurnal temperature drop was smaller, ranging from 22 to 15.9 °C. Relative humidity levels, which were between 65 and 75% during the day, increased at night to over 90% at the bottom of the basin and over 85% at 42 m.

During the night, conditions at the bottom of the basin were very calm, with variable wind directions. At 42 m, west quadrant winds predominated with slightly variable speeds not exceeding 0.5 m/s. This speed might be attenuated due to the presence of taller buildings in the vicinity. Between 3:30 a.m. and 5:00 a.m., a slight increase in wind (1 m/s at 42 m, 0.8 m/s at the bottom) was associated with the arrival of cirrus clouds.



Fig. 4 Chronological series of climatic variables (T°, H, and Wind) recorded at the bottom of the basin (Idl) and at an altitude of 42 m (Mgen) on the eastern flank from October 19 at 2 p.m. to October 20 at 1 p.m

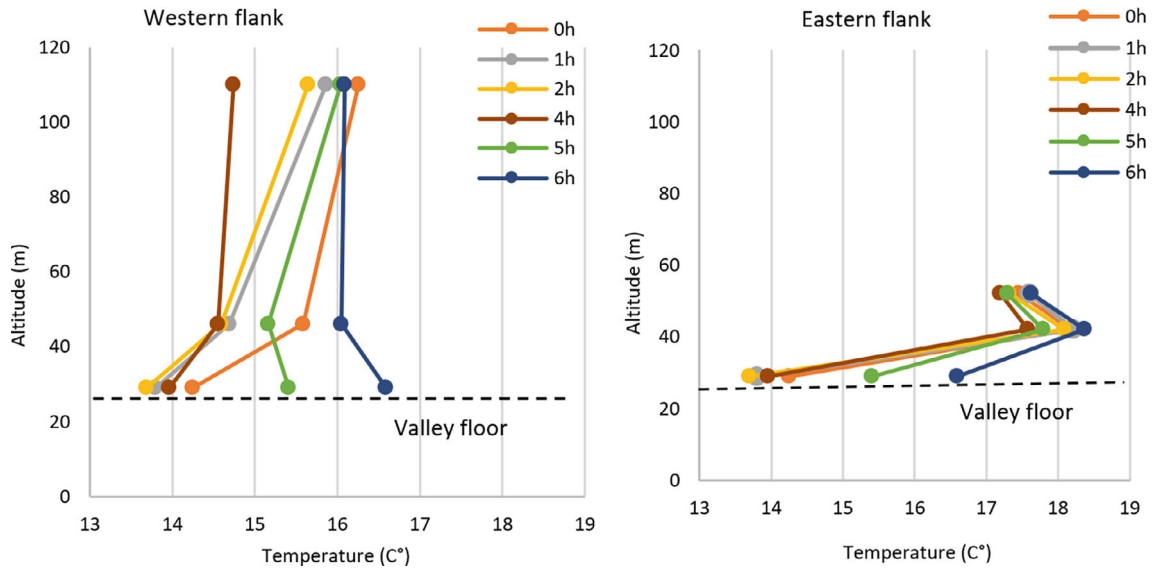


Fig. 5 Evolution of the thermal profile during a stable weather situation (altitude above sea level)

Figure 5 depicts the temporal evolution of thermal profiles along the two studied flanks. On both sides, the cold air accumulation zone remains relatively unchanged around an altitude of 25 m relative to the valley floor. Due to descending air movements, the upper part of the west flank is warmer than the basin floor. The relative cooling at the top of the east line is attributed to the station's exposure to cool breezes typically coming from the west. The graph demonstrates a gradual and persistent temperature decline at all measurement levels. The basin continued to cool steadily until 4 a.m. From that time onward, the basin floor begins to warm up more rapidly than the top. The vertical temperature gradient decreases until the breakup of the inversion at 6 a.m. between the bottom and the upper part of the flank. This is mainly attributed to the formation of a convective boundary layer at the valley floor.

4 Conclusions

The methodology developed in this study proved to be an effective approach for achieving a detailed representation of atmospheric dynamics. Therefore, measurements taken along both slopes are effective for detecting the occurrence of inversions in the basin. Nevertheless, there is a temperature difference between ground-level measurements and balloon-sounding measurements, especially at altitudes exceeding 25 m. The temperatures recorded by the weather balloon show higher values than those from the ground sensors on the western slope, possibly due to the descent of cool air toward the ground. The stations located on the line are then exposed to this flow of fresh air. On the eastern slope, temperatures are slightly elevated as a result of the warming of the air near the surface, driven by the sensible heat exchange from urban surfaces along with the movement of cool air descending toward the basin floor.

While precision may diminish above 25 m in the basin compared to vertical profiles obtained at the center, significant benefits are gained in identifying cold accumulation areas, achieving higher measurement frequency, and reducing costs through the use of ground-level temperature sensors.

In the future, we plan to analyze the link between thermal inversions triggered in the settlement and the accumulation of p.m. at the valley floor.

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How Likely Are Colombian Manufacturing Firms to Prevent the Environmental Damage They May Cause?

Iván Andrés Ordóñez-Castaño,
Lucía del Carmen Bolaños Bolaños,
and Wilson Eduardo Romero Palacios

Abstract

In Colombia, the industrial sector produces about 11.76% of the gross domestic product (GDP), the second largest production sector, but it is one of the sectors with the greatest impact on the environment in the country. While there is research in the country that describes the impacts of this sector on the environment, there is no research that empirically evaluates whether manufacturing industries implement strategies to prevent environmental damage. Based on the data from the surveys: (1) industrial environment and (2) departmental environment and institutional performance, by means of logit and probit models, the following variables were used as proxy variables: (1) the implementation of environmental risk studies, (2) the measurement of waste, (3) the expenses to mitigate or carry out actions to improve environmental quality, (4) the investments made by companies in environmental actions, and (5) the institutional robustness regarding environmental issues in the different regions of the country. In this sense, about 67% of the companies do not have waste measurement, 73% allocate insufficient resources to strengthen environmental policies and 69% make expenditures instead of investments for environmental actions that they disclose. Additionally, the institutional weakness of environmental issues in the country means that 43% of the companies in the industrial manufacturing sector are located in these areas. The probit model was selected according to Bayesian and Akaike criteria. Thus, a company that reports a measurement of its waste, invests in environmental conservation actions, makes fewer expenses related to the environment and located in areas with less institutional weaknesses in environmental issues is 32.69% more likely to implement environmental risk studies. Therefore, most of the companies in the Colombian manufacturing industry are more likely not to plan their actions to deal with possible environmental impacts. The results of this research should be a call to these companies, society and the country's institutions to strengthen public and private policies regarding sustainability with special attention to planning to mitigate the effects on the environment. Other issues that can be investigated are business maturity and the prevalence of the economic dimension of sustainable development in decisions regarding strategies to mitigate environmental impacts in Colombian industry.

Keywords

Environmental actions · Corporate strategies · Environmental policies · Industry · Colombian manufacturing firms

1 Introduction

In Colombia, since the last century, attention has been drawn to the benefits of taking environmental protection measures to avoid the costs associated with environmental compensation or ecosystem restoration (O'Neil et al. 2016). In this sense and taking into account that the industrial sector is one of the sectors that has historically polluted the territory (Deily et al. 1991; Dasgupta et al. 2001; Jayaraman and Lanjouw 2004; Gwatipedza and Barbier 2014), it is relevant to validate whether Colombian manufacturing industries implement strategies to prevent environmental damage.

I. A. Ordóñez-Castaño (✉)
Universidad de San Buenaventura, Cali, Colombia
e-mail: iaocasta@usbcali.edu.co

Universitat Politècnica de València, Valencia, Spain

L. del Carmen Bolaños Bolaños
Universidad Libre, Cali, Colombia

W. E. R. Palacios
Corporación Universitaria Centro Superior UNICUCES, Cali, Colombia

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Environmental damage is evidenced from several aspects, among them, the pollutants generated by productive activities, particularly industry impacts the air with particulate matter (Chen et al. 2022), water either by its use or discharge (Garcia-Garcia and Rahimifard 2019) and the land by its solid waste (Guarnieri et al. 2020). In addition, environmental damage is only evident, in the best of cases, in the medium term, leading the collective to think that the damage will not be a problem for the population of the time, but for future generations (Kot et al. 2020).

In this research, it was considered that one of the ways to prevent industrial pollution is directly related to the implementation of strategies by this sector that lead to the prevention of the environmental impact generated. These strategies should be based on the diagnosis and management of risk, constant measurement of the waste generated for monitoring and the resources allocated for these actions, prevailing the mitigation of the possible effects identified (Wang et al. 2022; Di and Matteo 2022).

2 Methods

Organizations, specifically industries, must protect the environment and respond to the changing environmental conditions that develop in their surroundings, always seeking to balance productive activity with socioeconomic needs. Accordingly, companies should have an efficient environmental management system, which allows the company to achieve the expected results both economically and environmentally from: (1) protecting the environment using prevention, (2) mitigating environmental impacts, (3) mitigating secondary effects according to the company's environmental conditions, (4) controlling the way in which the products and services offered by the organization are designed, (5) achieving financial benefits and operations that may result from applying related environmental alternatives that strengthen market positioning, and (6) communicating environmental information to stakeholders. In order to capture these effects in manufacturing companies in Colombia, these aspects were measured in 1871 companies generating the variables presented in Table 1.

With the purpose of validating if the companies are implementing strategies that lead to the prevention of the environmental impact generated from evaluating the factors that facilitate the realization of an environmental risk study as a planning instrument (Study_R_Env), being this the observed variable, the variable can take values of 1 or 0, as follows.

$$y = \begin{cases} 1\, with\ probability\ p \\ 0\, with\ probability, 1-p \end{cases}$$

Thus, the regression model seeks to predict the conditional probability of the dependent variable with respect to a vector of independent or regressor variables, as shown in Eq. 1. Depending on the probability function used, the model will be Logit—logistic probability distribution—or Probit—normal probability distribution.

$$p_i \equiv \Pr[y_i = 1|x] = F\left(x_i'\beta\right) \tag{1}$$

The control variable was defined as the status granted or in implementation of the ISO 14001 series (ISO Standard), since it is most likely that in the Colombian case, industries are not yet implementing clean mechanisms to prevent environmental damage, three categories were defined. The first one, where the standard is implemented, has the same proportion of those who have an environmental risk study and those who do not, in the second one, where the implementation process is in progress and some industries are more likely to not implement this study, as well as in the third one, where the implementation of the standard is not registered and which also represents the great majority of industries without risk studies.

Table 1 Variable description

Variable	Descripción de la variable	Tipo de variable
Waste-measur	Does the establishment have an instrument for measuring the waste it generates?	Dummy
Cost_expense	Total costs and expenses by category of environmental management and protection carried out by the Colombian manufacturing industry	Continuous
Invest_Exp	Total, investment and expenses by category of management and environmental protection carried out by the Colombian manufacturing industry	Continuous
InvestProtec_Bio	Total investment and expenses for the protection of biodiversity and ecosystems	Continuous
ISO standard	Status granted or in implementation of the ISO 14001 series	Discreta
Study_R_Env	Environmental risk study as a planning tool	Dummy
Pro_Cleaner	Cleaner production program as a planning tool	Dummy

Table 2 Results of marginal effects from logit regression

Logit marginal effects						
Dep. variable	Study_R_Env					
Method	dydx					
At	overall					
Explanatory or control variables	dy/dx	std err	z	P > |z|	[0,025	0,975]
Waste-Measur	−0.1698	0.031	−5545	0000	−0.23	−0.11
Cost_expense	−1.1270E-07	3.88E-08	−2906	0.004	−1.89E-07	−3.67E-08
Invest_Exp	4.1770E-08	1.46E-08	2864	0.004	1.32E-08	7.03E-08
InvestPro-tec_Bio	1.3960E-06	6.68E-07	2089	0.037	8.66E-08	0.00000271
ISO Standard	−0.0760	0.01	−7441	0.000	−0.096	−0.056
Pro_Cleaner	−0.2071	2.02	−10.420	0000	−0.0246	−0.168

3 Results

If an industry does not have an instrument to measure the waste it generates, there is a −16.98% probability that an environmental risk study is being implemented. When there is an increase in total cost and expense there is a probability of (−1.127e^−07) that a risk study is being implemented.

Similarly, when there is an increase in investment and expenditure, there is a probability of (4.177e^−08) that a risk study is being implemented, as with the investment in biodiversity and environmental care, but of (1.396e^−06) respectively. Similarly, if the ISO standard is not implemented, there is a 7% probability that the facility does not have an environmental risk study. Finally, if the facility does not have a cleaner production program as a planning measure, there is a 20.71% probability that an environmental risk study is not being implemented.

When looking at the total cost and expenditure, there is a high probability that this study is not being implemented, since, if it is evaluated empirically when costs and expenditures are increased in any industry, it is most likely that resources are not allocated for this type of environmental studies that usually monopolize a considerable part of them. While for the total investment and expenditure there is a great probability that this environmental study is being implemented, since, having money for investment, it is very likely that this study is being carried out because resources would be available for its implementation (Table 2).

4 Conclusions

It was observed that, firstly, the industries do not register the environmental protection mechanisms that should be implemented, and secondly, most of the industries do not have environmental protection measures, as was seen with most of the categorical variables. As a result of the above, the increase in economic development and the decrease in environmental pollution, respectively, have not been achieved in any sense. Confirming that industrial factors in Colombia do contribute to environmental deterioration in the country, and that in spite of worldwide advances in environmental protection, the transition of these mechanisms has not had the best reception or performance within the territory.

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Understanding the Accessibility of Urban Open Spaces through Behavioural Models—A Case of Kerala, India

Santhseelan Meenu and P. P Anilkumar

Abstract

Studying and quantifying accessibility to urban open spaces is critical to identify the barriers preventing people from using the space and factors contributing to inequalities in access. The information gained can be used to formulate policies that improve access, promote equity and aid in arriving at informed decisions regarding the location and design of open spaces. To minimise the disparity between measured and observed accessibility, accessibility measures and models incorporated into the planning process should consider non-spatial factors, such as psychological barriers, in addition to spatial factors, such as physical proximity. Identification of non-spatial factors is possible using the framework provided by behavioural theories. This study attempted to identify behavioural constructs that can aid in creating an accessibility framework for urban open spaces. Similar existing frameworks are based on the assumption that adequate open spaces are available for recreational purposes, and the use of open spaces is an integral part of the daily lives of citizens. However, the low priority assigned to urban open-space planning in developing nations has resulted in disparity in the geographical distribution, inadequate number and absence of varied typologies of open spaces. The perceived accessibility of open spaces is often low in these countries, leading to disuse and under-utilisation. This results in need for a modified accessibility framework to bring about a behavioural change in how inhabitants interact with and access these spaces. The current study documents the case of Kerala, India, as an example to determine appropriate behavioural constructs to quantify the accessibility of open spaces in the context of developing nations. A detailed literature review aided in identifying behavioural theories commonly used for urban planning interventions that integrate spatial and non-spatial factors. These models, along with recently developed ones, were then assessed for their strengths and limitations in determining the accessibility of open spaces. A list of relevant constructs to be validated through an expert survey to measure perceived accessibility was identified. A pilot study was conducted, and the reliability of the questionnaire was established. The outcome can hopefully aid in formulating an open-space accessibility framework.

Keywords

Perceived accessibility · Urban open space · Behavioural theory · Behavioural constructs

1 Introduction

Traditional measures of accessibility of open spaces have dealt with quantifiable measures such as distance, proximity and time (Wang et al. 2015a). Recent studies prove that an individual's cognitive processes influence their intent to use open spaces, and thus their spatial behaviour and accessibility to such spaces (Wang et al. 2013, 2015b). The extent to which an individual perceives an opportunity as accessible is termed perceived accessibility. Hence, it can be theorised that the overall accessibility of urban open spaces is dependent on geographical accessibility, as well as perceived accessibility. While geographic accessibility represents the objective nature of accessibility, perceived accessibility represents its subjective nature (Pot et al. 2021). Existing measures developed with this understanding still fail to address the challenges faced in urban open-

S. Meenu (✉) · P. P. Anilkumar
Department of Architecture and Planning, National Institute of Technology, Calicut, Kerala, India
e-mail: meenu_p200009ar@nitc.ac.in

P. P. Anilkumar
e-mail: ppa@nitc.ac.in

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space planning in developing nations in the global south. This study attempts to address this gap by identifying the constructs that can aid in explaining the perceived accessibility of urban open spaces, taking the case of Kerala, India.

Possible constructs influencing perceived accessibility were identified through a literature review. The pilot survey documented in this paper established the internal consistency of the questionnaire, which will be used for an expert survey to validate the findings. The constructs so identified will be used to aggregate variables previously collated. The results can hopefully aid in formulating an open-space accessibility framework with due consideration of the conditions of a developing nation.

2 Methods

One objective of this study was to identify behavioural theories and constructs of behavioural theories that can aid in quantifying perceived accessibility. Together with the variables and dimensions of physical accessibility, the constructs of perceived accessibility can help generate a framework for the accessibility of urban open spaces.

The initial stage was a literature study identifying behavioural theories commonly used in urban planning. Seventeen theories from 34 journal articles were shortlisted. The theory of planned behaviour (TPB) formulated by Ajzen (1991) was the most frequently referenced theory in the literature. However, since the theory assumes the availability of opportunities and resources to carry out the intended behaviour (Uturestantix et al. 2022), contradictory to the cases in developing nations facing scarcity of urban open spaces, supplementary theories must also be considered. Two additional theories, the behavioural drivers model and social cognitive theory, were added to the list because of their relevance to the topic. Theories with a scope unrelated to accessibility measurement or a narrow scope were excluded. Further screening was performed to understand whether the theories dealt with both endogenous and exogenous factors which influence the behavioural intent of a human being. The constructs of the final six theories were listed along with the definitions. Based on the keywords present in the definition of the constructs and the factors they measure in the context of accessibility of urban open spaces, some constructs were identified to be the same. The final list consists of 13 constructs (Table 1).

The next stage was the validation of these constructs for measuring the accessibility of urban open spaces. On conducting the pre-test, it was understood that the questionnaire with psychometric scaling was easier to follow than the direct evaluation of the constructs and their relevance to the perceived accessibility of urban open spaces. Seven point Likert scale ranging from strongly disagree to strongly agree was selected for marking responses for better control of type I error (Sangthong 2020). A pilot test was conducted among 10 subjects with urban planning/design backgrounds. For anal-

Table 1 Constructs and definitions

Constructs	Definition
Attitude	The degree to which a person has a favourable or unfavourable evaluation of the behaviour of interest
Perceived control	The perceived ease or difficulty of performing the behaviour assumed to reflect experience as well as anticipated impediments and obstacles
Social norms	The customary codes of behaviour acting as social pressure to perform or not perform a behaviour
Capability	An individual's psychological and physical ability to participate in an activity
Opportunity	Refers to external factors that make a behaviour possible based on perception and interpretation of their physical environment
Place attachment	Refers to the emotional bond or connection that individuals develop with specific places
Identity	The part of an individual's self-concept that is related to their relationship with the natural environment
Knowledge	The information, opinions, arguments and stories we are exposed to
Salience of behaviour	Degree of importance of the behaviour to the person and whether at the forefront of their thoughts
Habit	Whether part of a routine
Personal characteristics	Main attributes including age, gender, ethnicity, life cycle stage, education level, social status, poverty level, religious affiliation, household composition, possible disorders
Context	Physical settings, natural events and weather
Governing entities	Local authorities to international institutions through national governments

ysis of the results, statistical software Jamovi version 2.2.5 was used.

3 Results and Discussion

The final score for each construct was taken as an average of the responses to the questions formulated through psychometric scaling, and descriptive statistics were generated. In addition to scoring the constructs' relevance in measuring perceived accessibility, the respondents were also requested to score the perceived accessibility of urban open spaces in Kerala. The perceived accessibility (PA) score, as evaluated by the respondents in the pilot study, is low. Attitude and opportunity (Opp.) as constructs scored the highest regarding influence on perceived accessibility (Table 2).

From the pilot study, it was also identified that the concept of homestead plays an essential role in the context of Kerala. Historically, the yard spaces around the residence reduced the need for people to explore public open spaces for recreational purposes. Allocation of new public open spaces was often assigned low priority in planning, as the urban fabric was interspersed with adequate private green spaces ensuring environmental benefits. However, with increased built-up density, the existing open spaces are grossly inadequate to serve the growing population. After re-analysing the definition of constructs, it was decided to include homestead under the context construct.

Cronbach's alpha was calculated to measure the reliability of the survey questions. The alpha value aids in understanding how well the items in the scale work together to measure perceived accessibility. Values greater than 0.8 suggest that the questions are highly correlated and form a reliable scale.

Table 2 Descriptive statistics

	Attitude	Opp.	PA
N	10	10	10
Missing	0	0	0
Mean	6.33	6.60	2.80
Median	6.50	6.67	2.25
Standard deviation	0.544	0.605	1.16
Minimum	5.67	5.00	1.50
Maximum	7.00	7.00	5.00

From the pilot study, Cronbach's alpha value was found to be 0.801, indicating good internal consistency.

Lawshe's method for ensuring content validity (Lawshe 1975) will also enable determining the constructs essential for quantifying perceived accessibility. The modified questionnaire will be administered to an expert panel, the majority of which will be composed of urban planners/designers/town planners since the primary aim of the research is to contribute towards the planning process. Sociologists, behavioural scientists and experts from management will also be included in the panel.

4 Conclusion

The internal consistency of the questionnaire was established, and the identified constructs can be assumed to contribute to the perceived accessibility of urban open spaces. An additional factor, homestead, has been added for consideration by experts.

The subsequent stage will include an expert survey, and the results are hoped to illuminate significant constructs that influence perceived accessibility. Along with acting as an aid to aggregate previously collated variables, the identification of constructs will also aid in formulating an accessibility framework for urban open spaces. The outcome can hopefully aid in quantifying the accessibility of urban open spaces considering factors relevant to developing nations as well.

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A Functional Mock-up Interface-Based Software Architecture for Continuous Online Building Energy Model Calibration

Iker Landa, Jan L. Bruse, Marco Quartulli, Carlos Fernández, and Juan B. Echeverria

Abstract

This paper presents a software architecture for continuous online calibration of building energy models using real sensor data. A Modelica-based BEM is iteratively calibrated through a first-order RC thermal model and integrated into an API via the Functional Mock-up Interface (FMI). The approach enables real-time thermal characterization of building rooms using nocturnal temperature decay profiles. A comparison between Modelica- and FMU-based execution shows higher computational cost for the FMU approach, while offering greater portability and deployment flexibility.

Keywords

Building Energy Models (BEM) · Online Model Calibration · Functional Mock-up Interface (FMI) · Thermal RC Modeling

1 Introduction

Currently, buildings' energy systems operation accounts for a significant portion of the world's energy consumption. Modern simulators for buildings that focus on energy performance calculations and management, such as EnergyPlus, allow the replication of a buildings' energy performance under different external conditions, both real and simulated (Priarone et al. 2020; Moriyama et al. 2018). These simulators constitute a building energy model (BEM) and are widely used as a tool to assess the design, operation, performance rating, etc. for existing or for new buildings and thus provide a great potential for devising novel operation strategies leading to reduced building energy consumption (Zhang et al. 2019; Mhsson and Mclntyre n.d.).

Calibrating BEMs is crucial to ensure a correct match between simulation results and real-world performance. The discrepancy between simulation results and actual building performance is commonly referred to as the Energy Performance Gap, and its reduction has been widely addressed in the literature. The BEM calibration process is usually a time- and computational resource-consuming process, as it involves large volumes of building sensor data, required to feed the BEM and compare its outputs. Thus, BEM calibration can extend up to several days or weeks and is typically performed offline (Ramos Ruiz et al. 2016; Wüllhorst et al. 2022; Vellei et al. 2021).

Current literature primarily focuses on simulators that describe building energy performance using BEMs that were calibrated using static datasets, while few publications focus on integrated modeling of the building energy system and its communication with the physical building installation (Im et al. 2020).

To address these issues, we present here a novel software architecture integrating a functional mock-up interface (FMI) for calibrating the BEM's thermal behavior continuously and iteratively using real data provided by building sensors. The FMI is a standard to exchange simulation models through a combination of XML files, binaries and C code, allowing the execution of models using a wide variety of programming languages. In this study, we demonstrate that continuous online building energy model calibration becomes possible, generating a well-calibrated, up-to-date BEM that provides simulated energy performance data close to reality. Furthermore, the use of FMI facilitates the execution of BEMs in the actual installation, reducing its compu-

I. Landa (✉) · J. L. Bruse · M. Quartulli
Vicomtech, Donostia-San Sebastián, Spain
e-mail: ikerlandadelbarrio@gmail.com

C. Fernández
Universidad de Extremadura, Cáceres, Spain

J. B. Echeverria
Universidad de Navarra, Pamplona, Spain

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tational dependencies compared to traditional implementations.

2 Methods

This study focuses on the online calibration of a BEM simulator, which has been modeled based on a large office building located on the outskirts of Madrid, Spain. The lack of disaggregated monitorization of HVAC devices motivates the use of a multi-physical simulation of the system, replicating the energy performance of the whole HVAC system, using real local weather data, building's thermal characterization and nominal performance parameters of the HVAC devices. More information about the modeling method can be found in (Del Barrio et al. 2023).

2.1 BEM Model Calibration Subset

The building energy model was implemented using OpenModelica (v21.0.0) (Fritzson et al. 2020). The simulator is based on the Modelica language and employs the Buildings library (v9.0.0) for building energy performance simulation (Wetter et al. 2014). The whole BEM simulator consists of the replication of the HVAC system performance, which is mainly conditioned by the nominal performance parameters, the weather conditions, and the effect of the building's room thermal characteristics. Note that here the building has been modeled as a collection of rooms for which thermal behavior is represented by Modelica building blocks (Fig. 1).

The scope of this study is to show the thermal characterization of several rooms of the building using real temperature data collected by building sensors and a Cauer-type thermal equivalent circuit model (Otomo and Igarashi 2021), consisting of the translation of an RC (resistive-capacitive) electric circuit into an analogous RC heat transfer model. During the day, several heat sources transfer heat to the rooms—HVAC, solar gains, human sources, etc.—hindering the characterization of the thermal behavior of the rooms. However, at night, these sources are inactive, so that the heat stored in the building is transferred to the environment through the building envelope, similarly to the discharging process of an electrical capacitor through a resistor. Thus, the thermal discharge follows the expression:

$$\Delta T(t) = \Delta T_0 \left(1 - e^{-\frac{t}{\tau}}\right) \tag{1}$$

Being:

- $\Delta T(t)$ temperature difference,
- ΔT_0 initial temperature difference,
- t time,
- τ time constant defined by $\tau = \text{RC}$.

In order to simplify the calibration process of thermal R and C parameters for each room, a subset of the whole BEM simulator has been used that includes the mentioned Cauer circuit, as shown in Fig. 1.

The rest of the blocks are used to calculate the difference between real measured data and data produced by the thermal model, thus computing this difference incrementally by an integrator block. This allows for calibrating the needed thermal parameters effectively by approximating its result to the result of the first order exponential equation, based on the Eq. (1).

The created simulator is exported as a FMI unit (so-called functional mock-up unit, FMU) to be executed by languages other than Modelica, in this case Python. To achieve this, several inputs and outputs must be defined for the simulator, so that the Python interpreter can interact with the simulation model through these variables. In this way, the Modelica interpreter is not needed to execute the model, which allows the whole architecture to be executed in the same programming language and allows "packaging" the simulator within an application programming interface (API) that is independent of Modelica. In this study, both options are tested, comparing the execution times of the RC parameter calibration using (a) a FMU-based API and using (b) a Modelica-based API using the OMPython interface directly.

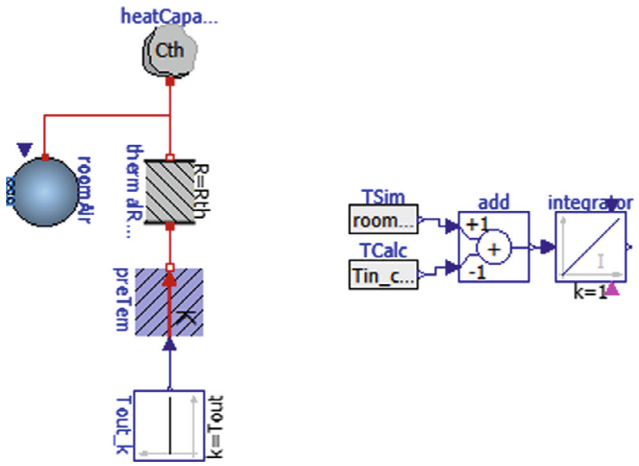


Fig. 1 Calibration subset block diagram in OpenModelica

2.2 Continuous Iterative Calibration Process

Temperature data collected by building sensors was stored continuously in an external database that was accessible to our simulator APIs (FMU- and Modelica-based). The

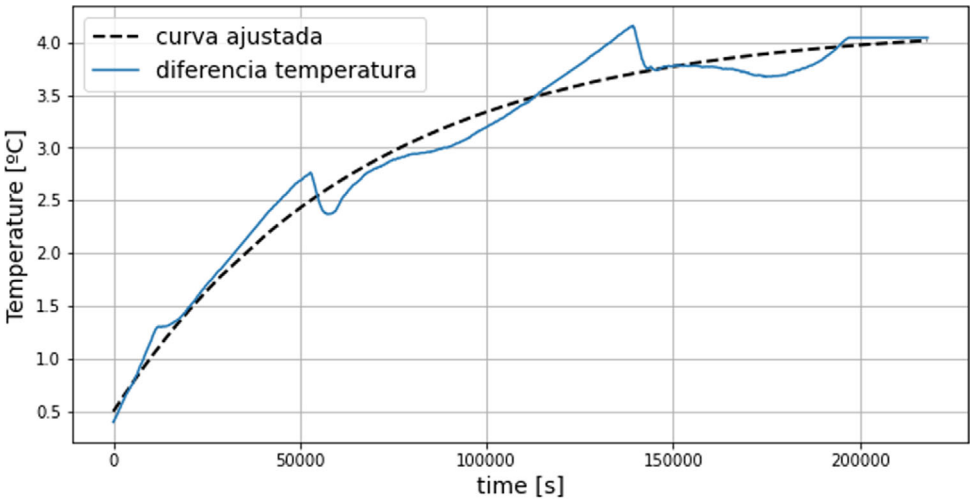


Fig. 2 Room FC20 real data versus approximated curve

calibration procedure was run on a daily basis, using the respective weather data as input and calculating the thermal behavior (i.e., temperature curves) for each of the rooms using either the FMU- or the Modelica-based simulator API. Simulated temperature curves were then compared with the actual recorded temperature curves to iteratively calibrate the room's RC parameters (Algorithm 1). The APIs were called in each iteration, after changing the RC parameters to update the simulator's thermal behavior.

Specifically, the building's rooms were characterized based on the thermal capacitance discharge Eq. (1) at night when the building is unused. Here, the received temperature profiles (T_{exterior} and T_{interior}) were approximated as a first order exponential function.

Being $\tau = R_{\text{th}}C_{\text{th}}$, we cannot identify each thermal constant from the mentioned curve. Thus, an iterative process has been performed, as shown in Algorithm 1.

Algorithm 1
Iterative calibration process.
1: Curve parameters (ΔT_0, τ, *res*) are declared
2: **While** (simulated curve–analytical curve) > threshold
3: R_{th} = initial guess + step; $C_{th} = \tau/R_{th}$
4: Set parameters on Modelica model via OMPython
5: Generate FMU and simulate.

3 Results

The mentioned approximated first order exponential curve is shown next for the room "FC20" of the Fig. 2.

After approximating the curve, the calibration was performed using both FMU- and Modelica-based APIs and computational costs were compared. The final RC calibration results are shown in Table 1 for a subset of rooms of the building, which consists of the two rooms shown in Fig. 2.

Computational times have been recorded for each method (Modelica and FMU), obtaining the results of Table 2.

4 Conclusions

In this paper, a novel software architecture is presented that integrates a building energy model (BEM) as a functional mock-up unit in an API for continuous, iterative calibration of room thermal behavior taking into account real building sensor data.

Calibration was performed using a) a FMU-based API as BEM replacement and using b) a purely Modelica-based API in order to compare their computational costs. The FMU-based API was found to be in in the order of six times costlier. This is likely due to the inability of OpenModelica to declare calibration parameters as tunable when exporting the simulated model to a FMU. Hence, the

Table 1 Calibration results for a subset of rooms

Room	R_{Th}	C_{Th}
FC_20	1.4E-4	9.82E+7

Table 2 Computational times for each calibration method

Method	T_{Cal}
Modelica	6 m 15.7 s
FMU	40 m 22.2 s

value of the parameters in the model had to be changed in each step before exporting the FMU and re-running the simulation. Future work should address this issue to make continuous online BEM calibration computationally more efficient.

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Method for the Analysis of Bottlenecks in Passengers Transport Systems: A Framework for Supply-Demand Interaction and Performances Evaluation

Massimo Di Gangi, Antonio Polimeni, and Orlando Marco Belcore

Abstract

The objective of this paper deals with the proposal of a general framework to simulate a transport system providing some performance indicators (e.g., waiting time, queues). The framework could support the management of arrivals at a transport node and improve efficiency and security in bottlenecks. Besides, it allows one to assess design scenarios and represents a means to individuate the measures to implement in relation to transport system traffic conditions. The core of the proposed framework is a dynamic network loading (DNL) procedure (using a mesoscopic approach) able to simulate the transport network considering explicitly the bottlenecks. The developed DNL model allows the simulation of user movements (if necessary, grouped into packets) in space and time, considering when the user is moving or is in a queue.

Keywords

Transport system modeling · Dynamic network loading · Mesoscopic model · Assignment models

1 Introduction

The economic and social growth of a metropolitan area also depends on the characteristics of the transportation system, considering both the infrastructure and the services (Tong and Yu 2018). Users organize their travels considering the available supply to minimize travel costs and the possible obstacles (e.g., bottlenecks and barriers) that may affect the transport system's capacity and level of service. Thus, quantitative methods are required to analyze the transport system, highlighting critical issues and defining possible policy measures.

The simulation of a transport system deals with various aspects such as the representation of the road network, the user choices, the demand management (Liao 2016; Ferguson 1990), to name a few. The approaches used to simulate the system can be static or dynamic (Cascetta 2009), and the choice of the approach depends on the problem in question. Focusing on dynamic network loading (DNL), the task is to get users to move through the road network, considering discrete intervals of time (Di Gangi et al. 2022). In mesoscopic DNL, users are grouped into packets (at the limit, one packet could contain one user) that move on the network (Celikoglu and Dell'Orco 2007). Such a simulation must consider singular points in the network, as bottlenecks where the users can suffer delays and queues. In road traffic analysis, Hale et al. (2021) proposed a data-driven approach to identify bottlenecks in a transport network. Similarly, Song et al. (2018) used probe vehicle data to individualize space and time bottlenecks. Li et al. (2018) identified the bottlenecks in a highway and proposed some measures (e.g., ramp metering and variable speed limits) to reduce the travel time and the risk of accidents. Zhang and Gao (2020) analyzed the effects of autonomous vehicles on urban bottlenecks. In the field of public transport, Garrido-Valenzuela et al. (2022) used GPS data from buses to identify and classify bottlenecks and proposed measures to solve them. Similarly, Bucknell et al. (2017) considered bottlenecks related to bus operations in a city using the automated vehicle location system.

This paper moves from the literature findings and aims to provide a general framework to simulate the supply-demand interaction, providing some performance indicators to assess the measures. The core of such a framework is a dynamic network loading (DNL) procedure, based on a mesoscopic approach, capable of explicitly considering bottlenecks and

M. Di Gangi · A. Polimeni (✉) · O. M. Belcore
Dipartimento di Ingegneria, Università degli Studi di Messina, Messina, Italy
e-mail: antonio.polimeni1@unime.it

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to simulate the changes (if any) in user behavior (e.g., mode change or route choice). The DNL has been implemented, developing some extensions (e.g., queue management, multimodality, class of vehicles) for a more realistic representation of the transport system. These extensions are based on: time-space simulation of the flow for each link; clustering of the users into classes; explicit modeling of the bottlenecks. A preliminary experimentation in a real case is provided, considering as study case the strait of Messina, where a branch of sea of about 3 km separates two metropolitan areas.

The paper is structured as follows. Section 2 contains the proposed framework. Section 3 reports the application. Finally (Sect. 4) the discussion and (Sect. 5) the conclusion.

2 Approach

The proposed approach (Fig. 1) is designed to individuate the bottlenecks in a transport system in both space and time. It is a general procedure, then easily exportable in other situations. The input of the problem is the *demand* (split into time slices) and the supply that feeds the *dynamic network loading* (DNL). The supply is represented by a graph $G(N, L)$, where N is the set of nodes, and L is the set of links. In addition, in mesoscopic DNL, the demand is grouped into homogeneous packets, and each link is divided into two parts: a running segment and a queuing segment. It allows us to simulate the movement and the wait in a queue for each packet. The DNL provides, as output, for each time slice, the *performances* of the system. Defined a set of threshold values for the performances (e.g., maximum travel time, maximum queue length, …), a procedure for identifying critical issues allows one to detect the bottlenecks for each time slice. Since the bottleneck position is known, in space and in time, a procedure for *measures definition* is applied to define the *measures* to implement to improve the system. Such measures can intervene on both supply and demand: as an example, supply-side by adding new services, demand-side by using procedures for the demand management. After the definition of the measures, the system is simulated once again to assess the adopted measures.

3 Results

In this section, a preliminary application of the proposed framework is provided. The case study (Fig. 2) refers to the crossing of the Strait of Messina (South Italy), where road vehicles are forced to embark on a ship to travel from Sicily to Italy (and vice versa). The service is scheduled according to the time period; the following application relates to the winter period. The average daily demand for road vehicles crossing the strait of Messina (classified as car, commercial vehicles, and motorcycles) comes from surveys.

4 Discussion

In this simulation, it is considered a ferry service in a time interval ranging from 6.40 to 24.00, in such an interval, the ship runs are scheduled every 80 min, for a total of 14 trips in about 17 h. Table 1 shows some simulation results. An analysis of waiting times, comparing the maximum, the minimum and the average values, indicates variable system performance across different time slots. In fact, there are

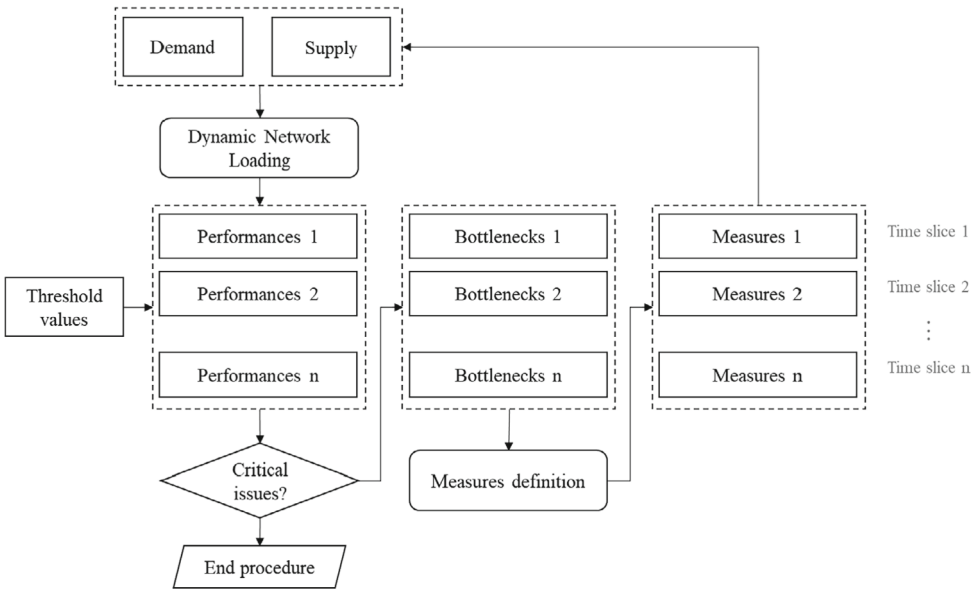


Fig. 1 Proposed approach

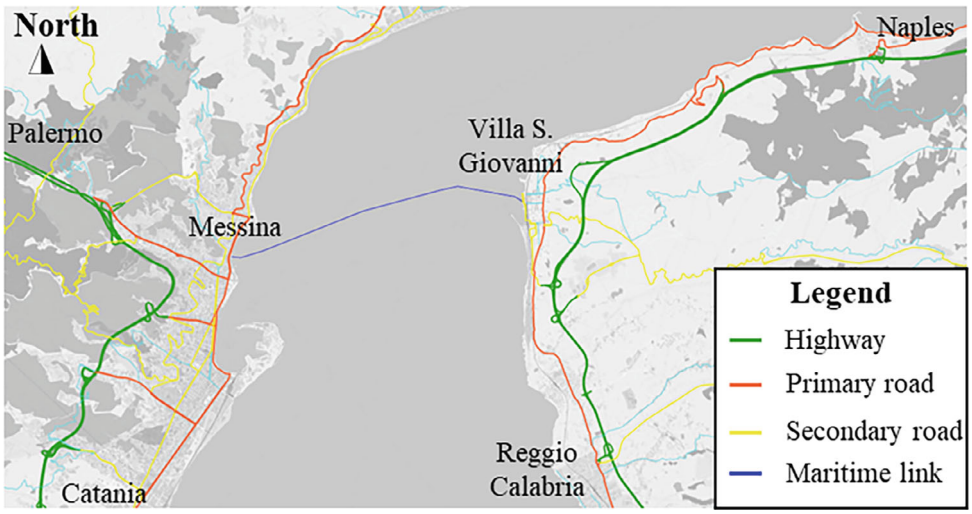


Fig. 2 Study area

Table 1 System indicators

Run	Departure	Waiting time (min)			% embarked	Missing capacity (%)
		Min	Max	Avg.		
1	06:40	5.17	5.17	5.17	100	0
2	08:00	0.08	79.17	29.40	100	0
3	09:20	13.16	79.17	43.05	81	22
4	10:40	16.08	93.15	61.30	92	9
5	12:00	0.21	89.16	41.77	98	2
6	13:20	27.78	81.13	54.01	62	57
7	14:40	48.00	108.00	82.91	67	52
8	16:00	26.52	128.00	80.35	78	31
9	17:20	16.57	108.00	63.05	81	23
10	18:40	1.16	98.00	66.10	100	0
11	20:00	1.16	78.00	43.88	100	0
12	21:20	0.38	78.00	33.26	100	0
13	22:40	0.08	76.00	51.43	100	0
14	24:00	42.07	76.00	58.04	100	0

some runs in the morning and in the afternoon when the waiting time is longer than the expected average value. This discrepancy arises when not all queued vehicles can be embarked during specific ship run (see the column with the rate of embarked vehicles). This suggests that some measures could be implemented to reduce such a delay. A first measure could be the addition of some runs in the busiest time slots (a constraint is the number of available vessels) or the use of a larger ship (in Table 1 the missing capacity of the ship is reported). Another measure could be a system of management that allows the users to buy a ticket for a run where they can surely come on board (with current management, the users buy the ticket and wait for the first vessel available). A combination of these two measures would further reduce the user's wait for boarding.

5 Conclusion

In this paper, a general framework has been proposed to simulate a transport system and identify the bottlenecks. Such a framework, starting from demand and the supply, simulates the system in a dynamic environment. It evaluates the presence of bottlenecks and assesses the measures to implement to mitigate the effects of the bottlenecks. The general structure of the proposed procedure makes it applicable to other case studies as well. An application has been provided for a test case, simulating the travels from Sicily to Italy through the Strait of Messina by embarking road vehicles on a vessel. Some possible measures have been proposed. Future developments will be addressed in a further disaggregation of the demand and an analysis of the access/egress system to/from the port.

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Xerophytic Plants for Sustainable Urban Green Areas in the Mediterranean Climate

Simona Aprile, Maria Carola Fiore, Antonello Maurizio Tucci, and Adele Salamone

Abstract

Proper planning and management of different sectors (transportation, water, housing, green spaces, etc.) plays a key role in sustaining highly complex systems such as cities especially as the urban population continues to increase. Multi-level working methods for urban policy (New Urban Agenda, 2017; Paris Agreement, Green New Deal) indicate how to sustain urban development through increased resilience and environmental protection. Thus, human-scale urban spaces and sustainable green areas will increase, assigning the use of plants an ecological function beyond urban boundaries. This paper investigates the agronomic response and adaptability of three native xerophytic plant species—*Rosmarinus officinalis* L. var. *prostratus, Crithmum maritimum* L. and *Halimione portulacoides* (L.) Aellen. subjected to experimental trials in low-maintenance garden beds. The experiment was conducted in Bagheria, a small town on the north-western coast of Sicily (Italy). Each species was grown in three replicated beds (plots). Plant survival, growth index and soil cover (%) were calculated and analysed. Weed species, observed in the beds, were collected and listed. Based on the recorded results, *H. portulacoides* showed the highest growth index and soil cover (close to 100%) values compared to the others. The rosemary plants also showed good growth performance. The results provide useful information and suitable plant species to introduce sustainable green spaces in Mediterranean cities' landscapes to designers, public authorities and citizen communities.

Keywords

Halophytes · Aromatics · Growth index · Ground cover · Underutilized species

1 Introduction

Currently, cities and human settlements deal with unprecedented threats mainly due to unsustainable production and consumption models by ecosystems. Numerous factors are responsible for the loss of biodiversity such as pollution, climate change, natural and anthropogenic disasters that undermine the achievement of several goals of the 2030 Agenda for Sustainable Development (United Nations 2015). All this is exacerbated by the continued growth of the urban population, which, by 2050, is expected to nearly double (United Nations 2017). New flows of people, new economic activities, social and cultural interactions, will produce new environmental and human impacts in cities, which poses enormous challenges to their sustainable future. Multi-level working methods for urban policy (United Nations 2016, 2017; European Commission 2019) indicate the ways to redesign, finance, govern and manage cities and human settlements to reduce inequality, promote inclusive and sustainable growth and environmental protection, needs most highlighted with the pandemic COVID-19 (Eggimann 2022). Unconventional urban models (tactical urbanism, multifunctional streets and superblocks) are testing in several European cities (Fabris et al. 2023), and a fundamental ecological role is assigned to new designs of urban green by their influence on some bioclimatic parameters (Zoulia et al. 2009; Chen et al. 2012). Thus, the spread of small and large sustainable green areas is promoted, and the plants at the street level can regulate the urban water cycle, reducing its outflow and encouraging the removal of pollutants (Milliken 2018; do Nascimento Rocha and Mussury 2020).

S. Aprile (✉) · M. C. Fiore · A. M. Tucci · A. Salamone
Research Centre for Plant Protection and Certification, Council for Agricultural Research and Economics, Palermo, Italy
e-mail: simona.aprile@crea.gov.it

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The ecological contribution of urban green space becomes more relevant in cities characterized by a dry summer typical of the Mediterranean climate (David 1971), where the choice is directed towards the use of plants growing in arid or desert environments, as the xerophytes. Several authors have tested these plants with good results in urban greening design and green roofs (Maloupa et al. 2006; La Mantia et al. 2007; Papafotiou et al. 2013; La Gennusa et al. 2018). This work evaluates the agronomic response of three native xerophyte species to low-input cultivation in an urban environment to provide a homogeneous green cover throughout the year. These are the aromatic *Rosmarinus officinalis* L. var. *prostratus* and the halophytes *Crithmum maritimum* L. and *Halimione portulacoides* (L.) Aellen.

2 Materials and Methods

The trial was carried out within the urban centre of Bagheria (Sicily, Italy) (38° 04′46.55″ N to 13° 30′47.30″ E, 72 m a.s.l.), located by the north coast of Sicily in the province of Palermo (Italy), characterized by a climate representative of the Mediterranean coastal areas. In January 2013, the trial started in three neighbouring urban flowerbeds measuring 125, 70 and 160 m^2.

Three plant species were compared: *H. portulacoides* (L.) Aellen, *R. officinalis* L. var. *prostratus* and *C. maritimum* L. The plant m^2 investment for each treatment was determined by the size and habitus of the plant species. For the planting, non-woven fabric covered with fine gravel was used as mulch.

At the time of planting, all the beds were irrigated with 20 l/m^2. Three irrigations were carried out during July–August to make up for water shortages in the soil, each with a flow rate of about 20 l/m^2. Data on average daily maximum and minimum temperatures (°C) and total daily rainfall (mm) were downloaded periodically from the thermal-pluviometric station of Misilmeri (PA), near Bagheria.

The experiment was arranged in a randomized block design with three treatments (species) and three repetitions for a total of nine plots. For each treatment, the sample observation consisted of three units of surface area of 1 m^2 randomly identified, starting two months after planting (March 2013) for ten months (December 2013).

Plants performances were evaluated by various indicators: *Plant height* (PH), *Growth index* (GI), *Plant Ground Cover* (PGC), *Plant survival* (PS).

Weed species found in the beds during the trial were collected and identified.

Data collected during a single sample observation (December 2013) were subjected to a one-way analysis of variance (ANOVA). Differences between the three species were detected with Tukey's multiple comparisons test, using PAST software. Percentage data were normalized expressing them as arc sin root square.

3 Results

During the test period, the thermometric trend (Fig. 1) was in line with typical values for the test environment. The highest average temperatures were recorded in July and August (32.9 and 33.2 °C).

The highest rainfall was recorded in January (158.7 mm) and February (126.8 mm), while from May onward there were sharp decreases to zero between July and August.

For the evaluation of the collected data, a descriptive analysis was first carried out (data not shown). A graphical representation of GI calculated over time (from March to December) is reported in Fig. 2. From the planting, the GI trend showed increasing values for all the species but there was a clear difference between the values of *H. portulacoides* (16.7) and those of *C. maritimum* and *R. prostratus* (8.7 and 9.8). *H. portulacoides* already reached values above 34 in mid-May (just over 5 months after planting), which the other species never reached during the trial.

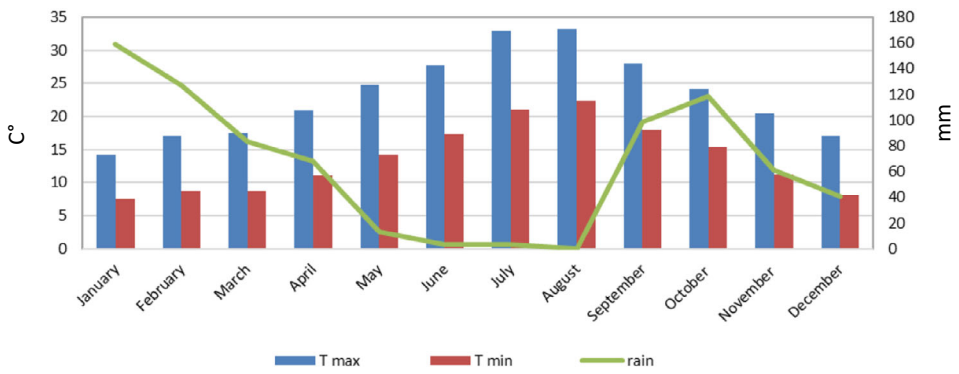


Fig. 1 Average thermo-pluviometric trend year 2013

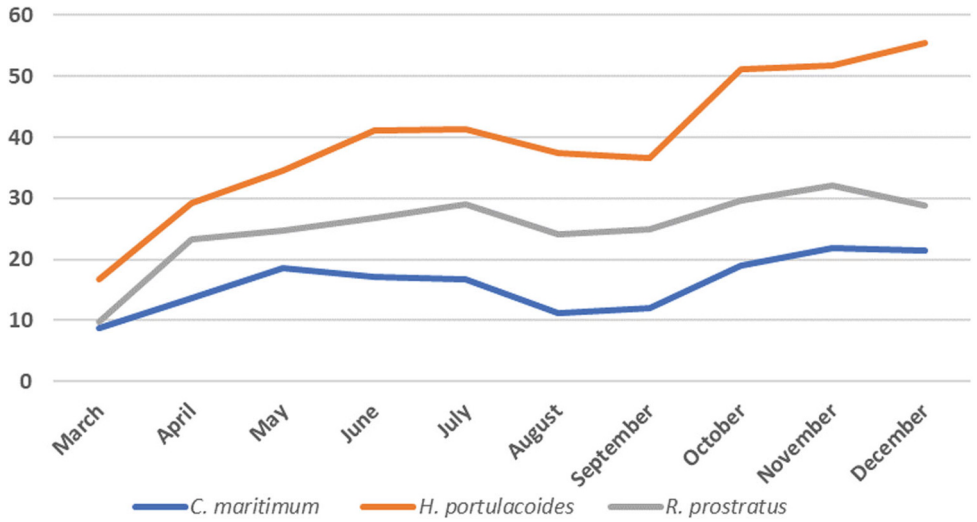


Fig. 2 Growth indexing the experimental period for all three species

Table 1 Effect of the experimental treatments at the end of the experiment

Species	PH (cm)	GI	PGC (%)	PS (%)
C. maritimum	18.9 b	21.4 c	62.2 b	68.2 c
H. portulacoides	66.2 a	55.4 a	98.3 a	98.8 a
R. prostratus	23.3 b	28.9 b	71.0 b	96.3 b

* = significant at $P \leq 0.05$

All the species showed a decline of values during the dry season between May and September, then the GI values started to increase again for all.

Then, one-way ANOVA was performed to compare the average values collected at the end of the observation period followed by Tukey's multiple comparisons test.

Significant differences in the four indicators were observed between treatments (species) (Table 1). *H. portulacoides* showed the highest pH value (66.2) significantly different to the other two species, which did not differ significantly between them. *H. portulacoides* also showed the highest mean value of GI and all thesis differed significantly from each other.

The percentage of PGC shows how *H. portulacoides* reached a very high mean value (98.3), statistically different from the other two species, which did not differ significantly between them. The percentage of PS shows the greatest losses in *C. maritimum*, with significant differences between all the theses.

The following species of weeds have been identified in the beds through the published literature (Conti et al., 2005; Pignatti et al., 2017), combined with the records from the *exsiccata* of the *Herbarium Mediterraneum Panormitanum* dell'Università di Palermo *(Herbaria)*: Amaranthaceae: *Amaranthus retroflexus* L.; Asteraceae: *Bidens pilosa* L., *Calendula arvensis* (Vaill.) L., *Dittrichia viscosa* (L.) Greuter subsp. *viscosa*, *Erigeron bonariensis* L., *Sonchus asper* (L.) Hill, *Symphyotrichum squamatum* (Spreng.) GL Nesom; Brassicaceae: *Coronopus didymus* (L.); Campanulaceae: *Campanula erinus* L.; Chenopodiaceae: *Chenopodium album* L.; Nyctaginaceae: *Boehavia coccinea* Mill.; Poaceae: *Cynodon dactylon* (L.) Pers., *Digitaria sanguinalis* (L.) Scop; Polygonaceae: *Polygonum aviculare* L.; Urticaceae: *Parietaria judaica* L.; Scrophulariaceae: *Verbascum sinuatum* L.

4 Discussion

Under the conditions described, *H. portulacoides* had the highest values for all the indicators (PH, GI, GC, PS) at the end of the experiment, with significant differences compared to the other species. Its PGC is close to 100% and the high values in the GI trend demonstrate good resistance to environmental conditions, confirming its suitability for the intended applications.

During the hot-dry season, all three species showed a decrease in the values of the agronomic indicators up to plant death, which in *C. maritimum*, was considerable. The values obtained for this species do not make it suitable for the study hypothesis.

R. prostratus, generally, maintained values between those of the other two studied species, showing a good development capacity under the tested conditions and potential for use at low input, as also reported by Ruggeri et al., 2016 (Ruggeri et al., 2016).

H. portulacoides and *R.officinalis* var. *prostratus* can be included among the native xerophytes with morphological or

functional characteristics suitable for use in urban green areas in the Mediterranean environment (Cassaniti & Romano, 2011).

Weeds collected allowed us to learn about the potential plant inclusions outside the planting, related to the anthropogenic environment of the test area.

5 Conclusions

The occurrence of hot-dry years can be a real discriminating factor for the plant species to be used in urban green areas in Mediterranean cities. In these conditions, the rapid rooting and growth of *H. portulacoides*, together with its rusticity, make it possible to obtain homogeneous green areas throughout the year in a reasonable time, saving water and maintenance costs; its height could play a role in intercepting rainwater before it reaches the ground. Even *R. prostratus* can be cultivated with low inputs, expanding the range of plant choice in street plantings. These plant species can be included in urban greening projects that can be implemented quickly and at low cost. As autochthonous plants, they can also have a strong impact in creative, participatory projects.

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Method for Analysing Individual Thermal Perception and Comfort of the Indoor Environment Using a Wireless Network of Low-Cost Sensors

Toky Rakotoarivelo and Bruno Malet-Damour

Abstract

The quest for novel methods to optimize building performance now extends to a meticulous examination of the individual to better quantify their real needs. Humans perceive their environment through various physiological sensors, which provide a detailed description of ambient conditions. In response, individuals decide to enhance or maintain their state based on sensations and preferences, a complex psychological, physiological and physical process. Literature underscores multisensory perception, while the interaction among multiple physical parameters can challenge conventional building design methods, occasionally detached from reality, as mathematical models tend to compartmentalize phenomena and introduce bias in comfort considerations. To construct a comprehensive database on multisensory interactions, rethinking measurement methods, often costly and arduous, is essential. This article presents a low-cost measurement system that synchronously and reliably integrates general environmental parameters, sensations and perceptions, demonstrating through experimental findings that the usual thermal parameters and other variables, such as light, can influence thermal sensation.

Keywords

Thermal · Comfort · Indoor · Perception · Sensor · Low-cost · Wireless

1 Introduction

Energy management is a significant contemporary challenge, particularly in the context of pressing environmental concerns. The building sector, in particular, grapples with the imperative to balance energy-intensive systems with the goal of achieving systematic thermal comfort. This equilibrium is centred on understanding the demand for cooling or heating, rooted in thermal sensation derived from physiological assessments of temperature fluctuations (Djongyang et al. 2010). Recent studies have broadened this perspective, revealing that thermal comfort is a complex interplay of thermal sensation and individual interpretation, known as thermal perception (Fanger 1973; Frontczak and Wargocki 2011; Humphreys and Nicol 1998).

This personalized thermal perception is pivotal in predicting individual comfort levels, yet it is influenced by various factors, including multisensory interactions shaped by occupants' environmental awareness. Researchers have developed tools to measure this intricate thermal perception, such as the data logging system designed by Carre and Williamson (2018) and the ComfortBox by Alavi et al. (2017). However, these tools have limitations, requiring on-site presence or leaving the specificity of participant equipment unclear.

Our work introduces CaPITeN, an innovative tool integrating physical, physiological, and psychological measurements. CaPITeN adopts an individualized approach, utilizing state-of-the-art methods to measure environmental parameters for assessing thermal and visual perception. In this article, we outline the general aspects of CaPITeN and present its application in a pilot study involving a group of participants. The study builds upon prior work (Rakotoarivelo et al. 2021), offering insights that may shape various future scenarios in this domain.

T. Rakotoarivelo (✉) · B. Malet-Damour
PIMENT Laboratory, University of Reunion Island, Saint Denis, France
e-mail: toky.rakotoarivelo@univ-reunion.fr; trakotoarivelo@estp.fr

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2 Materials and Methods

Our innovative system, CaPITeN, combines "Capteur de mesure de la Perception Individuelle" (Sensor for Individual Perception Measurement or CaPI) and "Totem de mesure environnementale" (Environmental Measurement Totem or TeN) (NF EN ISO 2019). CaPI focuses on individual physiological parameters with strategically placed, non-invasive sensors. It includes an integrated capacitive LCD screen administering ISO 10551-compliant surveys, assessing indoor environmental aspects like thermal comfort and lighting quality.

On the other hand, the TeN module records ambient environmental parameters, including illuminance, UV levels, light hue, air and globe temperature, relative humidity, overall illuminance, air speed, skin temperature and heart rate (Rakotoarivelo and Malet-Damour 2023). These parameters were carefully selected based on previous research, and the sensors used Fig. 1 maintain an approximate Mean Absolute Error rate of 5%, calibrated through rigorous regression analysis.

CaPITeN operates through synchronized measurements and WiFi-enabled remote monitoring. It ensures real-time tracking with a dual data backup system onto a micro SD card. Built on open-source principles, the system prioritizes affordability and accessibility, simplifying development and encouraging replication. The central control unit is the ESP32 microcontroller.

A pilot experiment, conducted in a classroom for half a day, focused on six individuals aged 18–32. Natural ventilation and daylight were utilized exclusively. Ten students initially participated, but four were excluded for non-compliance. Participants, seated in quiet study, maintained a targeted metabolic level of 1 Met. Communication and attire changes were prohibited. Each wore a monitoring device for two hours, answering a survey at the experiment's start and at half-hour intervals.

3 Results and Discussion

The subjective investigation of this pilot experiment findings is presented in the (a) section of referenced Fig. 2. Each individual's assessment appears as a histogram, depicting their perception on the 7-point ASHRAE scale (NF EN ISO 2019). These histograms showcase outcomes from three perception surveys for a comprehensive view of participants' thermal and visual perceptions. The two-hour exposure divided into five phases aligns with survey responses. Figure 2b segment displays minute-by-minute air temperature fluctuations during phases and mean skin temperature. Air temperature rises from 20.5 °C to nearly 22.5 °C in the initial phases, slightly declining to stabilize around 21.8 °C. Figure 2's final part illustrates illuminance values at eye level and environmental illuminance evolution. A peak in illuminance during Phase 2 coincides with outdoor sunshine, followed by a gradual decrease, maintaining average indoor illuminance constant until the assessment's end.

The graphical juxtaposition representations allows for a comprehensive comparison between shifts in the physical environment, participants' psychological responses, and physiological variables, facilitating a targeted analysis of individual and group perceptions. Trends in thermal perception votes reveal a gradual shift towards perceiving colder sensations over time. Despite this, the mean skin temperature curve shows minimal change, suggesting that the observed discomfort may not be solely attributed to the modest 0.5 °C variation in air temperature during Phases

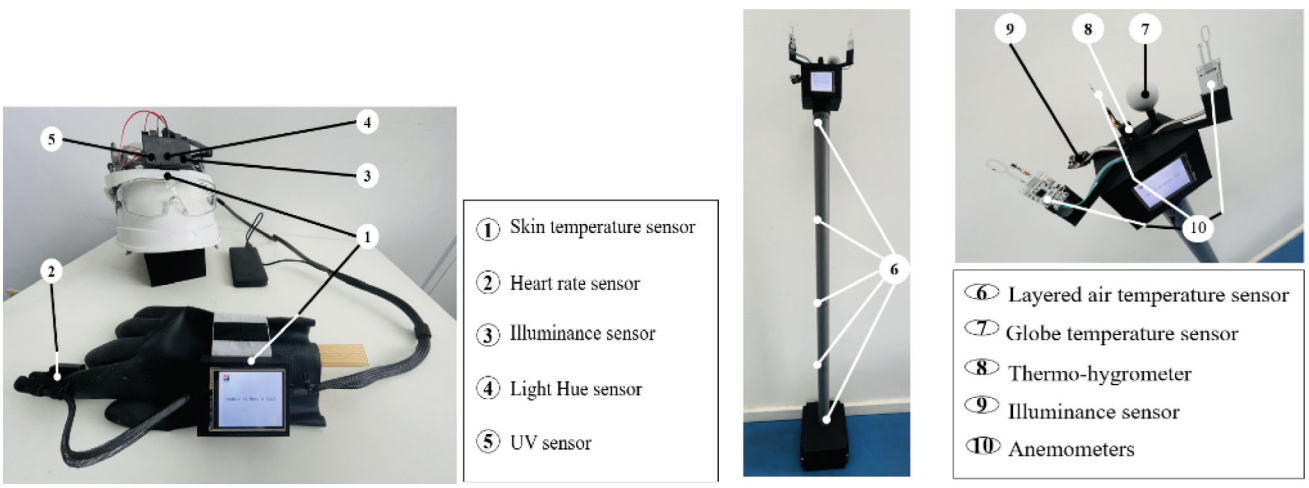


Fig. 1 Left—CaPI/Right—TeN

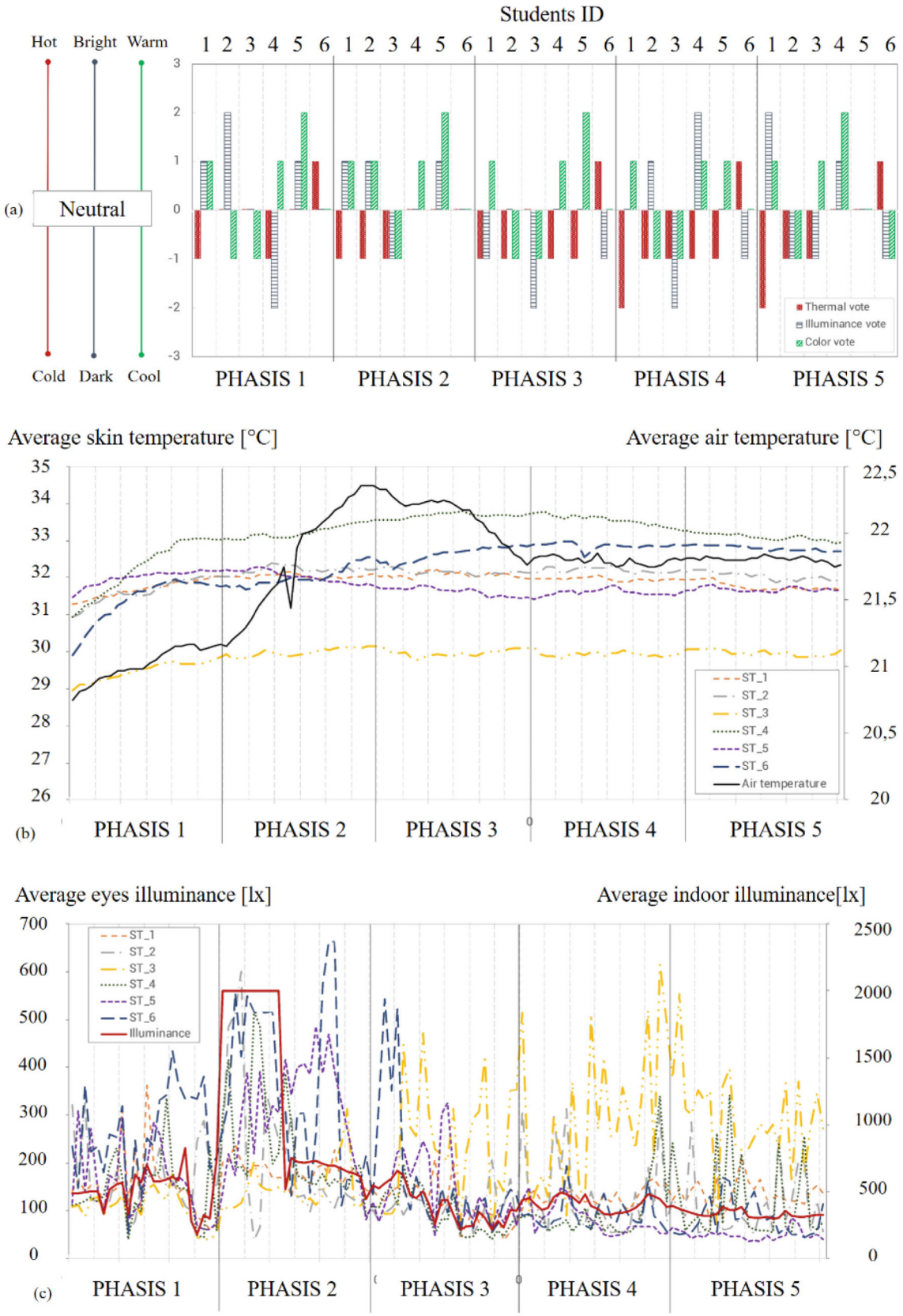


Fig. 2 Graphs of the data monitoring of **a** thermal perception, visual perception, colour perception, **b** evolution of average air temperature and mean skin temperature and **c** average indoor illuminance and Eyes level illuminance

3 and 4. Environmental factors, such as low airspeed and consistent relative humidity at around 60%, may play a role in participants' discomfort. These findings suggest a nuanced relationship between environmental conditions and human perception, emphasizing the importance of considering multiple factors in such analyses.

Furthermore, alterations in average indoor lighting conditions could contribute to thermal perception shifts. Diminished light levels might have impacted how participants perceived the thermal environment, potentially inducing a sense of colder temperatures. This notion aligns harmoniously with the Indoor Environmental Quality (IEQ) framework, emphasizing that overall comfort is shaped by factors extending beyond temperature, encompassing various sensory experiences.

The application of CaPITeN empowers the formulation of fresh hypotheses concerning the intricate interplay of diverse sensory elements in shaping holistic comfort experiences.

4 Conclusion and Perspectives

This article presents an innovative approach to using a low-cost technological solution to synchronously and reliably measure an individual's perceptual conditions. CaPITeN has provided an innovative means of analyzing the complex interaction between environmental parameters and individual perceptions. The design of this pilot study provides a solid platform for uncovering possible underlying mechanisms influencing thermal perception and perhaps other links. Supported by empirical results, the study shows how standard thermal parameters and auxiliary factors such as illuminance can influence thermal perception, reinforcing multisensory perception. The findings from this pilot study are intriguing; however, due to the limited number of participants and the duration of the experiment, it remains imperative to incorporate a validation dimension for further robustness and generalizability. We will then integrate other measured parameters, such as colour temperature, into the analysis to highlight the relationships governing an individual's perception and the temporal evolution of environmental variables. Statistical correlation tools will enable us to derive an initial model of thermo-photometric perception, offering new perspectives to a concept we support: sensory compensation.

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A Bibliometric Analysis of Updraft Passive Ventilation Applications in Residential Buildings

Modar Ali

Abstract

Research on energy efficiency in buildings and related policies has been extensive. Despite the residential sector accounting for over a quarter of EU final energy consumption in 2023, progress has been slow. Natural ventilation, a key low-cost design method for reducing cooling energy and ensuring indoor comfort, is the focus of this study. The aim is to analyze current publication trends, specifically regarding the use of updraft design techniques in residential buildings. The data is collected from Scopus and Web of Science as scientific databases and then examined. Parameters studied include keyword clusters, geographic distribution, publication count and their affiliated research fields. China, the UK, Iran, the US and Malaysia produced 65% of the total publication output, with 65% of the documents affiliated with the fields of engineering, energy, and environmental science. The analysis shows a rapid rise in publications from 2012 and highlights the current trends and possible future gaps of the discussed topic.

Keywords

Natural ventilation · Passive ventilation · Residential sector · Energy efficiency · Updraft

1 Introduction

In recent decades, significant progress has been made in energy efficiency regulations and policies for buildings, primarily focusing on industrial structures. However, residential buildings have lagged behind (Matsumoto et al. 2022), leading to an increased share of energy consumption, accounting for approximately 27% of the EU consumed energy (Eurostat 2023). The local climate and weather, the surrounding built environment, and the users' cultural background are the main factors influencing the residential buildings' energy performance (Matsumoto et al. 2022).

When airflow is vertically driven by buoyancy and crosswind effects, it is described as 'Updraft airflow'. Even though buoyancy is the main driving force, crosswind is often influential (Esmail et al. 2022). There are numerous examples of natural ventilation in the literature utilizing updraft airflow, often coupled with solar heating in solar chimneys (Bansal et al. 1993; Maghrabie et al. 2022; Zhang et al. 2022; Fine et al. 2022; Katona et al. 2021; Ali et al. 2021).

In solar chimneys, solar energy is utilized to induce vertical air movement; the top behaves as an outlet through which heated air is expelled from the building and replaced by cooler air through bottom openings (Bansal et al. 1993). Studies explore the factors influencing the solar chimneys' performance (Maghrabie et al. 2022), such as chimney size, solar radiation properties (Zhang et al. 2022), the incoming-air temperature and the building's overall height (Fine et al. 2022). The role of the efficiency of Venturi-topped solar chimneys in enhancing passive ventilation has also been investigated (Katona et al. 2021; Ali et al. 2021).

Researchers have conducted wide-scoped bibliometric studies on the topics of green building research (Zhao et al. 2019; Li et al. 2021), natural ventilation in vernacular buildings (Pan et al. 2024), sustainable innovations in sustainable housing (Moghayedi et al. 2021) and evaluating thermal comfort when operating passive ventilation in buildings (Abuhussain et al. 2023). This paper investigates updraft passive ventilation in residential buildings as a research topic by revealing the related research output and trends. Therefore, the novelty of this study lies in exposing research gaps in its specific defined scope and highlighting the potential improvement of the residential building sector by utilizing the relevant passive ventilation techniques.

M. Ali (✉)
Energy Design Research Group, Faculty of Engineering and Information Technology, University of Pécs, Pécs, Hungary
e-mail: ali.modar@mik.pte.hu

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2 Methods

This study employs bibliometric analysis to detect the research trends of the chosen topic. This method tracks the changes in the topic during a specified period offering insights qualitatively and quantitatively (De Bakker et al. 2005). By creating a publication profile, this approach not only enables researchers to assess current research activity but also facilitates further investigation in the field (Rey-Martía et al. 2016). This study uses two of the biggest academic research engines: the Web of Science (WOS) and Scopus (Agrifoglio et al. 2021), as they extensively cover high-impact literature across various fields of study, with their suitability for the chosen investigation (Gorraiz and Schloegl 2008). This study explores relevant literature on updraft natural ventilation in residential buildings using specific keywords that contain building elements commonly utilized for updraft airflow induction. It investigates research trends, including publication frequency, geographic distribution and fields of research. Additionally, it employs VOSviewer software to visualize and analyze keywords. The date of searching was July 21, 2023. The number of collected publication items was 150 through WOS and 166 through Scopus. Some of the results were excluded based on the publication period (starting from 1996), and the language (English). The final comprised number after applying the exclusion measure was 149 through WOS and 162 through Scopus.

3 Results and Discussion

Figure 1 shows the acceleration in the research outputs regarding the investigated topic. It begins in the mid 90's and peaks in 2019 and 2021. These peaks reflect the increasing attention to the topic which major correlating events could explain; the global energy price surge due to geopolitical reasons has pushed researchers worldwide to investigate energy-efficient solutions for residential buildings (Owjimehr et al. 2023). The other correlating reason is the widespread COVID-19 pandemic which highlighted the necessity of providing acceptable indoor air quality in buildings (Moghadam et al. 2023).

Table 1 presents the top three study fields with which the collected publications are affiliated. Their geographic concentration peaks in regions with hot–dry climates (Iran, Saudi Arabia, China, USA, Mexico and Italy) which is expected for many of the mentioned countries since their vernacular buildings developed to cope with their local climate. However, the concentration also peaks in regions with wet or tropical climates (India, the UK, Thailand and Malaysia) which highlights the possible implication of passive ventilation strategies in non-typical climate zones. Upon analyzing the gathered studies based on their case study size, nearly half of them focus on either multi-storey residential buildings (24%) or have a limited experimental scope (24%). Around 16% of the studies are centred on family house buildings. The remainder explores single rooms or theoretical approaches. Table 2 shows the top-cited publications in Scopus.

Figure 2 presents a visualization of the primary topics in the literature using VOSviewer, based on keywords with a minimum of 5 times appearance in both databases. The visualization highlights themes with considerable relevance such as comfort, thermal performance and energy efficiency.

4 Conclusions

This bibliometric analysis reveals the research production scheme of the topic 'updraft natural ventilation in residential buildings'. Findings indicate an increasing interest in this topic since its inception in 1996, peaking in 2019 and 2021. Research is conducted globally, including in regions unfamiliar with updraft ventilation, such as tropical climates, offering opportunities for experimentation in

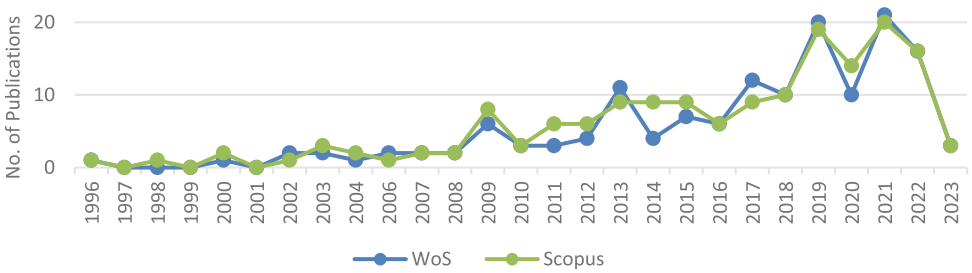


Fig. 1 Yearly publication output

Table 1 Top three study fields with which the collected publications are affiliated

Scopus	Share (%)	WOS	Share (%)
Engineering	34	Energy fuels	24
Energy	17	Engineering	23
Environmental science	13	Construction building technology	21

Table 2 Metrics of the top-cited publications in Scopus

References	Year	No. of citations	Type	Passive ventilation focus
Mathur et al. (2006)	2006	155	Research article	Roof solar chimney
Khedari et al. (2000)	2000	135	Research article	Solar chimney
Montazeri and Azizian (2008)	2008	113	Research article	One-sided wind catcher
Zhai et al. (2011)	2011	106	Review	Solar chimney
Prajongsan and Sharples (2012)	2012	87	Research article	Ventilation shafts

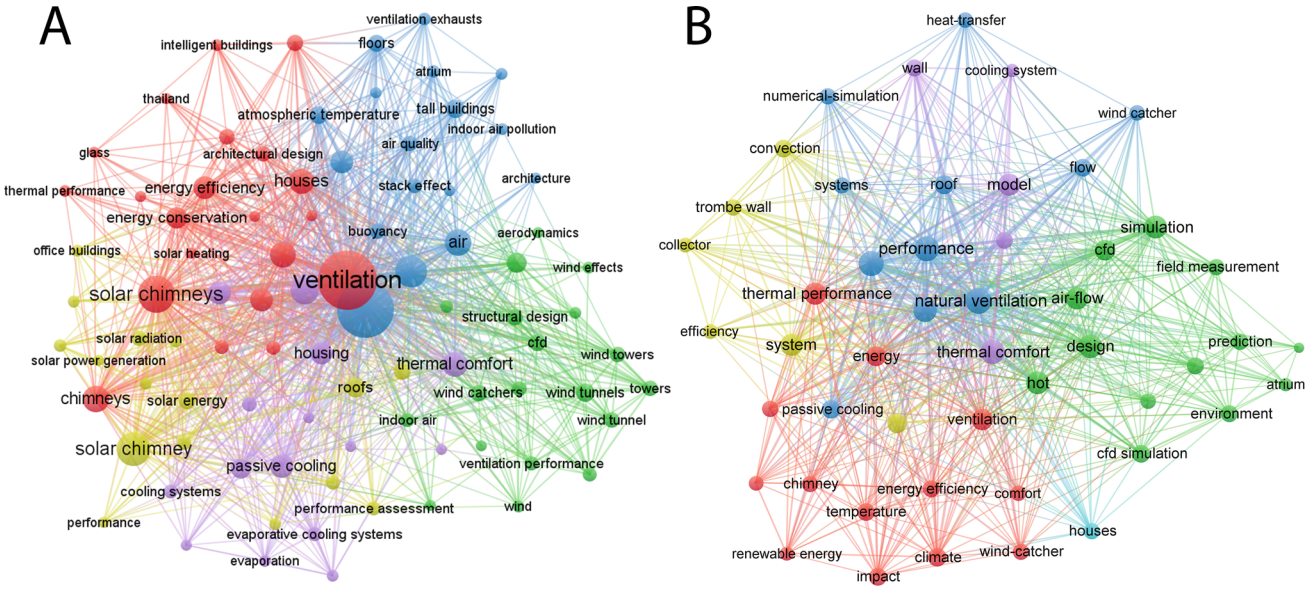


Fig. 2 Distribution of keywords clusters in Scopus (A) and WOS (B)

various climate zones. Engineering and energy fields dominate the publications, with architecture lagging behind. The analysis suggests the need for more architectural studies to explore the full potential of updraft ventilation, particularly in climates requiring customized solutions.

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Study of Fog/Haze and Its' Impacting Factors, in Different Cities of Indo-Gangetic Plain

Kanchan Lakra and Kirti Avishek

Abstract

The winters of Indo-Gangetic Plains are not only subjected to chilly weather but also to fog/haze. The air quality during the winters also worsens along with low visibility. There are numerous studies conducted on fog/haze but they are either studied considering the meteorological factors or the anthropogenic pollutants, but rarely combined. The above-mentioned reasons make it crucial to study the combined effect of meteorological components and pollutants in the formation of fog/haze. And foggy day trend is fundamental for future predictions. Hence, the objective of this study is to analyze the trend of foggy days and to identify the major contributing factors to fog/haze formation which sets the study apart from the previous body literature. The study is conducted for seven major cities: Delhi, Lucknow, Patna, Kolkata, Amritsar, Patiala and Hisar. The study was performed using the NOAA NCEI GSOD dataset, ISD as meteorological data and the Live Air Quality Data of monitoring stations provided by the CPCB. Stepwise regression analysis is employed to identify the major contributors. $PM_{2.5}$ was identified as the most important followed by Wind Speed and Dew Point depression. The R^2 values ranged from 62 to 89%. All the cities except for Kolkata showed an increasing trend in the number of foggy days observed through the past three decades. The study's findings are in harmony with the results of similar studies. The R^2 value may be because the atmosphere of cities is very complex; there might be other numerous factors involved all of which may be interlinked making it highly complex to be simply explained just by those two sets of factors. An increasing number of foggy days may have been the result of increasing air pollution in the cities. Sure, humans cannot control the meteorological factors but the sources of anthropogenic pollutants can be controlled, specific to that city, with the identification of major contributors in the occurrence of fog/haze.

Keywords

Fog/haze · Indo-Gangetic Plain · Meteorological factors · Air pollutants

1 Introduction

The cities located in the Indo-Gangetic Plains are among the most heavily populated and polluted cities in the world. These cities are prone to increased levels of air pollutants and this gets aggravated during the winter season (Ghude et al. 2017). The region is particularly susceptible to the formation of fog and haze due to its climatic and geographical factors along with the air pollutants that are either generated in the cities or travel into the region with the winds (Chauhan and Singh 2017; Singh 2018). The formation of fog and haze not only poses a challenge to the transportation sector but also to public health which in turn are indirectly responsible for other financial losses too (Kulkarni et al. 2019).

The worsening visibility and air quality in the cities of Indo–Gangetic Plain due to fog and haze is a concerning issue and it is important to understand the role of the factors involved in its formation (Lakra and Avishek 2022). Thus the study aims to identify the individual set of factors responsible for reduced visibility in—Delhi, Amritsar & Patiala (Punjab), Hisar (Haryana), Lucknow (Uttar Pradesh), Patna (Bihar), and Kolkata (West Bengal) taking into account the combined effect of Meteorological factors (daily mean of—Minimum Temperature, Maximum Temperature, Average Temperature, Dew Point, Wind Speed, Dew Point Depression and Relative Humidity) and air pollutants (sulfur

K. Lakra (✉) · K. Avishek
Birla Institute of Technology, Mesra, Ranchi, India
e-mail: phdcee10053.18@bitmesra.ac.in

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dioxide—SO_2, carbon monoxide—CO, nitrogen dioxide—NO_2, ozone—O_3, benzene—C_6H_6, toluene—$C_6H_5CH_3$, particulate matter ($PM_{2.5}$ and PM_{10}), nitrous oxide—NO, ammonia—NH_3, and oxides of nitrogen—NO_X).

2 Materials and Methods

The study takes into account only the winter months for the study, specifically December, January and February when the fog/haze formed is more persistent and is a characteristic climatic phenomenon of the region (Sawlani et al. 2019; Srivastava et al. 2016). For the study, the air pollutants data was acquired from the website of the Central Pollution Control Board (CPCB) and the meteorological data was from the Global Summary of the Day (GSOD) data collection provided freely by the National Centers for Environmental Information (NCEI), National Climatic Data Centre (NCDC) of the National Oceanic Atmospheric Administration (NOAA). Daily mean average data of both meteorological variables and air pollutants was considered for the study. For the trend analysis 33 years, for the model different set of years were taken into account depending upon the availability of pollution data.

The data was initially preprocessed by removal of duplicate data and missing data. The missing percentage of data was less than 10%. For pollution data, the average value was calculated from the values provided by the air quality monitoring systems located within the 15 km radius of the weather stations. The Dew Point depression and Relative Humidity are crucial influencing variables that were absent from the initially acquired raw data so they were later calculated. The Dew Point Depression was calculated by subtracting the Dew Point temperature from the average temperature ($T - T_d$) and the Relative Humidity was calculated using the following formula (Lawrence 2005)

$$\mathrm{RH} = 100 \left[\frac{e^{\frac{17.625*\mathrm{Dp}}{243.04+\mathrm{Dp}}}}{e^{\frac{17.625*T}{243.04+T}}} \right], \tag{1}$$

RH = Relative Humidity (%), Dp = Dew Point (°C) and T = Average Air Temperature (°C) and 17.625 (°C) and 243.04 (°C) are revised Magnus coefficients (Alduchov and Eskridge 1996).

Stepwise regression analysis was performed employing the SPSS tool. The stepwise regression was chosen for the study to specifically identify the set of controlling factors responsible for reducing visibility in each of the selected cities. The algorithm is based on the concepts of multiple regression model and involves two steps, namely forward selection and backward elimination. In the forward selection step, the models start with an empty model hand the variables are added into it iteratively based on their significance until adding more variables does not improve the model, if p-value < 0.05 the model is selected. In backward elimination, the complete model starts removing from the least significant variable iteratively and it continues to do so until removing more variables does not prove to improve the model (Väliaho and Pekkonen 1976).

3 Results

Figure 1 represents the progression in the number of foggy days from 1990 to 2023. In the figure, it can be seen that all the cities have observed an increase in number of foggy days, apart from Kolkata. Though the trend observed is not very significant.

The results from the stepwise regression analysis are represented in Table 1. In the analysis for identification of crucial predictors, it was found that Dew Point Depression was identified as the most prominent visibility-affecting factor in the cities of Amritsar, Delhi, and Patiala. Relative humidity was identified as prominent in Hisar and Kolkata, $PM_{2.5}$ in Lucknow and CO in Patna. From the selected list of predictors the R^2 value for most of the selected cities ranged around 75%, apart from Kolkata which was 60% and for Patna it was 90%. The model is statistically significant as all the cities have p-value < 0.0001. Considering the overall impact of variables in the cities, it could be said that $PM_{2.5}$ was the most significant variable as it was selected as significant in six cities out of seven cities, followed by Dew Point depression and Wind Speed that were selected as significant in five cities.

4 Discussion

The cities located in the western part of Indo-Gangetic Plain, i.e. Amritsar, Patiala, Hisar and Delhi have identified Dew Point depression, $PM_{2.5}$ and Relative Humidity as the top three significant factors. From this result, it can be said that these cities have reduced visibility attributing mostly to high moisture content in the atmosphere, to small Dew Point depression leading to saturation being attained faster and to the $PM_{2.5}$ acting as cloud condensation nuclei (CCN) leading to formation of fog. $PM_{2.5}$ is again responsible for haze. If we take into account all the considered cities for the study average temperature, NO_2 and C_6H_6 appeared significant only in one city each. This might be because the average temperature is not a clear representation of the tempera-

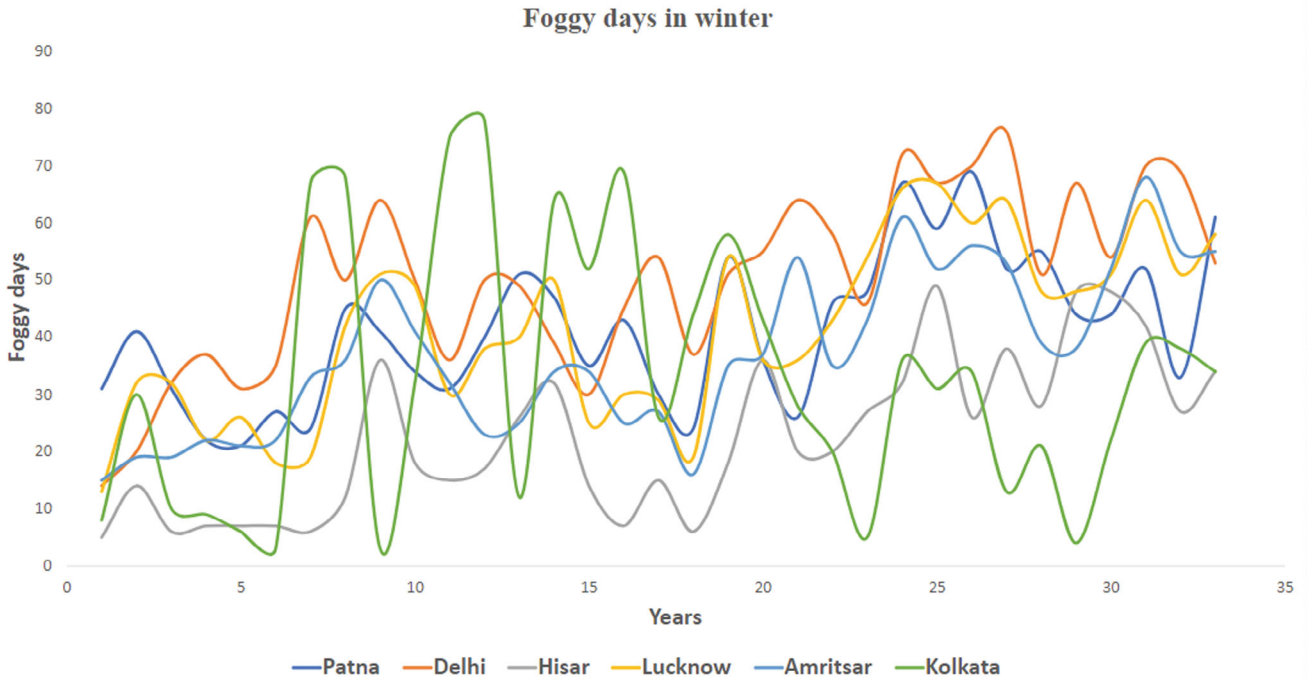


Fig. 1 Trend of foggy days over the past three decades (1990–2023)

Table 1 Results of stepwise regression analysis

City	Period	R^2	Adjusted R^2	Significant variables
Amritsar	2017–2023	0.749	0.744	Dew point depression, $PM_{2.5}$, wind speed, SO_2, $CH_3C_6H_5$, maximum temperature, O_3, minimum temperature, dew point and NH_3
Delhi	2015–2023	0.742	0.739	Dew point depression, $PM_{2.5}$, average temperature, NH_3, minimum temperature, wind speed, $CH_3C_6H_5$, SO_2, PM_{10} & NO
Hisar	2019–2023	0.747	0.743	Relative humidity, $PM_{2.5}$, maximum temperature, dew point depression, NO_X & O_3
Kolkata	2019–2023	0.602	0.590	Relative humidity, C_6H_6, wind speed, $CH_3C_6H_5$, dew point depression, minimum temperature, maximum temperature, CO, NO_X & $PM_{2.5}$
Lucknow	2020–2023	0.786	0.782	$PM_{2.5}$, dew point, NO, wind speed, relative humidity and NH_3
Patiala	2020–2023	0.710	0.703	Dew point depression, $PM_{2.5}$, dew point, wind speed, NO_X, minimum temperature, CO, NO, NO_2 and SO_2
Patna	2020–2023	0.899	0.897	CO, maximum temperature, PM_{10}, $CH_3C_6H_5$, relative humidity and O_3

ture required for fog/haze formation and NO_2 and C_6H_6 do not directly influence visibility. Though according to the model, the variables selected for the city of Patna give the highest R^2 value, and the selected variables for Patna are very different from those selected for other cities where CO is the major contributor to fog/haze despite it not being a direct contributor. Due to all these factors, there has been an increase in the number of foggy days in all the cities except for Kolkata and even the selected set of variables from the analysis cannot explain the reduced visibility in the city. This calls for a more in-depth study of the interaction of the meteorological factors with the air pollutant specific to the location.

5 Conclusions

From the analysis, it is clear that the atmosphere of an urban areas is highly complex and the reason for reduced visibility and poor air quality cannot be attributed to just meteorological factors or the air pollutants alone. It is the result of their combined effect along with other factors like their geographical location, the terrain of the area. Not all locations are the same so individual investigation is required to further our understanding of urban climatology, to develop better fog/haze forecasting systems, to better monitor the changing climate of the specific area and finally, so that the local administrative bodies and policymakers can take better

measures for controlling fog/haze related accidents. Though it is difficult to control the climate, it is relatively easier to control air pollution by taking good mitigation measures.

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Quality of Life, Eco-friendly Mobility Choices and Built Environment—A Case Study of Poland

Agnieszka Szmelter-Jarosz and Michał Suchanek

Abstract

Context/Purpose Changing lifestyles, urban sprawl, and pandemics caused changes in people's urban and suburban mobility. On the other hand, traffic is responsible for most of the air pollution, causing health problems and worsening self-assessed quality of life. Therefore, our study has to explore what factors affect eco-friendly travel choices and how the urban built environment and mobility offer should be rearranged. *Methods* There are 6794 total observations gathered from respondents living in Polish cities and suburban areas. The data was collected in three consecutive years (2020–2022) from a random stratified sample via a CAWI/CATI survey. Covariance-based structural equation modelling is used to verify the hypotheses regarding urban and suburban residents' environmental beliefs and attitudes and their relationship with the urban environment. *Results* The findings indicate a significant effect on the pro-ecological behaviour of the urban and suburban citizens in the urban environment coming from the car attachment—higher values indicating a lower proneness to ecological behaviour. Similar results are observed among residents having children aged 0–15 and fully employed. On the other hand, the higher use of mobility-related mobile applications resulted in more ecological travel behaviour. There is also a strong mediating effect by the quality of life (Kessler's six non-specific psychological distress scale), where people with higher self-assessed distress levels display lower eco-friendly beliefs and attitudes. The model represents an acceptable goodness of fit. *Interpretation* There are groups with very eco-oriented travel choices (young adults and older adults) and groups resistant to changes in travel behaviour to more ecologically oriented (people in their prime age) while reporting lower quality of life. We discuss possible solutions for changing their opinions and beliefs, including the mobility offer and changes in the urban built environment. *Conclusion* Our study provided in-depth, valuable insight into possible changes in cities and suburban areas which may help to create ecologically oriented travel choices in urban and suburban areas in Poland, covering 80% of the country's population.

Keywords

Urban mobility · Built environment · Mobility offer · Suburban areas · Urban sprawl

1 Introduction

Evolving lifestyles, continuous urban sprawl in bigger cities in Poland, and the disruptive influence of pandemics and, later in 2022, war in Ukraine have induced substantive changes and disrupted trends in urban and suburban mobility patterns. Some of the changes in mobility choices had short-term character, while others were more long-term (Szmelter-Jarosz and Suchanek 2023) and the long-lasting changes were rather not caused by sudden events. Additionally, the external costs of car mobility have worsened the quality of life, especially for urban and suburban residents. Consequently, our investigation's focal point and aim resides in comprehensively elucidating determinants that influence adopting eco-oriented mobility patterns. As a result, our research endeavours to delve into the set of elements that influence the decisions of individuals on how to plan and carry out everyday travels in Poland. No similar study existed in 2023 when we prepare our paper. Finally, we propose some changes helping to achieve an optimal restructuring of the urban landscape and the mobility environment,

A. Szmelter-Jarosz (✉) · M. Suchanek
Faculty of Economics, University of Gdańsk, Gdańsk, Poland
e-mail: agnieszka.szmelter-jarosz@ug.edu.pl

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to foster the development of more sustainable and ecologically friendly modes of transportation.

The literature on a similar topic discusses the conflict between short-term gains for car users and long-term losses to society, the resistance to behavioural changes due to decreased comfort and freedom (Steg and Gifford 2005). Vogt et al. (2020) indicate the importance of the impact of the design of the built environment on place value and quality, thereby influencing the quality of life. Then, Ivanescu (2023) emphasises the influence of various factors such as socio-demographic factors, land use, transportation infrastructure, travel cost and the importance of sustainable mobility and community involvement in shaping urban mobility-related projects. Finally, Fabris et al. (2023) provide a comprehensive analysis of the implementation and impact of strategies like the 15-minute city, Tactical Urbanism and Superblocks in global cities, evaluating their feasibility for sustainable urban transition and their role in addressing health, social and economic inequities, especially in the context of the COVID-19 pandemic. The general conclusion drawn from our literature review is that there is a need to build more resilient cities and adapt to present and future challenges. However, it will depend on people's mobility choices and willingness to be eco-friendly in that area.

2 Materials and Methods

After the literature review, we prepared the survey questionnaire and conducted the pilot study with 47 respondents. We expected the following results:

- Car-oriented city users present lower eco-friendliness and quality of life level (Steg and Gifford 2005),
- Users of mobility applications (e.g. route planners including different modes of transport and use of the infrastructure) will present similar result (Vogt et al. 2020),
- The analogous effect should be shown in the group of parents having young children (0–15 years old) (Westman et al. 2017) and in the group of full employed city users (Frey 2010).

The questionnaire included three parts: 14 questions about mobility choices in which in five included statements regarding the built environment related to mobility infrastructure, seven questions about the quality of life and six questions about the socio-economic characteristics of the surveyed person. After the questionnaire validation, we collected information via CAWI/CATI survey from a total of 6794 people who live in cities and suburbs in Poland. This data was gathered over three years, from 2020 to 2022 (in late October 2020 $n = 2000$, in late October 2021 $n = 1700$, in early November 2022 $n = 3094$). Stratification of the research sample was always made in the same way: random sampling was made based on the gender, age group and place of living of respondents. For the sampling, only residents of cities and suburban areas were surveyed, but suburban areas were the functional urban areas assigned to 58 cities in Poland (Functional Urban Areas 2023).

To check the relations between people's attitudes, opinions and their choices, partial least squares structural equation modelling (PLS-SEM) was used to verify the hypotheses regarding urban and suburban residents' environmental beliefs and attitudes and their relationship with the urban environment. The fundamental approach of estimation is PLS-SEM. As opposed to covariance-based structural equation modelling, it uses a component-based estimate approach. PLS-SEM fits a composite model to the data instead of a common factor model to the data, in contrast to covariance-based techniques to structural equation modelling. It maximises the amount of variance that is explained in this way. The PLS-SEM algorithm employs bootstrapping because the variables' distributions are skewed and non-normal. Instead of utilising parametric assumptions to judge the accuracy of the estimates, this non-parametric resampling method evaluates the variability of a statistic by looking at the variability of the sample data. Following Davison et al. (2003), this finding can be applied to PLS-SEM because it is incompatible with the distribution-free character of PLS-SEM to make assumptions about some parametric underlying distribution.

3 Results

The results derived from the analysis unveil a substantial influence exerted by car attachment on the pro-ecological attitudes of urban and suburban inhabitants. By addressing these multifaceted dimensions, we elucidate perceptual and behavioural change within the demographic subsets that presently manifest reluctance. This strategic course of action promises to foster a more harmonious and ecologically oriented urban mobility landscape. We have noticed that some groups of people, more precisely young (younger Y generation, also Z generation, generally born after 1990) and older adults (especially born before 1962), really like to choose eco-friendly ways of travelling. People in their middle years (X generation and older Y generation, so people born between 1963 and 1990), do not want to change how they travel to be more eco-friendly, even though they say their quality of life is not so good. They usually have children aged 0–15, are full-time workers.

There is also a strong mediating effect by the quality of life (Kessler's six non-specific psychological distress scale shown in the Figure as NSPD), where people with higher

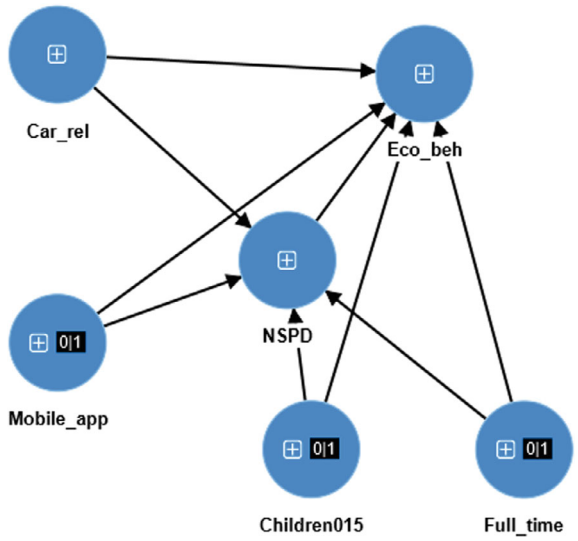


Fig. 1 The final PLS-SEM model for the surveyed groups in 2020, 2021, 2022

self-assessed distress levels display lower eco-friendly beliefs and attitudes. The model is presented in Fig. 1 with all the significant paths with a $p < 0.05$. The model represents an acceptable goodness of fit with RMSEA < 0.07 and both CFI and NFI above 0.9.

4 Discussion

As mentioned, there are groups with very eco-oriented travel choices (youngest adults and oldest adults) and groups resistant to changes in travel behaviour to more ecologically oriented (middle-aged people) while reporting lower quality of life. While analysing the statistically significant variables, it is clear that parents are less willing to use eco-friendly transport means because of the comfort. Usually, having children is stopping developing eco-friendly choices because of commuting to school when usually one-way travel is without children and with children the other way. This result confirmed Frey's previous conclusion (Westman et al. 2017). These findings suggest that interventions to promote active transport for children should focus on improving road safety, building social trust and addressing the influence of parental driving behaviour.

Also, if the person assesses the quality of life is lower, the eco-friendliness of this person is lower as well. Full-time workers and parents usually show it, so people managing their time more strictly. If so, it is clear that the life stage defines the quality of life and also mobility choices and patterns (cumulated information about individual mobility choices builds mobility patterns). Research consistently shows that long commutes, often associated with full-time employment, can lead to lower life satisfaction (Westman et al. 2017). This is particularly relevant in the context of urban sprawl and the prevalence of car ownership, which can make public transport less attractive (Steg and Gifford 2005; Ivanescu 2023). High residential density alone does not necessarily lead to sustainable transport, with factors such as attitudes, socio-demographics and public transport availability also playing a significant role (Szmelter-Jarosz and Suchanek 2023). Furthermore, the environmental costs of travel are influenced by, e.g. income (Ivanescu 2023).

However, the survey year was not indicated as the important factor, so shaping the mobility patterns is a long-term process and is resistant to short-term disruptions, as mentioned by Fabris et al. (2023). It is a long-term process impacted by everyday life characteristics, opinions and attitudes of people, which can change in the short term because of sudden event (e.g. pandemics) but are resistant to them in the long term.

We discuss possible solutions for changing their opinions and beliefs, including the mobility offer (new legal solutions, restricted urban areas, more integrated mobility offer, adjusting the offer to the mobility demand in suburban areas and many others) and changes in the urban built environment (e.g. access to all the needed points of sales in walking distance, access to the stations, ease of using mobile apps and others). We are also thinking about ways to change the opinions and beliefs of different age groups (the communication methods and channels and content adjusted to the age groups' preferences). One idea is to improve the options for getting around, like having better public transportation and access to low-cost bikes and e-scooters. We are also considering changing how the cities are designed to make choosing eco-friendly travel easier (e.g. implementing the 15-minute city concept).

5 Conclusions

Our research has given us a good understanding of how to make cities and areas around them more eco-friendly in Poland. This could lead to implementing mobility system changes, encouraging people to choose more environmentally friendly ways of travelling. This is important because the areas we looked at include about 80% of the country's population. Our study diagnoses the current state of people's mobility choices and their long-term resistance to sudden disruptions. Sudden events usually do not cause permanent or long-lasting changes. To catch the long-term trends in changing mobility patterns in Polish cities and suburban areas, our study should be deepened by qualitative research and continued by subsequent surveys.

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Method for the Analysis of Bottlenecks in Passengers Transport Systems: A Framework for System Design

Antonino Vitetta and Corrado Rindone

Abstract

The transport system generally provides services available in continuous space and continuous or discrete time. A particular case is related to discontinuous space in which the users have high disutility in mobility and specific transport methods are required to support decisions. The main objective of this work is to propose a preliminary framework of transport network design models in a discontinuous space. The analyzed components of the framework are divided into objectives, constraints, control variables, solution algorithm. The framework is adapted in the Strait of Messina reporting the first indications for the methods application; the area presents the characteristics of discontinuity for mobility.

Keywords

Transport system modelling · Network design · Sustainable transport system

1 Introduction

Transport allows people and business to perform their activities distributed in space and time. The transport system generally provides services available in continuous space and time (e.g. individual cars) or in continuous space and discrete time (e.g. transit services). A particular case is related to discontinuous space where there is a barrier in the transport services (e.g. Messina Strait): all the services, including the private car, are available in discrete time for the use of shared services needed to cross the barrier. In this context: the user's choice is influenced by the space-time discontinuity; the economic and social components of sustainability are of high disutility for citizens. Specific transport methods are required to support decision-makers and takers to design a sustainable transport supply system to mitigate the effects.

The main objective of this work is to propose a preliminary framework of transport network design models in a discontinuous space. The analyzed components of the framework are divided into: objectives (sustainability's components and different points of view); constraints (technical, external and behavioural); control variables (transport services); solution algorithm (metaheuristics). The proposed framework is adapted from the methods commonly used in continuous territorial systems for discontinuous contexts.

The framework components are adapted for the area of the Strait of Messina defining indications useful for the method specification. The area presents characteristics of discontinuity and the framework is specified through: aggregate components of supply and demand; actors involved; sustainability goals and points of view in planning.

After this introduction the paper has three sections. Section 2 describe the framework's methodology components. Section 3 illustrates the framework's adaption for the for the Messina Strait. Section 4 discusses the results and closes the paper with final remarks.

2 Framework's Methodology

The proposed framework adapts the methods commonly used in continuous territorial systems for discontinuous contexts. It considers the three sustainability's components (economic, social, environmental). By following a multi-criteria approach, the objectives are related to different points of view (user, real provider, MaaS operator, citizen).

A. Vitetta (✉) · C. Rindone
DIIES, Università deli Studi Mediterranea di Reggio Calabria, Reggio Calabria, Italy
e-mail: vitetta@unirc.it

C. Rindone
e-mail: corrado.rindone@unirc.it

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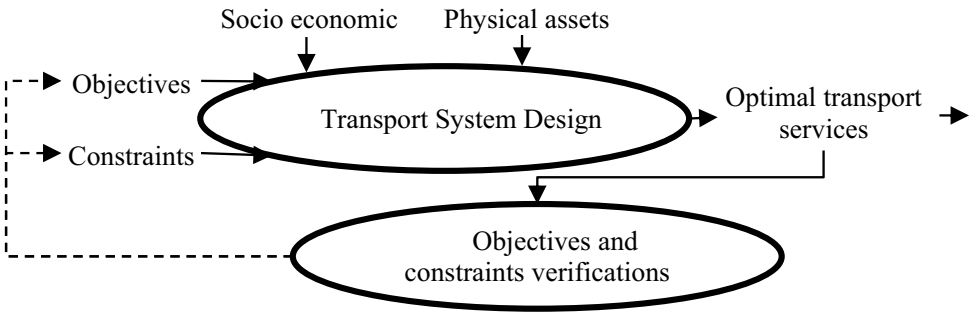


Fig. 1 Framework

Constraints comprehend law and guidelines, technical and behavioural aspects. The control variables are related to the transport services to be designed in a context in which several operators manage the services in the same transport system, in some cases in competition and they are relative to individual and collective services. The solution algorithm is based on metaheuristics considering the large number of discrete and continuous variables, multicriteria evaluation, nonlinear constraints and objectives. The framework consists of two steps (Fig. 1). The first step regards the transport system design (Cascetta 2013) aimed at individuating optimal transport services that generate effects according to the objectives and the constraints. The second step regards the verification of objectives and the respect of constraints with the variation of the control (or design) variables. If the designed services do not encounter the expectations of decision takers, it is necessary to re activate the process.

From a general point of view, the problem can be specified as the minimum of a multicriteria objective function, $\mathbf{\Phi}(\mathbf{f}, \mathbf{y})$, depending on the flow, $\mathbf{f}$ and control variable vectors, $\mathbf{y}$. The control variables and the flow have to respect the law and guidelines, technical and behavioural constraints ($\mathbf{S_y}$ and $\mathbf{S_f}$). The behavioural constraints are specified with static fixed-point problem vs. dynamic day to day and/or within day problem:

$$\mathbf{y}, \mathbf{f} = \text{Arg Min}_{\mathbf{y},\mathbf{f}} F(\mathbf{f}, \mathbf{y}), \text{ subject to } \mathbf{y} \in \mathbf{S_y}, \mathbf{f} \in \mathbf{S_f} \quad (1)$$

3 The Framework's Adaption for the Messina Strait

The study area of the Strait of Messina presents characteristics of discontinuity for people and goods mobility. The area comprehends the territories of metropolitan cities of Reggio Calabria, in the Calabria region and Messina in Sicilia region. The two territories are separated by the sea. There are maritime services for people (high speed and ro-ro) and freight (ro-ro and combined sea-railway) operating between Villa San Giovanni and Reggio Calabria ports, in Calabria, and Messina and Tremestieri ports, in Sicilia. In the area lives about 500,000 inhabitants and it is separated in two sub-areas by a branch of sea. In each sub-area there is a city (Messina and Reggio Calabria) and each city has about 200,000 inhabitants. The two sub-areas are connected by maritime services used on average by 20,000 users/day (Russo and Rindone 2023). The framework is adapted for the study area specifying: objectives, in relation to the sustainability components and different points of view of actors involved in planning; constraints, in relation to the behavioural component; control variables, in relation characteristics of transport services to be designed; solution algorithms, in relation to the possible heuristics to be adopted.

Objectives. Objectives regards the classical three components of sustainability (economic, environmental, societal). By considering the Sustainable Development Goals (SDG), it is necessary to reach the defined target for mobility in the strait of Messina. Many objectives could be considered (Vitetta 2022; Athanasopoulou et al. 2022).

Constraints. The discontinuity imposes the use of almost two mode of transport. As far as concerns people mobility, the travel user's choices are influenced by the discontinuity. Many constraints could be considered. Some possible constraints related to the specific problem are: 1. Law and guidelines, related to regulations; 2. Technical, related to means of transport and infrastructure characteristics; 3 Behavioural, related to travel choices in presence of a barrier.

Control Variables. Control variable represent the transport services characteristics in relation to the travel's components and different individual and/or collective classes. More in general, it is necessary to define the characteristics of information, transport and payments services following the Mobility as a Services paradigm (Maas 2022; Russo 2022). It is possible to design travel packages that include the combination of integrated transport services, information, ticketing and payments modes (Cirianni et al. 2023; Musolino 2022).

Solution Algorithm. The design problem requires the specification of a nonlinear multicriteria objective function, nonlinear behavioural constraints and mixed integer and continuous control variables. For the solution of real-scale problems, there are a high number of design variables. The solution of the problem requires the adoption of metaheuristics mainly based on genetic algorithms.

Table 1 Examples of sustainable objectives in relation different point of views (in italic character the discontinuity implications)

		Points of views			
		User	Real provider	MaaS operator	Citizen
Sustainability components[a]	E	• Max satisfaction • *Min discontinuity effects*	• Max efficiency • Max financial/ economic revenues	• *Max MaaS users*	• Max land values • Max effectiveness of public resources
	A	• Min noise, pollution, …	• Min energy resources	–	• Min noise, pollution, …
	S	• Max accessibility • Max safety	• Max workers safety	• *Min discontinuity effects*	• Max working opportunities • Max citizen safety
Classes of constraints[b]	L	• Driver license • Vehicle emissions limits	• *Authorization regimes* • Contracts' conditions	• ICT and data • Privacy	• *Territorial continuity* • Pollutants and noise limits
	T	• Vehicles performances (e.g. speed)	• Infrastructure capacity • Vehicle capacity • Financial budget	• Vehicle capacity • *Boat capacity*	• Land uses and urban restrictions • *Financial resources for maritime services*
	B	• Max utility and services choice		• Max revenue	• Quality of life
Control variables[c]	C		• *Intermodal hub* • Fleet of shared vehicles • Human resources • *Integrated timetables*	• Bundles packages • Information and payment services	• Urban land use • *Characteristics of terminal and infrastructures concession*
	I		• Traffic light phases • Speed limits • Parking location • System transit paths, stops, timetable	• Bundles packages • Information and payment services • Specific transit paths, stops, timetable	• Characteristics of low emission zone

[a]E = Economic, A = environmentAl, S = Societal; [b]L = Law and guidelines, T = Technical, B = Behavioural; [c]I = Individual services, C Collective services; *italic character is adopted for the variables that must be specified for the presence of a spatial discontinuity*

Table 1 reports some examples of objectives, constraints and control variables specified in relation to the classical sustainability components and the different points of views (users, real operators, MaaS Operators and citizen or collectivity).

By using the italic character, Table 1 underlines the variables that must be specified for the presence of a spatial discontinuity. This specific physical characteristic implies the necessity to more specify objectives, constraints and relative variables respect to a transport system serving people mobility in a continuous space. MaaS paradigm can be the correct approach for mitigating the effects produced by the spatial discontinuity (Militão et al. 2025).

4 Discussion and Final Remarks

With spatial discontinuities in transport systems, users must necessarily use collective transport systems with consequent waiting time before the service use. Travel is always through the use of multiple services/modes of transport. In these cases, the integrated design of the transport system is necessary to reduce the high users' disutility.

In this paper, a preliminary evaluation of the objectives, constraints and design variables to be adopted in a general framework for the transport network design has been opened, identifying them in the case of discontinuous transport services. In this case, specific objectives are needed that consider the particular, disutility to which users are subjected and demand models that simulate user behaviour in these systems.

The proposed framework requires future experiments in a real context, e.g. the Messina Strait area. Some studies and experiments in this area have already been developed by the same authors, but they must be considered pilot studies. The resulted framework can be useful for public and private operators, decision-makers and takers to support decisions.

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Author Contributions Rindone: framework, conceptualization, data curation. Vitetta: methodology, supervision, validation, Rindone and Vitetta: writing.

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Inhabitants' Perceptions of Public Urban Green Spaces: A Case Study of a Maghrebian City, Sousse

Rania Ajmi, Faiza Khebour Allouche, Aude Nuscia Taïbi, and Safa Belfekih Boussema

Abstract

Urban green spaces (UGS) have been linked to both an ecological environment and the well-being of city dwellers, enhancing the quality of life. The positive effects of UGS on individuals are usually dependent on the extent of these green spaces and their uses. However, the existing research on southern Mediterranean cities mostly focuses on the spatial pattern of UGS types, their surface area distribution, and the Ecosystem Services they provide but ignores the residents' preferences for UGS types and their social services. This study aims to evaluate and assess the individuals' perceptions and use of public green spaces in Sousse, Tunisia. Then, the findings will be compared with the current situation in our study area. This will help improve the condition of these green spaces and make them more functional for the residents. A total of 250 people responded to a face-to-face survey of close-and-open-ended questions. The survey questions were related to socio-demographic characteristics, and perceived characteristics of UGS. The respondents were randomly selected across the neighborhood of the green spaces in our study area. The data collected was analyzed using the RStudio program. The study revealed that the respondents valued green spaces and believed that it helped them to feel more relaxed and happier. Hence, they refer to UGS in terms of well-being and life in the first place (52%), plants in second place (20%), and beauty, cleanliness, and beautiful smell in third place (11%). Furthermore, regarding the participants "overall UGS demand, many participants (24%) mentioned the need for more public gardens, and more spaces with play areas for children (17%). Most importantly, they wanted better preservation and distribution around the city (11%). Our results highlight the complex challenge facing decision-makers and public actors in UGS planning, who must consider and integrate the residents" aesthetic and recreational needs. Therefore, in the context of land use policies, the methodology adopted can be reproduced in Meghrebian cities to identify the needs of inhabitants in terms of UGS and thus ensure a better quality of life and lessen inequality in cities.

Keywords

Public green spaces · Urban planning · Perception · Face-to-face survey · Well-being

1 Introduction

According to the MEA (2005), urban green spaces (UGS) offer a wide range of ecosystem services and personal benefits, including relief from stressful daily life (van der Berg et al. 2010), improvements to human well-being (Hystad et al. 2019), an enhancement to physical activity (Hunter et al. 2015), and better health (van den Bosch and Sang 2017). To increase social contact (Peters et al. 2010), cohesion, and recreation (Ugolini and Pearlmutter 2022), UGS also supports cultural ecosystem services. Public green spaces are an important asset for urban planning that must be both aesthetically pleasing as well as entirely functional to meet the demands and preferences of the inhabitants (Ryan 2011). Therefore, there is good evidence that

R. Ajmi (✉) · F. Khebour Allouche · S. Belfekih Boussema
Departement of Horticultural Sciences and Landscape, High Institute of Agronomic Science of Chott Mariem (ISA-CM), Sousse University, Sousse, Tunisia
e-mail: ajmi.rania.ep.ismail@gmail.com

National Agronomic Institute of Tunis, Lr GREEN TEAM (LR17AGR01), Carthage University, Tunis Mahrajène, Tunisia

R. Ajmi · A. N. Taïbi
Angers University, CNRS, ESO, SFR CONFLUENCES, Angers, France

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cleanliness and a sense of order in the environment can reduce mental stress and even depression, so well-being depends on specific features of green spaces that facilitate both social and physical outdoor activities as well as the quality of the greenery itself (Meyer-Grandbastien et al. 2020). This study aims to assess the perceptions of urban residents in Sousse, Tunisia, and their level of satisfaction with specific aspects of UGS.

2 Materials and Methods

During March, April, and May 2021, a survey of 250 Sousse city residents was conducted to assess their attitudes and use of public green areas in Sousse. The survey questions were related to socio-demographic characteristics, and perceived characteristics of UGS, including its availability, quality, accessibility, benefits, problems, and preferences of respondents regarding types of green spaces and activities. To represent the population of Sousse city, which is equal to 241,971 inhabitants, the minimum sample size was calculated.

The data were collected by face-to-face interviews following the questionnaire we developed. The surveys were actively carried out in public and meeting places, residential areas, and commercial districts. We spent four days interviewing various types of people in each borough (users and non-users of green spaces). The respondents were furthermore asked about their proposals for development and their needs. Moreover, all respondents were asked about their main reasons for visiting public green spaces in Sousse. Data were analyzed using descriptive statistics (frequencies and percentages) and Chi-square tests (Ugolini et al. 2021) to identify statistically significant variations between the respondents' visitation reasons for urban green spaces, the need for investment in UGS, and the development proposals components. The findings were processed in Excel and analyzed by the RStudio program.

3 Results

3.1 Description of the Respondents

The respondents consisted of 250 surveys conducted over the five boroughs, ranging from 14 respondents in Medina to 68 in Jawhara (Table 1). Overall, the sample is balanced in terms of male-female distribution (Fig. 1). In fact, during the surveys we tried to balance between men and women to represent the population of the town, which is equitable between the two categories. In terms of age distribution, the over-sixties and the under-20s are under-represented (Fig. 2). These people are very difficult to meet and to survey, given the very specific sanitary conditions.

Table 1 Number of respondents by district in Sousse city

Arrondissement	Jawhara	Sidi Abd Elhamid	Erriadh	Khzema	Medina
Number of inhabitants (2020)	69,588	60,454	56,525	51,297	4107
Number of respondents	68	60	56	52	14

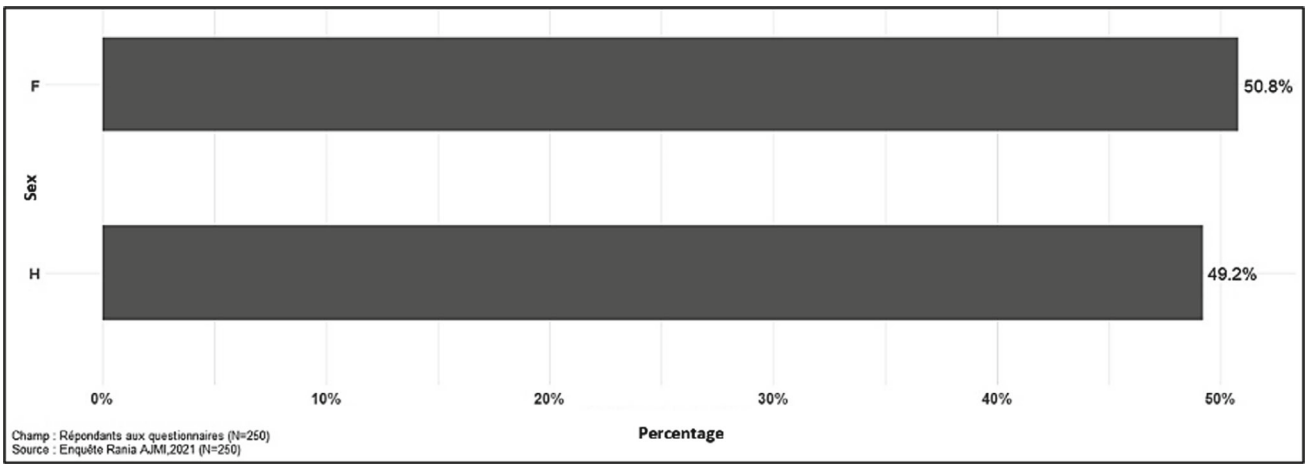


Fig. 1 Percentage of respondents in Sousse city by sex, 2021

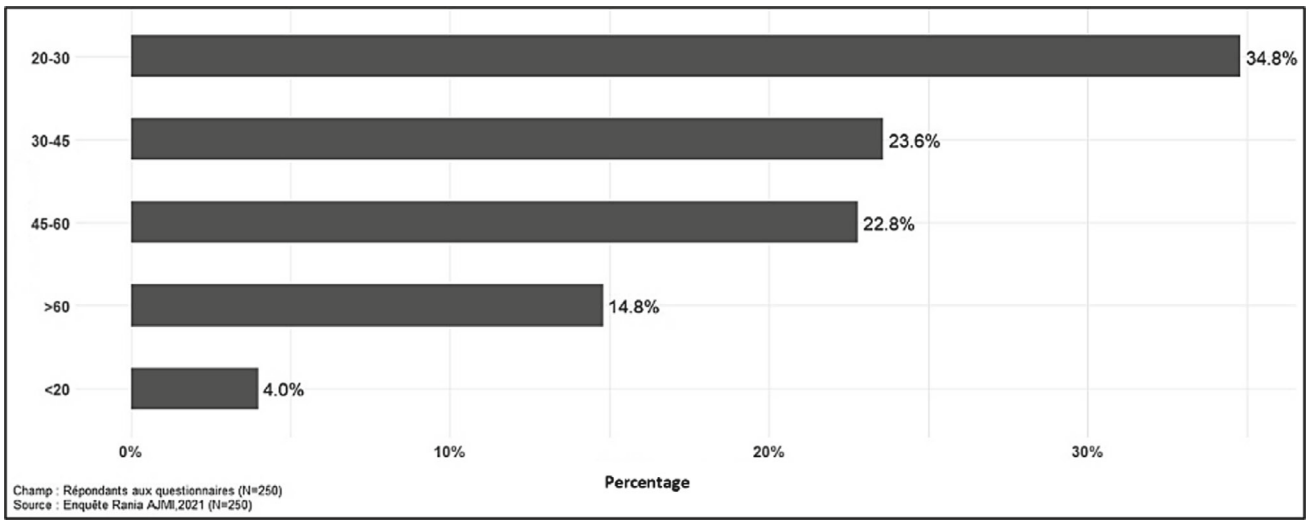


Fig. 2 Percentage of respondents in Sousse city by age category, 2021

3.2 Perceptions on Issues Related to UGS

The first question asked was "What do urban green spaces represent for you?" Some people were able to answer quickly and spontaneously, while others took a little time to reflect. As the question was open-ended, responses were very varied, over 80 words were cited. Some words and phrases were said much more than others, such as "comfort," "well-being," "relaxation," "life," "tree," "oxygen," "fresh air", "entertainment," "greenery," "psychic," "mental", etc. The words and/or expressions cited by the respondents were then grouped into six categories as follows: Well-being, life, Beautiful, clean, nice smell, Leisure, Flora, and Ecosystems.

According to Fig. 3, most of those surveyed linked urban greenery with well-being and life (52%). 29% of them express this in terms of "psychological comfort," and others in terms of "relaxation" (23%). The flora category comes second (20%). The most cited word in this category is "tree" (45%). Others used words related to beautiful, clean, and nice smell (11%), such as "beauty" (56%) and "cleanliness" (20%). Very few respondents used words related to leisure (7%) and ecosystems (6%).

Furthermore, when asked about participants' general UGS needs, several (24%) cited the need for more public gardens, as well as more spaces with play areas for children (17%). Most crucial (11%), they want maintenance and distribution of UGS around the city.

4 Discussion

Green spaces in cities are a crucial component of urban infrastracture, and they are priceless owing to the vast range of roles they fulfill and the advantages they bring to residents. However, this study confirms previous findings (Palliwoda and Priess 2021; Tzoulas and James 2010) by demonstrating that the assumptions guiding various aspects of UGS management, design, and policy are frequently not aligned with public perceptions or needs. Moreover, the quality project can withstand any crisis: even with certain limitations on users' access and activity, a public area with pleasant architecture and aesthetic appeal may nevertheless evoke inhabitant's well-being (See 2021). As a result, our findings emphasize the need to align planners' and managers' decisions with users' requirements to deliver better services and benefits and contribute to the quality of life of citizens.

5 Conclusions

Our results highlight the complex challenge facing decision-makers and public actors in UGS planning, who must consider and integrate the residents' aesthetic and recreational needs. Therefore, in the context of land use policies, the methodology adopted can be reproduced in Meghrebian cities to identify the needs of inhabitants in terms of UGS and thus ensure a better quality of life and lessen inequality in cities.

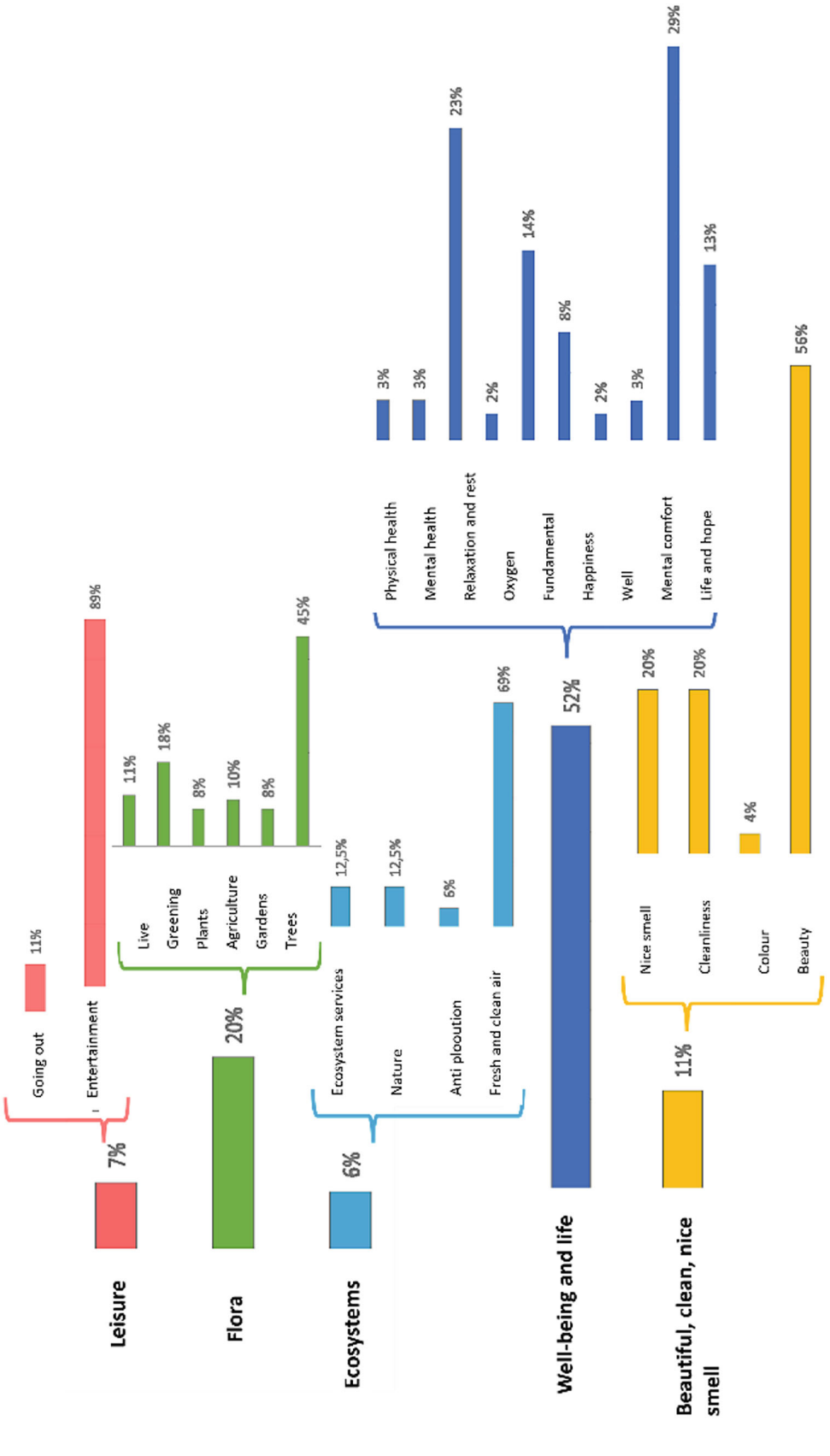


Fig. 3 Bar graph of percentages of words cited by respondents in Sousse city, 2021

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Effects of Urban Planning on Mental Health: NeuroUrbanism: A Case Study of Kozhikode, Kerala

Promiti Mallik and K. Chithra

Abstract

Since the beginning, a transaction has happened between humans and their surroundings. It is undoubtedly believed that the environment in which we live impacts how we behave and perceive things. This research contributes to finding evidence on how the environment shapes and influences our behaviour and mind, using it to build more human-centric cities. Though much research has been done to understand this interaction, fewer studies relate it to city building. This research aims to understand the essential components of cognitive foundations, the science behind the human-environment interaction, and studies undertaken in a similar context, which will ultimately reinstate the importance of human-centric designs. The research conducts a preliminary investigation by conducting an experiment that maps the psychological impact experienced by a participant while navigating diverse urban setups. To gain a comprehensive and first-hand understanding of the study's relevance within the Indian context, a deliberate decision was made to focus on a single participant in this research. The research paves the way for future inquiries and broader implementation. The criteria for selecting streets were based on the type of urban enclosures formed, urban road widths, and the presence of natural elements. A mobile Electroencephalography headset device was used to study neural activities. The study confirmed the hypothesis that our surroundings possess the capacity to influence our behaviour and identified specific locations within urban spaces that elicit positive or negative emotions, establishing the importance of connecting back to the elements of nature like water bodies, grass, visibility to the sky, etc., in our modern cities. The study concludes with specific planning recommendations based on neural responses to make the city healthier, liveable, and human-centric.

Keywords

Urban planning · NeuroUrbanism · Environmental psychology · EEG · Sustainable built environment

1 Introduction

A continuous dialogue happens between the physical environment and the brain functions of a human being. Upon first exposure to a physical environment, the brain receives environmental information through the five senses. How the brain responds to the received environmental information determines people's emotions, perceptions, and behaviour (Ahmadpoor 2022). Environmental design disciplines can advance the understanding of human-environment interaction, guiding design for improved fit and harmony (Horayangkura 2012).

Post-1960s, the study of human-built environment interaction has evolved, driven by advancements and interdisciplinary collaborations, yielding novel perspectives (Tulay Karakas 2020). Urban planning, on the other hand, is known to be a people-centric discipline indicating the need to develop places considering the well-being of the residents. Neuro Urbanism is an idea that aims to create liveable, habitable, happy urban spaces by realizing the mental health challenges of city living, including stress, anxiety, and depression, all of which appear to be increased in the city (Adli et al. 2017). This study examines urban environment's cognitive impact, focusing on city dwellers. Objectives include understanding cognitive foundations/methodologies, navigation experiments, and analyzing psychological impacts via EEG.

P. Mallik (✉) · K. Chithra
National Institute of Technology, Calicut, Calicut, Kerala, India
e-mail: mallikpromiti@gmail.com

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2 Methodology

This study uses a systematic approach, the first objective links neuroscience and urban planning through a comprehensive literature review.

For objective two, an experiment mapped the psychological impact of urban spaces in Kozhikode. Using a mobile EEG (electroencephalography) headset, real-time neural activity measurement was conducted, selecting streets and urban setups based on defined criteria. These criteria are drawn from case studies to evoke strong human expression through diverse urban landscapes (Neale 2017; Savary 2019). These criteria include:

1. Urban busy areas with buildings on both sides of a wide road (12 m);
2. Urban busy areas with buildings on both sides of a narrow road (7 m);
3. Urban areas with a natural feature on one side of a wide road (12 m);
4. Urban areas with a natural feature on one side of a narrow road (7 m);
5. Streets with natural features on both sides of the road.

One participant was selected to navigate the identified locations while wearing the EEG headset. Given that it was a pilot study with equipment and time constraints, selecting one participant ensured standard readings across different urban setups. Selected locations offer diverse stimuli for varied emotions. EEG captures neural responses, analyzing the urban environment's psychological impact.

To achieve the third objective, the recorded EEG data were critically analyzed. This analysis involved integrating the acquired data with the literature and case studies.

3 Results

The urban stretch criteria identified seven different urban street stretches Mavoor Road market area (1), Mananchira (2), Beach Road (3), YMCA Road (4), SM Street (5), Gujarati Street (6), and Sarovaram (7) (Fig. 1).

The results were given in the form of six performance metrics by the emotive insight EEG headset, each state (indicator) rated on a scale of 100 (See Table 1).

For Mavoor Road, the engagement index was the highest, i.e. (62), followed by interest (65). Excitement was (54),

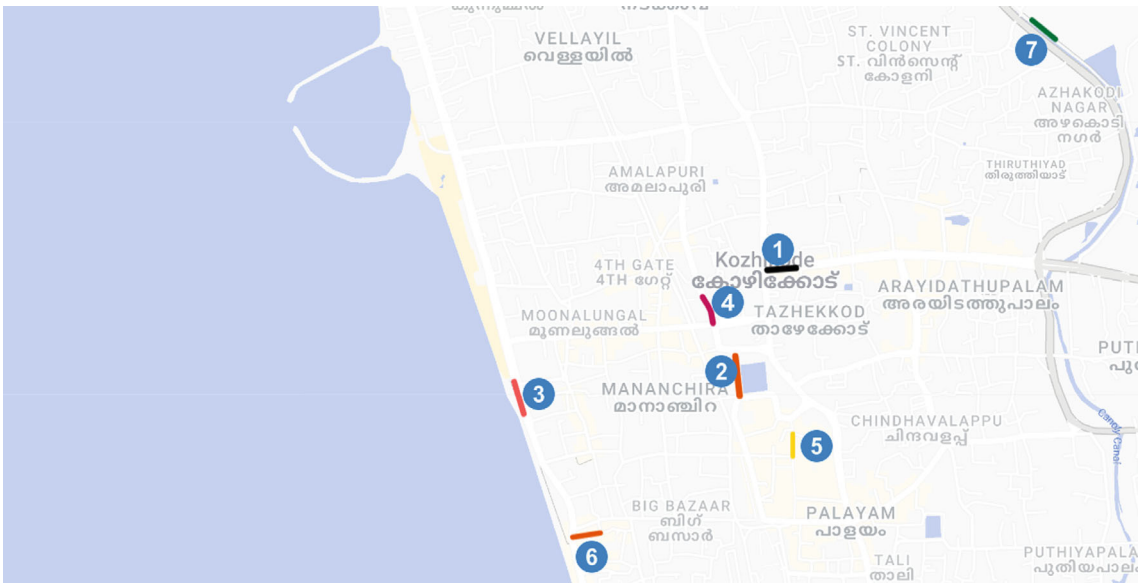


Fig. 1 Locations of identified urban stretches

Table 1 EEG headset (Emotiv Insight) performance metrics (Emy 2019)

States	Definition
Excitement	Awareness or feeling of psychological arousal
Interest	The degree of attraction or aversion to the current stimuli
Stress	A measure of comfort with the current challenge
Engagement	Alertness and the conscious direction of attention towards task-relevant stimuli
Focus	The measure of fixed attention to one specific task
Relaxation	Measurement of an ability to switch off and recover from intense concentration

focus (50), relaxation (45), and stress (54). Busy urban setups like Mavoor road may elicit heightened Beta brain waves, indicating heightened engagement and alertness due to the constant need for consciousness. The second street was the Mananchira, which showed a higher value for excitement and interest, with excitement being (63) and interest at (57). The participant's excitement from the lake or traffic can vary positively or negatively. Unlike Mavoor Road, Mananchira's lower engagement (24) may stem from its one-way design, requiring less vigilance. The third street was the beach road; as expected, the results show a high value for interest, excitement, and relaxation. Low stress was reported likely due to Arabian Sea presence. Beaches offer serenity, wide roads reduce congestion, allowing individuals to walk at their own pace.

The next street was YMCA, the values were higher for engagement, interest, and stress. High stress suggests low engagement; congestion on narrow road without footpaths could be contributing factors. The next location was SM Street, similar to YMCA Road; the value was higher for stress here as well, along with engagement and excitement. The sixth street was Gujarati Street, it had an increased engagement value (46), excitement (52), and stress (46), with relaxation and interest both at (43) and focus at (44). Gujarati Street selected for wall art impacts study; congestion and litter affected observations, validating recorded values.

The last and final stop was Sarovaram, where engagement (69) and relaxation (52) were higher. Relaxation is more, which makes the statements accurate about natural setup inducing a sense of serenity and well-being (Fig. 2).

4 Discussion

Based on the results of the study, a pattern was seen, often places that were crowded induced stress in the participant. Urban busy areas with wider roads or a natural setting on at least one side of the road make the residents more alert and engaged, whereas when the streets are narrower and crowded, it induces stress and excitement, potentially in a negative way. In addition, it was noticed that green spaces and access to nature positively impact mental health as it has a restorative effect stated by various researchers. This shows that the presence of a natural setting on crowded roads or in any urban area can help reduce stress among the residents. These findings align with the case studies of Virginia (Neale 2017) and Beirut (Savary 2019) reinforcing a consistent association between urban planning, emotional responses, and the crucial role of green spaces in enhancing overall well-being. The case studies demonstrated similar correlations between urban environments and emotional experiences.

The study faces participant-related challenges like preconceived notions, external influences, and equipment limitations, including cost, usage constraints, handling difficulties due to mobile app development, sensor issues, and vulnerability. Pilot study constraints led to fewer participants and limited urban setups.

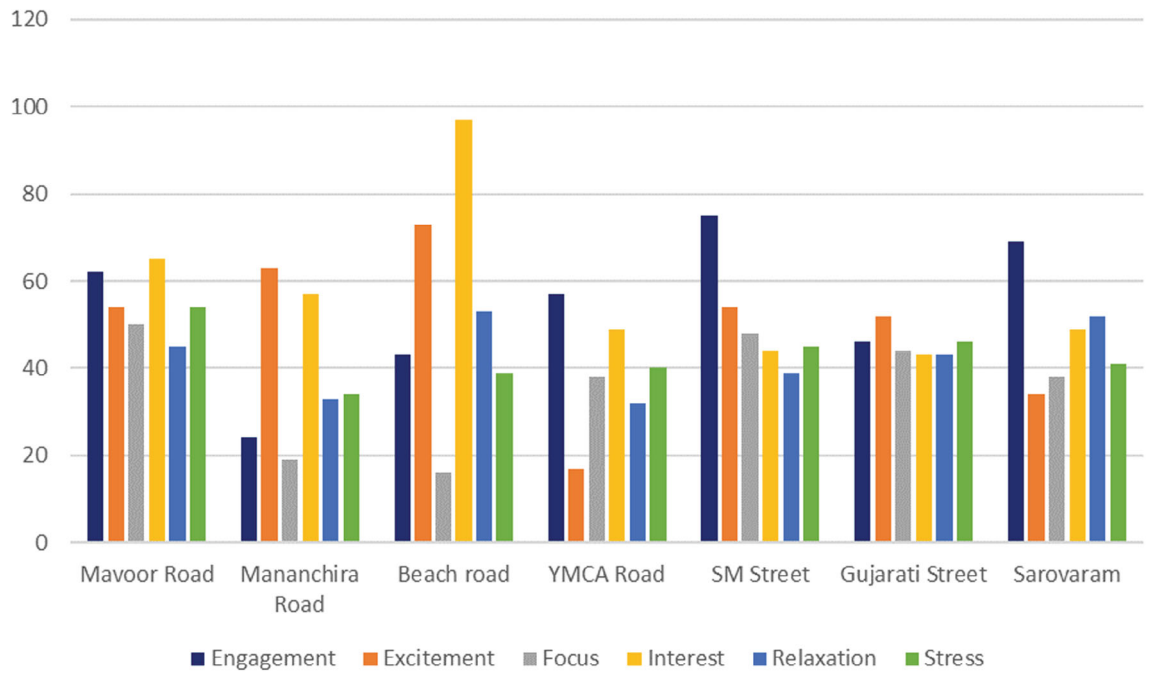


Fig. 2 Consolidation of the performance indices values for each Urban Stretch

5 Conclusions

In the light of the study's insights into urban navigation and emotional states, these recommendations are intricately linked to promoting mental well-being. Integrating green spaces addresses stress, while prioritizing safe walkability and bike-ability fosters physical activity, known to positively impact mental health. Emphasizing mixed land use and welcoming amenities enhances social connections, contributing to emotional well-being. Additionally, community engagement, nature-inspired design, and flexible public spaces aim to create environments that nurture positive emotions and overall mental well-being, reinforcing a holistic and evidence-based approach to urban planning.

While most of the recommendations suggested have already been stressed over the years for multiple reasons, this study is a take on the evidence-based approach for a sustainable and better-built environment in consideration of the mental well-being of the residents. In future studies, broader participant involvement has the potential to enhance subsequent research.

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An Empirical Approach to Catch-up Theory for 2030 Developing Countries' NDCs

Su Yeon Jung and Seung Jick Yoo

Abstract

This study aims to assess the greenhouse gas emission levels of developing countries compared to developed countries by estimating the income elasticities of GHG emissions in 34 countries. Previous studies have analyzed the fair emission levels of developing countries, but the fact that developing countries are growing economically in a greener way than developed countries is not considered. The income elasticity of GHG emissions, which refers to how much GHG emissions increase relative to income growth, is an important indicator for assessing the fairness of emissions level of developing countries when they achieve the same ability as developed countries. This study estimates the income elasticities for 34 countries both including Annex II countries and G20 countries among non-Annex I countries, over 50 years (1970–2019) using the functional coefficient panel model, which define income coefficients varying with income as well as time. The results show that the lower income group achieved decoupling at lower level of income rather than higher income group. Also, the decreasing annual rate of change of income elasticity is higher for lower income group. Finally, the income elasticity of developing countries is lower than the income elasticity of developed countries at the same income level of $7000–9000 and $9000–11,000. It suggests that developing countries are not emitting at a higher level than developed countries, but rather at a lower level than developed countries in terms of income. The significance of this study is that it provides an indicator to evaluate GHG emissions based on the ability of developing countries to reduce their emissions at the same income level as developed countries. Further research can test the hypothesis that follower countries catch up to the income elasticity level of leader countries as their income increases and the hypothesis that follower countries catch up to the growth rate of income elasticity of leader countries using estimated income elasticities from this study.

Keywords

GHG emissions · Elasticity · NDC target emissions · Functional coefficient panel model · Catch-up theory

1 Introduction

Under the Paris Agreement, where all parties set and implement voluntary greenhouse gas emission reduction targets, research on the fair targets and emission levels of parties has become active. Studies on allocating GHG emissions to countries by calculating their fair share of global emissions has been dominant, with Höhne et al. (2014) deriving a fair mitigation pathway for each region based on several criteria (equality, capability, etc..) and Gidden et al. (2019) trying to estimate the convergence of regional GHG emission intensity.

Since the economic development in the past when developed countries emitted and the current development with technological advancement are different, the approach of sharing GHG emissions equally or converging on regional emission intensity cannot be a fair assessment of developing countries. Even if developing countries have reached the same income levels as developed countries in the past, it should be considered that their growth is greener than that of developed countries. In this sense, the income elasticity of GHG emissions, which refers to how much GHG emissions increase relative to income growth, is a key indi-

S. Y. Jung · S. J. Yoo (✉)
Sookmyung Women's University, Seoul, Republic of Korea
e-mail: sjyoo@sookmyung.ac.kr

S. Y. Jung
e-mail: soo951221@sookmyung.ac.kr

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cator for assessing the fair emissions for developing countries when they achieve the same capabilities as developed countries.

This study is significant in that it estimates individual country elasticities that incorporate the relationship between income and GHG emissions for 34 countries through panel data analysis. It has the advantage of being able to compare income elasticities not only longitudinally but also cross-sectionally. Also, we identify common patterns in the elasticities to assess whether developing countries are likely to follow similar trajectories in the future.

2 Estimation Model

In this study we use the functional coefficient panel model proposed by Chang et al. (2016) to estimate the relationship between GDP per capita and GHG emissions over a 50-year period (1970–2019) for 34 countries.[1] We analyze Annex II parties to the Convention (23 countries), which were already leading economies and major emitters at the time of the UNFCCC adoption, and non-Annex I countries that joined the G20 more recently (11 countries).

Chang et al. (2016) proposed a functional coefficient panel model to analyze the long-run equilibrium relationship between GDP, time, and electricity demand. The model assumes that the income coefficient changes with time and income. It defines the income coefficient as a function of time (t) and income (x_{it}) to allow the most flexible form for the functional coefficient $\beta(r, x)$. The estimation equation for the model is shown in (1).

$$y_{it} = \alpha' c_{it} + \beta(t, x_{it}) x_{it} + v_{it} \quad (1)$$

i is country, t is time, y_{it} is GHG emissions, x_{it} is GDP per capita, α' is fixed effects of each country, and c_{it} is group binaries to capture cross-sectional heterogeneity. By estimating a nonlinear panel data model in (1), we can obtain the income coefficient varying with income and time for each country. Based on the empirical results of the income coefficients, we can also derive the income elasticity by additionally estimating nonparametric derivative estimator of $\beta_x(r, x_t)$ in (2).

$$\epsilon(t, x_t) = \beta(t, x_t) + x\beta_x(t, x_t) \quad (2)$$

Since many of the income levels achieved by developing countries in the period 1970–2019 were already achieved by developed countries before 1970, the pre-1970 income elasticities for developed countries are backward forecasted to compare elasticities of developing countries at the same income level.[2] We use statistical analytical program R studio for the analysis.

Table 1 Grouping by income level

Group	Income level (GDP per capita)	Results
1	AnnexII, higher than $70,000	Norway, Luxembourg, Ireland, Switzerland
2	AnnexII, $50,000 ~ $70,000	Australia, United States, Iceland, Sweden, Denmark
3	AnnexII, $30,000 ~ $50,000	New Zealand, Canada, Japan, Netherlands, United Kingdom, Finland, Austria, Germany, Belgium, France, Italy
4	Non-AnnexII, $30,000 ~ $40,000	South Korea, Saudi Arabia
5	Non-AnnexII, $10,000 ~ $20,000	China, Russia, Turkey, Argentina
6	Non-AnnexII, $3000 ~ 10,000	South Africa, Brazil, Mexico
7	Non-AnnexII, lower than $10,000	India, Indonesia

3 Results

3.1 Income Elasticity of GHG Emissions for Developed Countries

In order to observe the pattern of the estimated income elasticity for each country, countries are classified into groups as shown in Table 1 based on the income level achieved by each country by 2019.

The income elasticities of the developed countries commonly turn negative during the analysis period. The income level at turning point when income elasticities become negative is lower for lower income group. The income elasticity turns negative when the income level is $36,000, $33,000, $27,900 for Group 1, 2, 3 for each. Also, the decreasing annual rate of change of income elasticities is higher for lower income group. The average year-on-year decrease in income elasticity for Group 2, 3 is − 1.31%, − 2.37% for each when income rises from $30,000 to $40,000, indicating a faster decrease in income elasticity for Group 3 (Figs. 1 and 2).

[1] We used USDA (US Department of Agriculture) for GDP per capita and Climate Watch (PRIMAP historical data) for greenhouse gas emissions.

[2] We used GDP per capita growth rates from 1940 to 1969 from the Maddison Project Database (MPD).

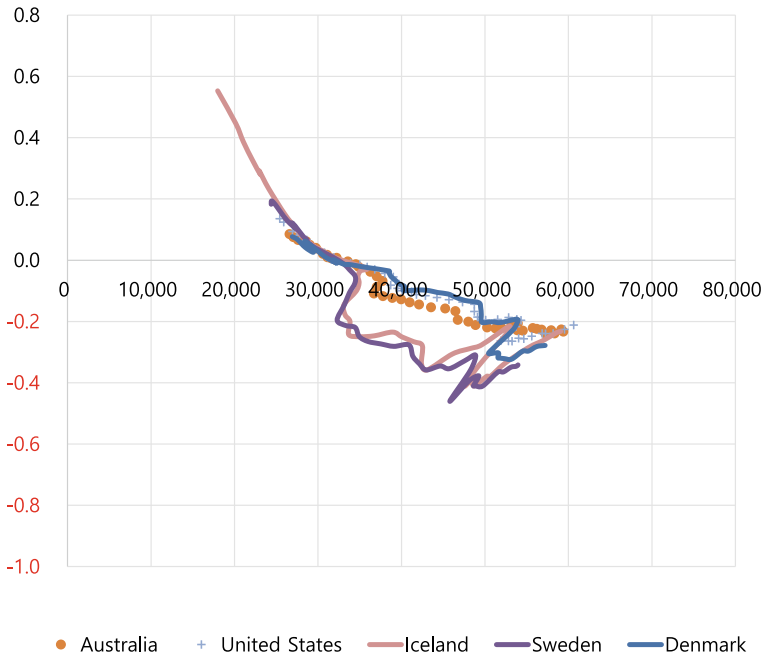


Fig. 1 Group2 (x: income, y: elasticity)

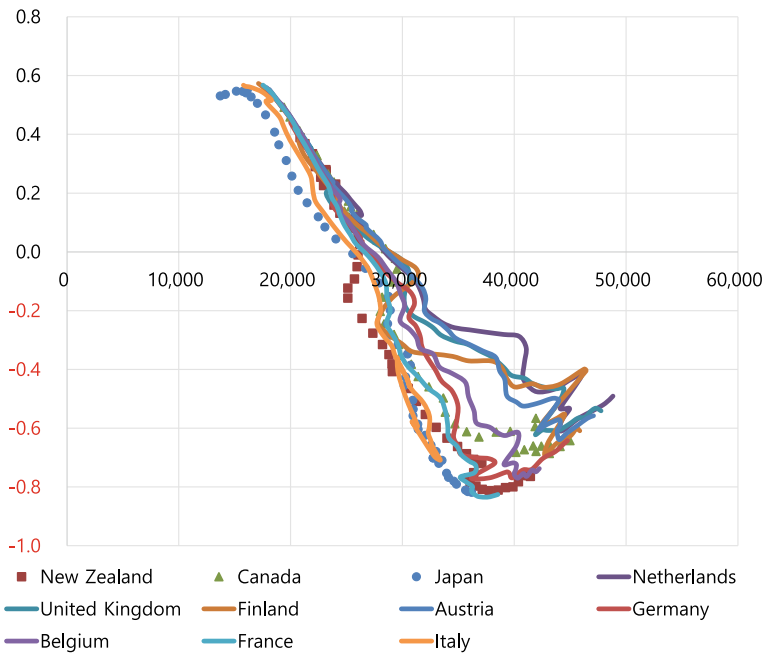


Fig. 2 Group3 (x: income, y: elasticity)

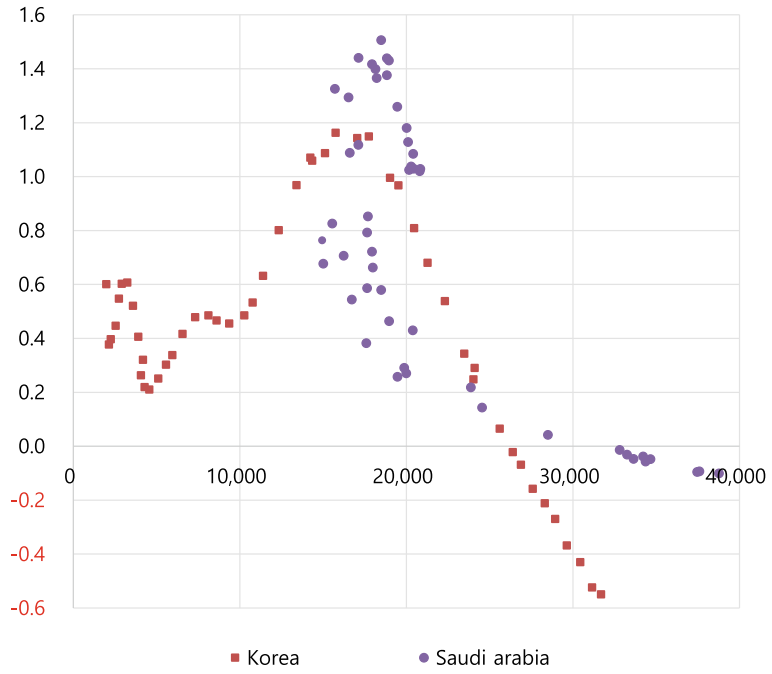


Fig. 3 Group4 (x: income, y: elasticity)

3.2 Income Elasticity of GHG Emissions for Developing Countries

The pattern of elasticities in developing countries is different among themselves (Figs. 3, 4, 5, and 6). Apart from South Africa and Argentina,[3] developing countries have elasticities that gradually converge to zero as income increases, although at different times. The growth of emissions slows down as income increases, but emissions still increase.

3.3 Comparison Between Developing and Developed Countries of Income Elasticity of GHG Emissions

When comparing the income elasticities of developed and developing countries at the same income level ($7000–9000 $9000–11,000), the income elasticities of developing countries are generally lower than those of developed countries. In this context, at the same income level, the emissions growth rates in most developing countries are lower than those in developed countries as income increases. However, Australia, the USA, and Denmark have lower income elasticities than some developing countries (Fig. 7).

4 Discussion

The results of the estimated income elasticity for the developed country group show that the group of countries that reach economic growth more recently (Group3) achieved decoupling faster and at a higher level than the group of countries that reach high income levels first (Group2).

This is evidenced by the fact that the income elasticity levels of Group2 turns to minus at the income level of $32,000–33,000, while the income elasticity levels of Group3 turn to minus at the income level of $25,000–30,000. Also, the decrease rate of the income elasticity of Group3 after the point where the elasticity turns to minus is higher than Group2 (− 0.6% for Group2, − 1.96% for Group3).

In the estimation results for the group of developing countries, we observe some similarities in the pattern of income elasticities between those countries that achieve higher income levels first and those that follow. The inverted U shape observed for Korea until the income level of $30,000 was observed in the elasticity pattern of China until the income level of $10,000.[4] The cubic function form observed for Indonesia until the income level of $4000 was similar to the pattern of India's income elasticity until the income level of $2000.[5] In addition, the income elasticity pattern of Group 4 was very similar to Group2 at the same income level. This implicates that the catch-up of income

[3] The blue scatter in Fig. 4 represents Argentina, and the red scatter in Fig. 5 represents South Africa.

[4] The red scatter in Fig. 3 represents Korea, and the red scatter in Fig. 4 represents China.

[5] The red scatter represents India, and the blue scatter represents Indonesia both in Fig. 6.

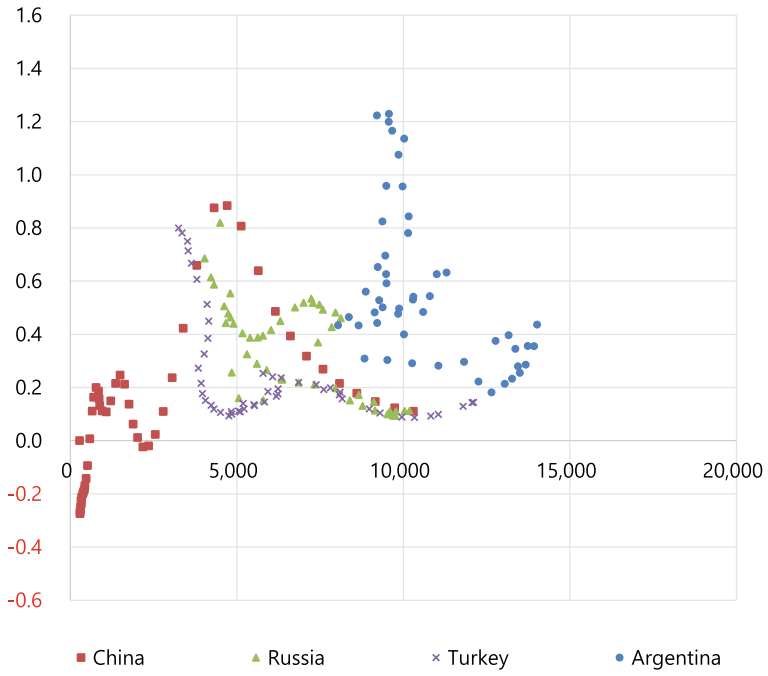


Fig. 4 Group5 (x: income, y: elasticity)

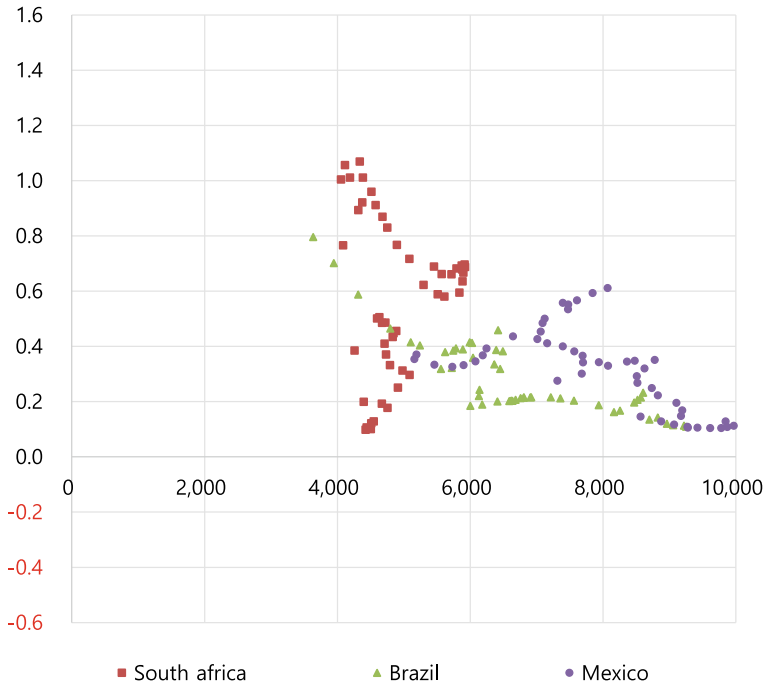


Fig. 5 Group6 (x: income, y: elasticity)

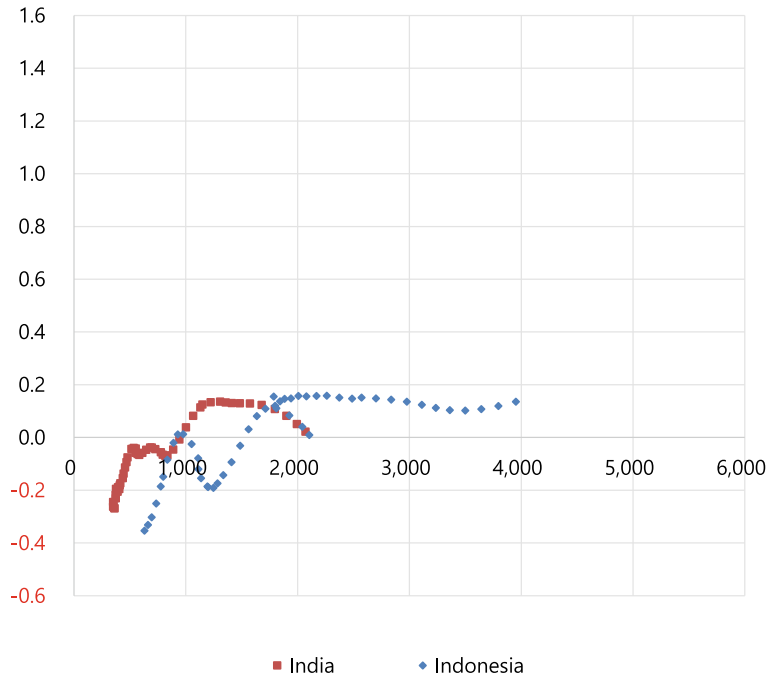


Fig. 6 Group7 (x: income, y: elasticity)

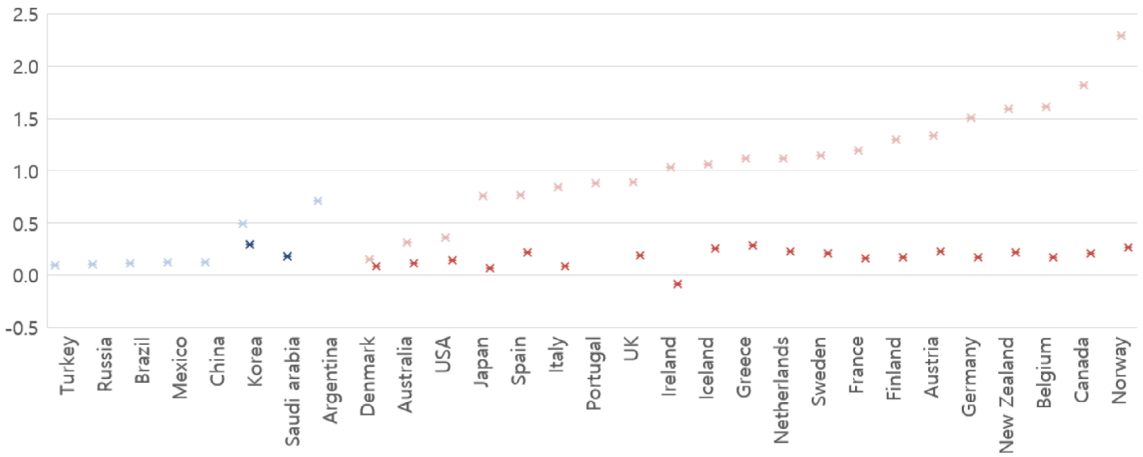


Fig. 7 Elasticities by country at incomes \$7000 ~ 9000 and \$9000 ~ 11,000 (light blue: \$7000 ~ 9000 (Non-Annex I), deep blue: \$9000 ~ 11,000 (Non-Annex I), light red: \$7000 ~ 9000 (Annex II), deep red: \$9000 ~ 11,000 (Annex II))

elasticities based on the pattern of income elasticity between countries can be applied in practice by expanding the scope of analysis in the future.

5 Conclusions

The significance of this study is that it estimates the income elasticity of GHG emissions by country and compares the patterns and compares the elasticities of developed and developing countries based on the same income level. Previous studies have estimated the income elasticity of GHG emissions, but Liao (2013) only estimated the elasticity by income group and did not analyze the income elasticity by country in detail. Liddle (2015) assumed that the relationship between income and GHG emissions is fixed in the long run.

Based on the income elasticity derived in this study, catch-up theory can be applied to further develop the

research. The hypothesis that follower countries catch up to the level of elasticity of leader countries at the same income and the hypothesis that follower countries catch up to the growth rate of elasticity of leader countries can be established and verified, and GHG emissions can be forecasted based on this. The functional coefficient panel model used in this study can contribute to the study of forecasting the GHG emissions of developing countries by 2030 and evaluating the levels of emissions reduction target compared to their 2030 NDC GHG emissions reduction target.

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Evaluating the Impact of Climate Change & UHI on Energy Demand of a Vulnerable Neighborhood in Madrid

Shoaib Amin, Emanuela Giancola, Silvia Soutullo, F. Luis Zarzalejo, and Rohinton Emmanuel

Abstract

The rapid urbanization and increased population density in cities have led to the Urban Heat Island (UHI) effect leading to higher temperatures and reduced wind speeds in urban areas. This significantly impacts the thermal comfort and energy demand of buildings. Madrid presents an interesting case study as research has analyzed climate change effects across EU and observed second highest temperatures in this Spanish city. This paper showcases the impact of UHI on the energy demand of buildings within a comprehensive research endeavor that seeks to optimize the urban microclimate in a vulnerable neighborhood of Madrid. Therefore, Urban Weather Generator (UWG) is utilized to assess energy performance of the urban block under UHI. Energy performance of non-retrofitted and retrofitted buildings are compared under reference and extreme climate conditions. The max UHI intensity is simulated as + 12.9 °C in summer and − 3.2 °C in winter. The UHI implications are simulated as − 3.4% reduction in heating demand under reference weather conditions and − 19.5% for RCP 8.52050 scenario indicating stronger UHI impact with regard to climate change. The TMY file for Madrid shows a − 3.4% decrease in heating demand due to UHI, but a + 162% increase in cooling energy demand. The RCP 8.52050 weather file indicates a − 19.5% drop in heating demand and a + 27% rise in cooling energy demand due to UHI. This research suggests that in the future, cooling demand is expected to exceed heating demand in all scenarios, regardless of UHI presence. The findings highlight the negative impact of UHI on buildings, with annual cooling demand surpassing reduced heating demand. Thus, based on this, the research will further progress to assess urban microclimate improvements, optimizing heat sinks and addressing potential adverse impacts on indoor and outdoor thermal comfort.

Keywords

Urban weather generator (UWG) · Building energy demand · Urban heat island · Climate change · Energy poverty

1 Introduction

By 2050, the world's urban population is expected to reach 68% (UN WUP 2023). The European Union (EU) is committed to achieving climate neutrality through the Green Deal aligned with the Paris Agreement (European Green Deal 2023). Buildings play a crucial role in achieving a low-carbon future as they contribute significantly to global energy consumption and carbon emissions (ODYSSEE and MURE Homepage 2023; Santamouris 2020). Energy poverty is also a challenge in the EU, particularly in countries like Spain (Santamouris 2020). The EU's Energy Performance of Building Directive (EPBD) aims to enhance energy efficiency through building renovations to address energy consumption, poverty, and emissions reduction. The urban environment introduces complexities, including the UHI, which disproportionately affects vulnerable populations, impacting building energy consumption and thermal comfort (Santamouris 2020; Martín-Consuegra 2020). Understanding the interactions between urban morphology, materials, and the microclimate is crucial (Santamouris 2020). While extensive research exists on the impact of UHI on energy consumption (Naboni 2020; Soutullo 2020), there is a need for evaluation in local context before evaluating the potential of retrofitting strategies (Salvati 2023). Therefore, a holistic approach that considers the interaction

S. Amin · R. Emmanuel
Glasgow Caledonian University, Glasgow, UK

E. Giancola (✉) · S. Soutullo · F. Luis Zarzalejo
Energy Department, CIEMAT, Madrid, Spain
e-mail: emanuela.giancola@ciemat.es

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between buildings and the urban environment is essential for effective climate change adaptation. Currently, building energy modeling is carried out using weather files that are not representative of the microclimate around buildings (Natanian 2020). Integrating building performance and UHI can lead to more effective climate change adaptation strategies. In this sense, specific objectives of this study include developing a tailored workflow using tools like Urban Weather Generator (UWG), Ladybug Tools, and EnergyPlus for assessment of a whole urban block (Urban Weather Generator 2023; Ladybug 2023; DOE 2023). The study evaluates annual building energy demand with and without UHI influence using reference and RCP 8.52050 weather files. Additionally, it simulates the benefits of envelope retrofitting combined with UHI, specifically in decreasing annual heating energy demand.

2 Materials and Methods

2.1 Case Study Area

The study focused on the Barrio Orcasur in the south of Madrid, which has a semi-arid climate (Koppen-Geiger coefficient: Csa) with mild cool winters and hot summers. The area mainly consists of buildings constructed before 1979. The selection of this area was based on a review of previous studies in Madrid (Martín-Consuegra 2020; Soutullo 2020; López-Moreno 2022) and is one of the two areas focused on in the URBAN therCOM project (URBAN 2023). Surface material characteristics were provided by (Pérez 2022), building façade and operational requirements related information were modeled considering previous research (Soutullo 2020) and regulated by the Spanish normative for the year before 1979 and 2006 (Spain 2023) (Fig. 1).

2.2 Model Development and Simulations

LIDAR data (LIDAR 2023), material characterization information and Spanish technical code were used as basis for model development in Rhino Grasshopper (Grasshopper 2023) through ladybug tools (Ladybug, Honeybee, Dragonfly (Ladybug 2023)). Energy simulations were run through URBANopt API (URBANopt 2023) of EnergyPlus. UHI impact was simulated using UWG. The reference TMY and RCP 8.52050 weather files were obtained from Meteonorm v8 (Meteonorm 2023). For retrofitted building scenario, changes on the buildings envelope (addition of thermal insulation on the façade) were made according to Spanish technical code of 2006 (Fig. 2).

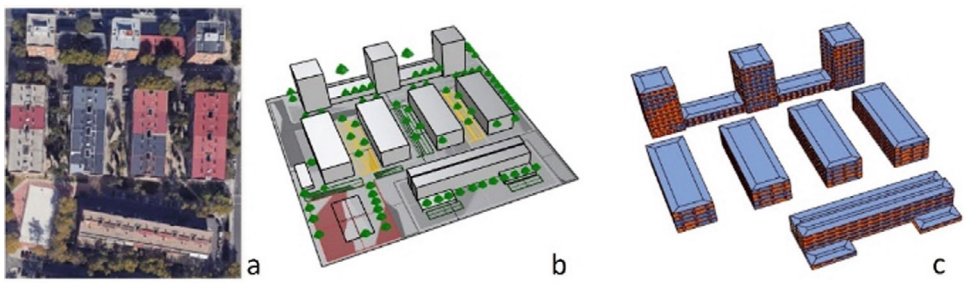


Fig. 1 Study area urban texture (**a**); Rhino 3D model (**b**); and dragonfly model (**c**)

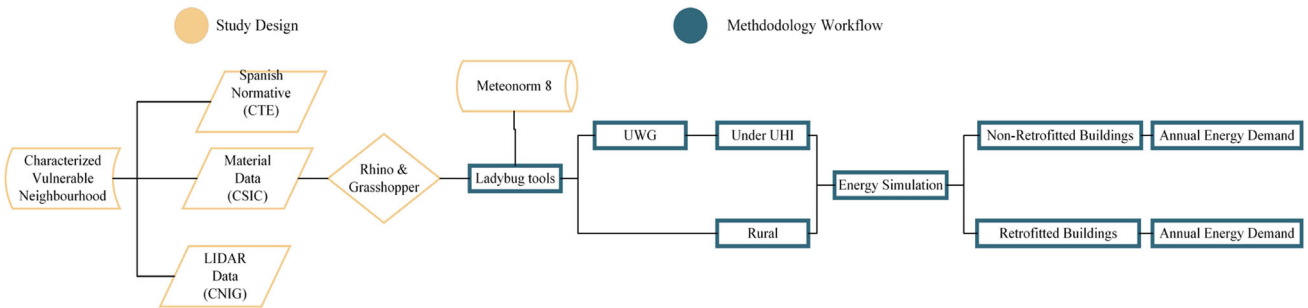


Fig. 2 Outline of methodology workflow

3 Results and Discussion

UWG was used to generate a morphed weather file, considering UHI effect in the current climate conditions. The nighttime UHI effect is evident from (Fig. 3). The most significant temperature differences and frequency shifts occur in June and July. The highest simulated difference is + 12.9 °C in summer and − 3.2 °C in winter.

Figures 4 and 5 show the annual variation of heating and cooling energy demand in different scenarios: current weather with UHI effect, retrofitting (addition of thermal insulation on the façade), and RCP 8.52050 climate change projection. For the current weather scenario there is a positive effect on the heating demand, while a negative effect is observed for the cooling energy demand. The retrofitted buildings experience only a minor 2% decrease in cooling demand, indicating a limited effect on cooling demand but is more effective in reducing heating demand.

Based on the results simulated for the RCP 8.52050 climate change, it can be observed that without accounting

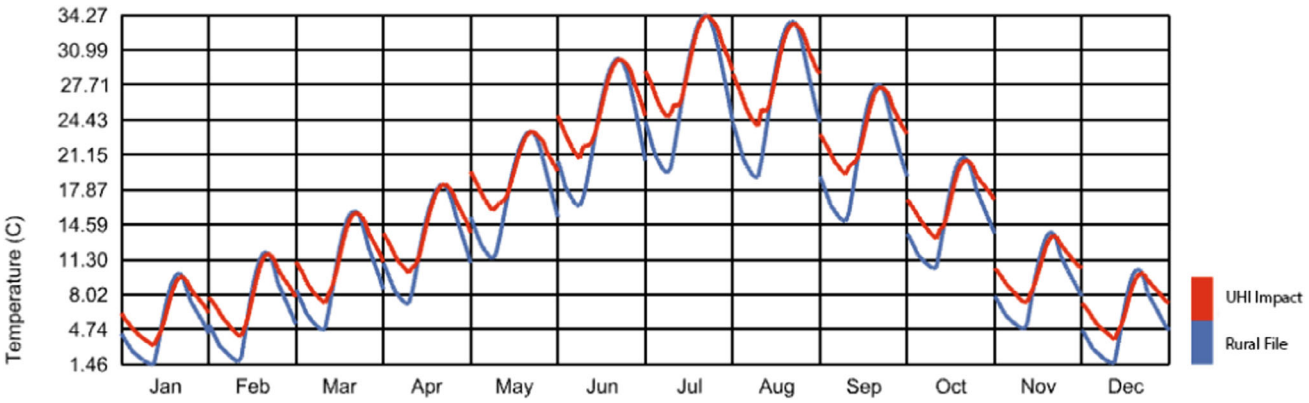


Fig. 3 Annual variation of UHI intensity comparison of morphed file and rural file for dry bulb temperatures for monthly per hour values

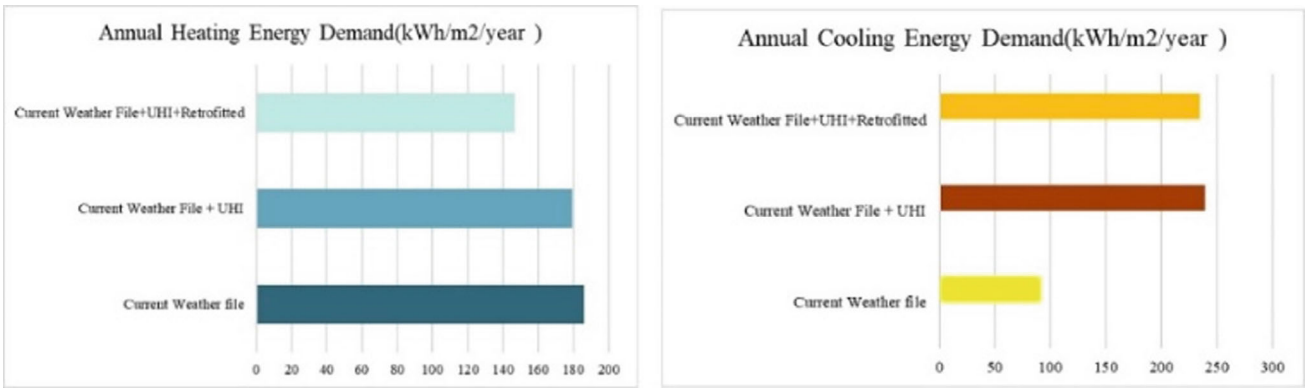


Fig. 4 Annual variation of heating and cooling energy demand for current weather scenario

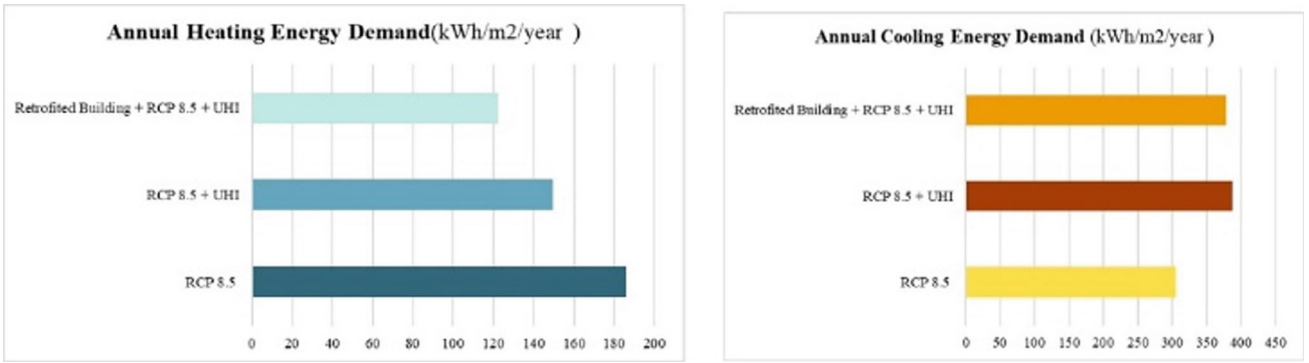


Fig. 5 Annual variation of heating and cooling energy demand for RCP 8.52050 climate change

for UHI effect, the regional climate change will increase the cooling energy demand while retrofitting buildings will only result in decrease of 2.27%. The results indicate that the major cause of increasing cooling demand would be the regional changes in weather. Therefore, studies shall focus on evaluating climate adaptation strategies at local scale to combat climate change and UHI together.

The study finds that accounting for the Urban Heat Island (UHI) effect significantly affects heating and cooling energy demand. Under the reference weather scenario, considering UHI results in a 3% reduction in heating demand, while for the extreme RCP 8.52050 climate scenario, there's a substantial 20% reduction in heating demand, indicating UHI's strong influence in extreme climate change situations. Retrofitting at the facade level shows promising results, leading to an 18.2% reduction in energy demand for retrofitted buildings compared to non-retrofitted ones, while considering UHI. However, for cooling energy demand, the impact of UHI and future warmer and drier climate is drastic. Under the reference climatic condition, cooling energy demand increases by 162% due to UHI. Improving facade envelopes reduces only 1.9% of this increased demand. Simulating future extreme climate scenarios alone results in a 234% increase in cooling energy demand due to higher temperatures and reduced diurnal temperature ranges. Overall, the study emphasizes the higher impact of cooling energy demand compared to heating demand, and careful assessment and implementation of UHI mitigation strategies are essential to address cooling energy demand and thermal comfort challenges alongside retrofitting measures.

4 Conclusions

The study highlights the consequences of neglecting UHI and climate change scenarios in evaluation of building energy performance. While UHI combined with warmer future climate and envelop retrofitting can reduce the heating demand, cooling energy demand is of significant concern that can worsen the issue of energy consumption, energy poverty in EU. This study confirms changes in energy demands due to climate change and UHI in the local case study area. The drastic increase of cooling energy demand under UHI and climate change impact needs to be addressed through research backed strategies at urban scales focused on improving the microclimate such as vegetation and cool materials. The results of this paper are presented in the perspective of extending the research toward the strategies at urban scales focused on targeting the enhancement of microclimates and UHI mitigation through measures like vegetation and cool materials and in to the potential adverse effects of envelope modernization, particularly its influence on both internal and external thermal comfort.

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Climate Adaptation and Mitigation for Emerging Dwelling. Conception of a Co-housing Community for the Elderly in the Marianella ex Polifunzionale, Naples

Eduardo Bassolino, Sabrina Puzone, and Alice Pallotta

Abstract

The objective of the research activity is to create guidelines for the creation of life-time homes for the elderly in disused buildings, starting from the energy-environmental redevelopment project of Marianella ex Polifunzionale, a signature building constructed in the 1980s in the area north of Naples. The research refers to two important opportunities, the C40 Cities Reinventing Cities competition, and the Building AHA research project, financed by Action 1.1 'Creation of an urban space dedicated to the lives of the elderly' Health Development and Cohesion Plan—FSC 2014–2020 of the Ministry of Health. The creation of a co-housing community in which elderly people can live together with younger passes, first of all, by synthesising the objectives and needs of the competition and the research project. In particular, through urban regeneration actions aimed at climate adaptation and mitigation, to guarantee the highest performance for the new users who will live in the building, it is possible to define an innovative model of co-housing, which can integrate both smart technologies for living, sensors, and devices for health monitoring and the energy requalification of the building, with the integration of passive technologies for energy generation. This is complemented by open space regeneration actions to improve environmental conditions with a view to climate adaptation. The study has made it possible to define a framework based on actions and simulation tools for the evaluation of applicable environmental health and comfort parameters, with a specific focus on thermal and environmental exchanges, for the definition of those factors that condition the perception of the well-being of users in conditions of thermal stress (e.g. heat waves). Through the introduction of simulations with ICT tools and the identification of climatic data for the definition of the microclimatic comportment of the area, the objective is to recreate the real conditions in order to obtain admissible results from the simulation processes and to define the environmental performance, with particular reference to the increase in urban temperatures. The result is the definition of a framework of actions capable of responding to a new way of living through experimental climate-adaptive urban regeneration actions.

Keywords

Emerging dwelling · Climate-adaptive design · Building retrofit · Human-centred approach · Environmental data-driven design

1 Introduction

Climate change and global warming pose a serious threat to people today, requiring a unified global response at all levels of society. In 2018, the IPCC highlighted the unprecedented scale of the challenge needed to contain warming to within 1.5 °C to pre-industrial levels (IPCC 2018). Five years later, this challenge has become even greater and if it is not addressed, cities are destined to expose themselves to environmental risks, becoming increasingly vulnerable to the negative impacts of climate change (IPCC 2022). One opportunity for cities to implement more sustainability-conscious policies is to promote initiatives for the development of innovative urban projects that can increase resilience, such as the Reinventing Cities call (Reinventig Cities n.d.), initiated by the C40 Cities Climate Leadership Group Inc. which invites multidisciplinary teams of professionals to transform under-utilised city sites into beacons of sustainability and resilience with the goal of combating climate change in order to achieve an inclusive,

E. Bassolino (✉) · S. Puzone · A. Pallotta
University of Naples Federico II, Naples, Italy
e-mail: eduardo.bassolino@unina.it

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Fig. 1 Images of the Marianella ex Polifunzionale

prosperous and sustainable future. A further opportunity is represented by the implementation of strategic and operational planning processes, with which trajectories for the sustainable management of underused built heritage can be elaborated. An example of this type is the Building AHA research project carried out by the University of Naples Federico II, whose aim is to promote the creation of a centre dedicated to the elderly population, in which autonomous living spaces equipped with 'smart' products and services can be built, and with a sharing of social and health care and first emergency services, as well as useful services for socialisation.

At the centre of the two initiatives is the former Marianella Polifunzioanle, a burnt-out building from the 1980s on the northern outskirts of Naples, now almost completely unused (Fig. 1).

The proposal presented envisages the definition of a methodological framework of actions for the technological retrofit of the building and the climatological redevelopment of the open spaces, proposing a scalable and replicable urban regeneration model for the entire urban district.

2 Methodological Framework

At the basis of the intervention methodology identified for the Marianella Polfunzionale, there is the study of the state of decay and conservation of the building, which has a surface area of approx. 3600 m^2, originally intended for a school complex, with an auditorium, cultural centre, medical centre, sports centre and a garden-terrace.

Starting from the current state of the place, the redevelopment project envisaged a multi-scalar approach aimed at defining an integrated eco-system in which health needs and the built environment can converge, where the organisation of the social-welfare services will constitute an innovation with respect to the current offer in favour of the elderly population. In particular, on the one hand the natural propensity to ageing in place is improved, on the other hand integration processes and multigenerational cooperation are to be fostered through the creation of co-housing areas derived from the organisational and functional remodelling of spaces in relation to lifestyles, the environmental and urban context and the levels of perceived well-being (Attaianese et al. 2022). The research aims to transform the living space of elderly people, without isolating them from the surrounding environment, by proposing new and different activities that foster individual and collective health, through intelligent products and services based on ICT, automation and AI technologies.

In order to realise a new plano-volumetric configuration of the ex Polifunzionale, it was necessary to investigate the structure of the Brutalist style building, verifying the thermal transmittance index of the building envelope. This presented values above the limits imposed by the UNI 10349/2016 standard, suggesting the need to intervene through a technological retrofit intervention. Subsequently, microclimatic analyses were performed using the ENVI-met 5.5 software, with reference to 3 August 2022, the hottest day in 2022 for the city of Naples. In particular, graphs and average values were extracted for air temperature, surface temperatures, PMV (Predicted Mean Vote). These resulted in an average air temperature of approximately 32 °C. Subsequently, an intervention strategy was defined to improve the environmental comfort conditions of the project users.

The intervention methodology is based, therefore, on a semi-conservative approach, with the aim of introducing a new functional layout, intervening with a technological and energy retrofit and the redefinition of the open spaces from a climate proof point of view.

3 Results

The results obtained can be traced back to the redefinition of the functional layout for the creation of a life-time home, with the first and second floors used as living quarters, with living quarters designed following the principles of domotic living space, in order to monitor the individual's health parameters and to allow the management of internal systems in absolute ease for pathological and/or physically limited individuals, while on the third and fourth floors, where there

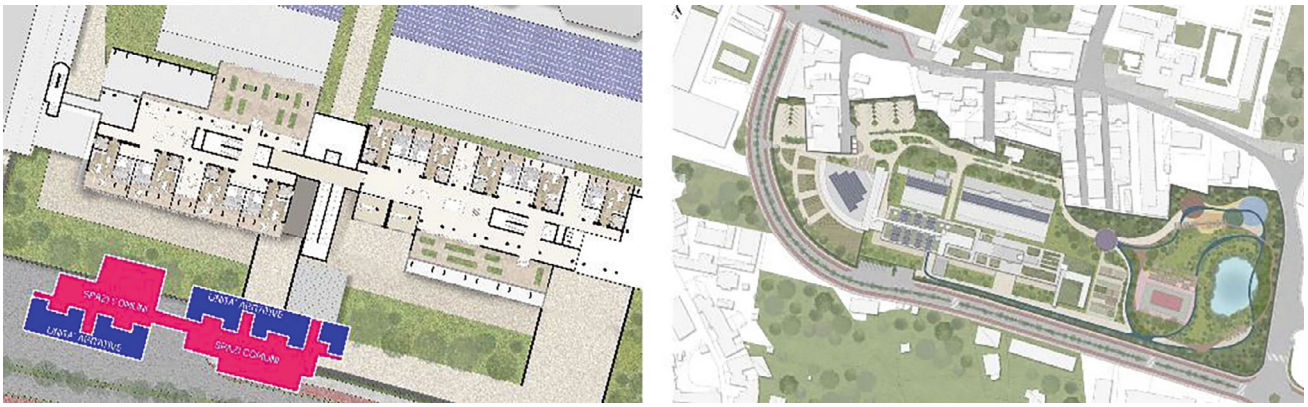


Fig. 2 On the right, reconfiguration of interior spaces, on the left, redevelopment of open spaces. In the functional diagram, in red: common spaces; in blue; residential units

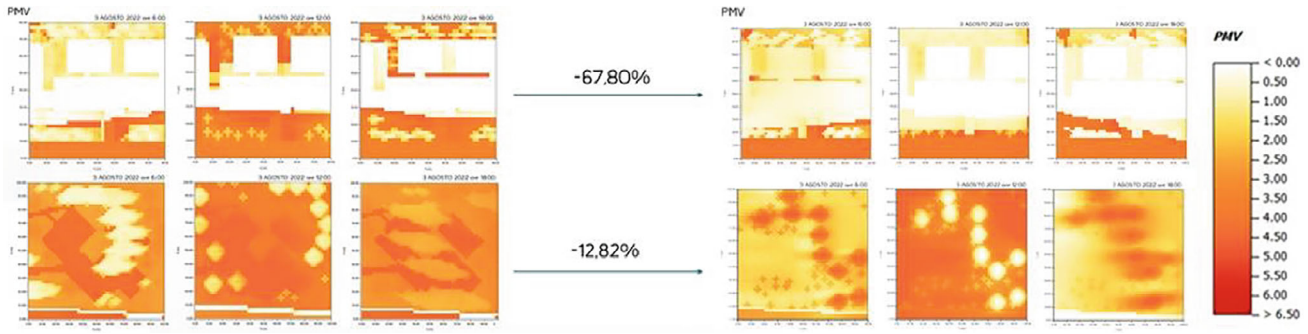


Fig. 3 PMV analysis: on the right the current condition, on the left the design configuration

is already a library, collective and social, recreational and learning functions have been included. These collective and sharing spaces are designed to offer socialisation opportunities that act as a facilitating and multiplying element for activities with a high added value for health with respect to cognitive functions, physical activity and independent living, socialisation and nutrition (Fig. 2).

For the open spaces, environmental strategies of greening, water bodies, depaving, cool materials, shading, intervening on the percentage of permeability of the soil, on the increase of vegetation, on the creation of a bioclimatic oasis with the aim of reducing perceived temperatures and increasing thermal comfort have been planned. Following the implementation of the identified strategies, it was possible to verify that these resulted in a 32.8% decrease in surface temperature (Fig. 3).

Thus, from the analysis of the results obtained, it is visible how the research carried out on the adaptation, mitigation and functional and spatial redevelopment project of the ex Marianella Polifunzionale in Piscinola makes it possible for it to become a point of reference in the area north of Naples and the fulcrum of a process of redemption for the entire district and a beacon of sustainability.

4 Discussion

The research was based on the identification of an intervention methodology starting from the study of theoretical assumptions concerning building renovation and the realisation of new emerging dwelling models, in particular for the elderly. This made it possible to define a list of requirements and performances that would allow the achievement of the pre-established objectives for the creation of an urban space centred on new models of residency integrated on the territory, the creation of an innovative co-housing model and the definition of a climate and pandemic proof urban environment.

On these principles the intervention methodology has been identified and based on a sustainable project viewpoint enlarged to the context, which is capable of conferring to the system of indoor and outdoor spaces qualities and prerogatives as a result of the building redevelopment, such as to represent a basic condition for innovative urban equipment as well as for the health and well-being needs of the elderly person. To do this, specific technological solutions were introduced to meet the functional and social needs of the elderly

person's life and to improve the building's performance, but the effectiveness of these planned solutions will have to be verified with the appropriate energy analysis tools to prove the efficiency of the technological retrofit solutions.

Finally, the limits of the research concern the possibility of considering this study as a reference model for interventions in other social/environmental contexts, in fact, the solutions identified are linked to the reality of the northern suburbs of Naples and its climatic and microclimatic context.

5 Conclusions

The research allowed the development of a resilient intervention, capable of adapting to the effects of climate change through a series of indoor and outdoor solutions, which involve both the building itself and its annexed open spaces, but also extends into a redevelopment intervention of the entire Piscinola-Scampia district. The focal point of the project's organisational feasibility is the connection between the ex Marianella Polifunzionale and the Scampia School of Medicine, located a few kilometres away. This will allow the start-up of all the activities identified within the project and will foster the involvement of local communities.

The final aim is to broaden the research perspectives with the aim of creating a new intervention model that can be applied in multiple contexts but that has the common objective of creating living environments on a human scale with particular attention to the most fragile categories of users, such as the elderly, designing spaces that meet their needs and at the same time inaugurating a new set of demanding-performance requirements, fundamental in the fight against climate change.

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Contribution of X-Reality in Healthcare Settings to Improve Working Sustainability: A Narrative Review

Elpidio Maria Garzillo, Maria Grazia Lourdes Monaco, Arcangelo Cioffi, Anna Rita Corvino, Daniele Guida, and Monica Lamberti

Abstract

Context/Purpose: The X-Reality (XR) approach in healthcare organization can contribute to improving working sustainability in several ways, as for training and education providing immersive and interactive training programs for healthcare workers, learning about environmental sustainability practices, such as waste management or optimizing energy consumption within healthcare facilities. For example, Augmented Reality (AR) technology can facilitate sustainable procurement practices in healthcare settings. Healthcare workers can use AR applications to scan and analyze product labels, providing information about the environmental impact of various materials, chemicals, or packaging. This narrative review, drawing inspiration from the updated literature, intends to summarize the leading knowledge regarding these items. According to literature data, the authors profiled some main findings, summarized in macro-items. Methods: A string search based on these topics was used on PubMed, Google Scholar, and Scopus from June 2019 to June 2023. Then, a manual review was performed according to a selection based on predefined items characterized by four different perspectives: Training and Education, Energy Efficiency, Waste Reduction and Recycling, and Environmental Monitoring and Behavioral Change. Results: Of the 828 documents extracted from the search string, 24 were included and reported in the article. Interpretation: XR applications can encourage positive behavioral changes among healthcare workers by providing real-time feedback and incentives related to environmental sustainability practices. By fostering a sense of gamification and competition, AR can motivate healthcare workers to adopt more sustainable behaviors in their daily routines. Overall, XR has the potential to enhance environmental and working sustainability in the healthcare setting by supporting training, optimizing energy usage, facilitating waste reduction and recycling, enabling sustainable procurement practices, aiding environmental monitoring, and promoting positive behavioral change. Conclusion: By leveraging the capabilities of AR technology, healthcare facilities can contribute to a greener and more sustainable future.

Keywords

X-reality · Augmented reality · Occupational health · Training and education · Healthcare

E. M. Garzillo (✉)
Department of Prevention, Abruzzo Local Health Unit No. 1, L'Aquila, Italy
e-mail: lo@asl1abruzzo.it

M. G. L. Monaco
Occupational Medicine Unit, University Hospital of Verona, Verona, Italy

A. Cioffi
Section of Occupational Medicine, Department of Diagnostics and Public Health, University of Verona, Verona, Italy

A. R. Corvino · D. Guida · M. Lamberti
Experimental Medicine Department-Hygiene, Occupational, and Forensic Medicine Division-Occupational Forensic Area, University of Campania "Luigi Vanvitelli", Naples, Italy

1 Introduction

The integration of X-Reality (XR) technologies, such as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), is revolutionizing every field of human activity, including occupational settings. Although no relevant clinical studies have been conducted on the effect of XR in medicine, there is a growing trend of publications on the topic (Eckert et al. 2019).

The adoption of XR in healthcare settings offers a range of benefits, including improved training, diagnostics, patient care, enhancing working sustainability. Chen et al. illus-

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trated how VR-based interventions are improving the physical and psychological well-being of patients undergoing rehabilitation (Chen et al. 2017). Ma queste nuove tcnologie dovrebbero essere estese al settore healthcare anche per la valutazione di altri aspetti più gestionali e organizzativi, come le sostenibilità dei processi lavorativi in termini di efficienza energetica, impatto ambientale e possibilità di riciclo. Pham HC et al. explore the development of a VR-based learning environment for energy efficiency (Pham et al. 2018).

XR technologies have emerged as promising tools and new perspectives about their role in healthcare, are constantly increasing in scientific literature; several studies are providing a roadmap to guide future research efforts (Delgado et al. 2020).

This review aims to explore the ways in which XR technologies are transforming healthcare settings, improving working sustainability. Through an analysis of relevant literature and studies, this review provides a narrative overview of how XR is contributing to the healthcare industry's sustainable development.

2 Settings

A research based on full text available on PubMed, Google Scholar, and Scopus from June 2019 to June 2023 was performed. The string used for the selection of the papers is the following: ("virtual reality" OR "augmented reality" OR "mixed reality" AND "healthcare." The first random selection was 828 papers. Then, the authors proceed to a manual revision of the paper focalizing on four thematic: Training and Education, Energy Efficiency, Waste Reduction & Recycling, and Environmental Monitoring and Behavioral Change, summarized in Fig. 1.

3 Results

The result of the search string was 828 papers. After a manual revision according to the inclusion criteria based on prefixed items (see Fig. 1), the authors included 24 articles. The selected articles for discussion were given in Table 1, with indication of authors, year of publication, and main topics.

4 Discussion

The integration of X-Reality (XR) into healthcare settings has shown significant potential to enhance working sustainability; this paper reviews the multifaceted applications of XR technologies in healthcare, highlighting their contributions to training, patient care, and operational efficiency.

X-Reality technologies have begun to revolutionize medical education and training. By creating immersive and realistic scenarios, medical professionals can practice procedures and gain experience in a risk-free environment. A study by Kononowicz et al. examined the impact of VR-based training on medical students' surgical skills (Kononowicz et al. 2019), showing that VR training significantly improved their performance and confidence, emphasizing the positive influence of XR on training sustainability.

The results showed an increasing trend in the number of publications on AR in medicine. There were no relevant clinical trials on the effect of AR in medicine.

Nowadays, these technologies are increasingly being combined with artificial intelligence. The impact of this mix

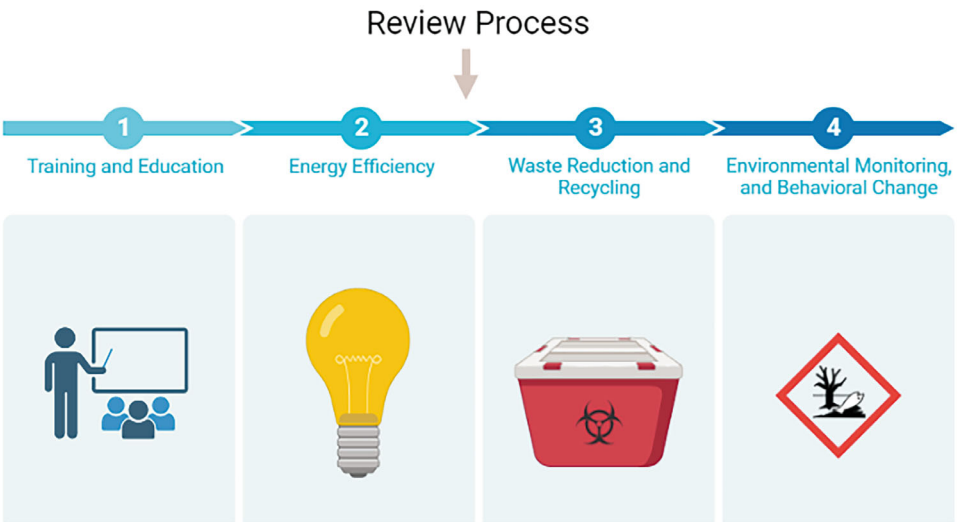


Fig. 1 Macro-item outlined for manual review process

Table 1 Articles selected for discussion

Authors	Year	Main topic	Type of article
Fernandes et al.	2023	Mixed reality and telementoring	A
Mao et al.	2021	VR training in surgical training	R
Bracq et al.	2021	MR in healthcare professional training	R
Vervoorn et al.	2023	MR in surgical practice	R
Liaw et al.	2020	Training in virtual reality versus live simulations	A
Ryan et al.	2022	Immersive training in healthcare students	R
Meese et al.	2021	VR simulation against healthcare stress	R
Van der Kruk et al.	2022	VR training as a patient education tool	R
Psillaki et al.	2023	Energy efficiency in healthcare setting	R
Kaur et al.	2020	Virtual algorithm for energy efficiency	A
Chias et al.	2019	VR applied to hospitals' design	A
Collin et al.	2020	VR on healthcare space management	A
Cetin et al.	2023	VR application to improve surgical field	A
Jung et al.	2023	VR in biophilic hospital design	A
Saudagar et al.	2023	Analysis of AR/VR integration	A
Jeong et al.	2021	VR for recycling and disassembly	R
Frizziero et al.	2019	AR in supporting design processing	A
O'Grady et al.	2021	VR in circular economy	A
Halbig et al.	2022	VR in supporting hospital management	A
Chauban et al.	2022	Digitalized technologies and circular economy	R
Gan et al.	2023	VR in medical education	A
Corvino et al.	2019	AR in health and safety training	R
Pandey et al.	2023	Conceptual framework of IoT in healthcare	R
Kotha et al.	2020	XR in reducing intra-hospital infections	R

Legend. A: Original Article; R: Review

on healthcare is promising and shows great potential for their further development in this area (Ma et al. 2023).

Despite the potential benefits, the adoption of these technologies in healthcare settings faces challenges such as high costs, technological complexity, and concerns about patient data security. However, ongoing advancements in XR hardware and software, coupled with increased awareness, are likely to mitigate these challenges over time.

4.1 Training and Education

This is the main researches' topic so far in scientific literature on the argument. Research conducted by Fernandes et al. demonstrated how AR visualization of medical images improves the understanding of complex anatomical structures (Fernandes et al. 2023). Medical students, nurses, and surgeons can practice surgical procedures, patient interactions, and emergency responses in safe and controlled virtual environments. This accelerates learning, boosts confidence, and reduces the risk associated with traditional training methods. Mao et al. showed that VR simulators provide accessible, low cost, realistic training adjuncts in time and financially constrained systems (Mao et al. 2021). According to Bracq et al., some non-technical skills of healthcare professional such as teamwork, communication, and situation awareness are useful increased by VR simulation (Bracq et al. 2019). Vervoorn MT highlighted that future direction should be aimed at improving head-mounted display technology as well as design of trials including the integration of MR with real-time images, or by constructing holograms that reflect the dynamic organs nature (Vervoorn et al. 2023). Replacing conventional training programs with X-reality-based ones for healthcare workers is also the subject of recent studies. Liaw et al. support the potential use of virtual reality to replace conventional simulations for training communication teams (Liaw et al. 2020). Immersive teaching also plays an important role in the education of undergraduate medical and nursing students, with learning gains equal to conventional methods (Ryan et al. 2022). VR training could also use for working stress coping strategy in clinical environment (Meese et al. 2021), but also a valuable aid in communicating medical

information to patients to improve understanding of potential unintended consequences (van der Kruk et al. 2022).

4.2 Energy Efficiency

X-Reality technologies can also contribute to energy efficiency by enabling better visualization, simulation, and optimization of energy systems. Psillaki et al. proposed to comparatively examine hospital units in different cultural and socioeconomic environments, in order to evaluate an energy-efficient system in hospital units to save resources (Psillaki et al. 2023), and XR could be useful for this scope. Virtual reality is expected to have a decisive impact on the way complex hospital spaces are designed, especially in terms of energy efficiency. In fact, this methodology will become an indispensable tool for sustainability impact before facilities are built. Kaur K et al. discusses the use of VR for energy efficiency education, proposing virtual simulations trails for enhancing energy efficiency (Kaur et al. 2020). AR could also provide real-time information during procedures, avoiding to request other brand-new diagnostic exams. VR is expected to have a decisive impact on the way complex hospital spaces are designed, especially in terms of energy efficiency. In fact, this methodology will become an indispensable tool for sustainability impact prior to the construction of facilities (Chías et al. 2019; Collin and Tamati 2020; Cetin et al. 2023). VR can even facilitate methodological advances in the application of neuroscience related to the biophilic design of hospital environments (Jung et al. 2023).

However, Saudagar et al. issue a warning on this topic: regardless of the benefits for information processing, X-reality will raise new questions not only about energy efficiency, but also about data privacy and systems integration (Saudagar et al. 2024).

4.3 Waste Reduction and Recycling

Waste management and recycling processes involve multiple stakeholders. Mixed reality could facilitate immersive educational experiences about waste reduction and recycling, gamification elements, interactive AR apps, and VR tours of recycling facilities might motivate individuals to adopt more sustainable habits (Jeong et al. 2021). XR technologies could help industries transition to circular models encouraging innovative recycling practices, also aiding designers and manufacturers in creating more easily recyclable medical products and/or devices (Frizziero et al. 2019; O'Grady et al. 2021). XR could also facilitate remote collaboration among waste management teams, allowing experts to provide guidance and support to different hospital branches. This can lead to standardized waste reduction practices across multiple locations (Halbig et al. 2022). Immersive simulations can help reinforce correct waste management practices, leading to fewer errors and reduced waste generation (Chauhan et al. 2022).

4.4 Environmental Monitoring and Behavioral Change

Medical staff who experienced VR teaching mode had more determined career pursuit and active willingness to learn, better evaluations in surgical clinical practice, better scores in physical examination, and image reading (Gan et al. 2023). To help healthcare workers adopt proper behaviors to reduce injuries and occupational diseases, these new technologies, however, call for a multidisciplinary approach that manages the opportunities and risks of these new tools in a well-defined framework (Corvino et al. 2019). The use of XR and its admixture with other technologies (such as AI, IoT) is broad, as it is flexible in almost any technology that can provide relevant information about their performance, and also about environmental conditions that need to be monitored and controlled remotely (Pandey and Pandey 2023), not only in terms of patient care, but also in terms of control for environmental sustainability. For example, a valuable aid that could involve the use of XR and integration with other systems, such as IoT in environmental monitoring processes, could relate to preventing and reducing the rate of intra-hospital infections (Kotha 2020).

The contribution of this article is mainly to analyze some very particular aspects within the healthcare environment. Indeed, while training is a hot topic in this work environment, others such as energy efficiency and waste reduction and recycling need additional interest from the scientific community.

5 Conclusions

X-Reality technologies are making significant contributions to healthcare settings, enhancing training, diagnostics, communication, and patient care. The integration of XR is fostering sustainable practices within the healthcare setting, even if continued research, development, and collaboration among stakeholders are essential to unlocking the full potential of XR in this context.

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Prospective LCA for Decision Support for Buildings—A Case Study to Answer Ten Questions

Simon Bruhn and Morten Birkved

Abstract

A previous study raised ten relevant questions and answers concerning the usefulness prospective LCA (pLCA) in decision support for buildings. This extended abstract explores these answers in a more practical manner. Through the case study of a 150 m^2 single-family house, three different LCA methodologies are compared: conventional LCA; static pLCA for 2030; and pLCA with dynamic inventory modelling for 2030–2100. Eight prospective databases were created with *premise* v.1.6.1 according to SSP2-base scenario for the years 2030–2100, and used for the background system modelling. The results show respectively 7.1E5, 5.8E5, and 1.9E5 kg CO_2eq for the compared methodologies. 78–93% of those emissions originate from the residential energy use, which was considered all electric. Hence the positive evolution of the electricity mix expected in the chosen scenario explains the largely reduced emissions resulting from the dynamic pLCA. It should be noted that SSP2 is but one out of five available Shared Socioeconomic Pathways, which can be coupled with several—more or less pessimistic/optimistic—political global warming mitigation scenarios. The addition of dynamic inventory modelling in pLCA is proved to be of significant importance, as it can increase the accuracy of decision support. The study could be improved by estimating prospective foreground system by expert judgement or stakeholders.

Keywords

Future scenarios · Prospective LCA · Dynamic LCA · Stepwise dynamism · Decision support · Buildings · Premise · Shared socioeconomic pathways

1 Introduction

In order to reduce the substantial environmental impacts from the built environment—which accounts for 33% of anthropogenic greenhouse gas emissions (Eberhardt et al. 2020)—it is essential to provide sound decision support when, e.g. planning new buildings. A widely recognized methodology for said task is life cycle assessment (LCA) (Parisi et al. 2020). The field of prospective LCA (pLCA) is currently evolving quickly, as an improvement in decision support. In short, pLCA changes the foreground and background systems as to "project" the LCA to a given target year (and its technological contexts), e.g. which decision has lower emissions in 2050 or 2100? (Arvidsson et al. 2023; Bisinella et al. 2021).

A recently published paper by Bruhn et al. (2023) highlights ten relevant questions concerning the implementation of pLCA for decision support in the built environment, as well as suggesting possible answers to these questions. This extended abstract further explores some of these questions via a case study. Below, we briefly summarize those ten questions and answers, referring to Bruhn et al. (2023) for the detailed information.

1. **Future Environmental Impacts**: pLCA assesses environmental impacts based on future scenarios, relevant for buildings due to their long lifespan and high energy use.
2. **Temporal Dependencies**: pLCA includes future projections, crucial for buildings with long-term construction, operation, and demolition phases.

S. Bruhn (✉) · M. Birkved
SDU Life Cycle Engineering, University of Southern Denmark, Odense, Denmark
e-mail: morb@igt.sdu.dk

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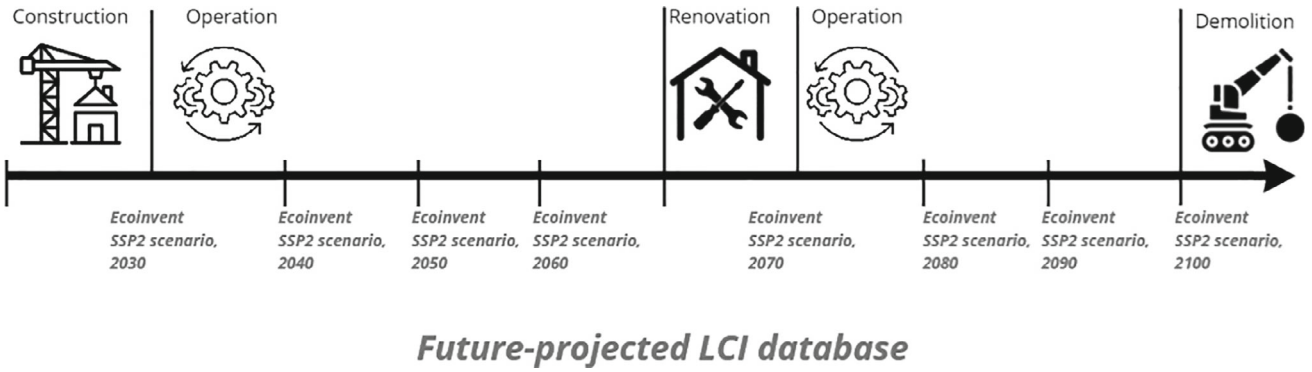


Fig. 1 Illustration of buildings life cycle inventory, which has been made dynamic in 10 year intervals

3. **Goal and Scope**: Most pLCA studies use a 25–35 year horizon, shorter than the typical 80-year building lifespan, and often lack clear system boundaries.
4. **Estimating Future Systems**: Foreground and background systems should align with the study's temporal scope, using stakeholder input and scenario narratives.
5. **Integrating Scenarios**: Scenario narratives are used in LCA, but many studies lack detailed implementation methods, leading to potential errors.
6. **Software for pLCA**: The premise software modifies databases for future projections but lacks integration for some advanced methods.
7. **Dynamic Elements**: pLCA mainly projects inventories to a future year, providing a static snapshot.
8. **IAM-Based Scenarios**: IAMs focus on costs, energy, and emissions, potentially misestimating other indicators.
9. **Scenario Narratives**: Only the SSP2 scenario is currently available for use with premise; custom scenarios require expert input.
10. **Standard Procedures**: Inconsistencies in pLCA literature can be improved with scenario narratives and tools like premise, but thorough documentation is essential.

2 Methods

The original ten-questions paper by Bruhn et al. (2023) was based on systematic literature screening of 47 studies using pLCA, as well as several discussions with developers and expert users in the academic pLCA community. Finally, deep knowledge was acquired via first-hand experimentation with available software tools.

The case study in this extended abstract conducts a cradle-to-grave pLCA on a 150 m^2 single-family house in Denmark. The pLCA is conducted with stepwise dynamism in the lifecycle inventory. In essence, the ecoinvent 3.8 (cut-off) database is systematically transformed to correspond to future projections from the SSP2-base scenario (based the REMIND integrated assessment model (Luderer et al. 2022)). The database is practically transformed via the software *premise v.1.6.1* considering future projections of the following sectors: power generation, cement and steel production, freight and passenger road transportation, and supply of conventional and alternative fuels (Sacchi et al. 2022).

The life cycle inventory is modelled in several steps in the software *Activity Browser* (Steubing et al. 2020). The construction phase is modelled with a 2030-projected version of ecoinvent; renovation is modelled with a 2070-projected version; and demolition is modelled with a year 2100-version. Finally, the residential energy use of the house is modelled in ten-year intervals (with corresponding yearly projected databases). In this way, we improve the pLCA by the addition of a dynamic life cycle inventory. For simplicity, we consider the foreground system to be unchanged, i.e. renovation and demolition practices as well as residential energy use are assumed not to change in the future (Fig. 1).

The inventory data is inspired by undisclosable (but accurate) data from Lanau (2020). We estimate rough amounts of building materials, transportation, and energy used along the life cycle. Residential energy use (assumed all electric) is based on average Danish data: 40 GJ pr person and 2.6 persons living in the analyzed building. It should be noted that the accuracy of the inventory data is not crucial for this case study, as the case study explores the *difference* in the results when using the proposed dynamic pLCA method compared to a conventional static LCA. Results are evaluated for a **conventional LCA** using the conventional ecoinvent 3.8 database; a **static pLCA** using a version of ecoinvent projected to 2030 (construction year of the building); and finally a **dynamic pLCA** with dynamic inventory as described above.

Results are evaluated as GWP100a by the IPCC2013 method.

Table 1 GWP results for the compared LCA methods in kg CO_2eq

Method (*Kg CO_2eq)*	Construction	Renovation	Demolition	Residential energy	Total
Conventional LCA	3.4E + 04	2.0E + 04	− 3.7E + 03	6.6E + 05	7.1E + 05
Static pLCA (2030)	3.4E + 04	2.0E + 04	− 3.6E + 03	5.3E + 05	5.8E + 05
Dynamic pLCA (2030–2100)	2.9E + 04	1.6E + 04	− 2.7E + 03	1.5E + 05	1.9E + 05

3 Results

The GWP results of the conventional LCA amount to 7.1E5 kg CO_2eq, whereas the static pLCA amount to 5.9E5 kg CO_2eq. The dynamic pLCA has a significantly lower result of 1.9E5 kg CO_2eq. The residential energy use accounts for respectively 93%, 92%, and 78% for the three compared cases. Note that this is the total GWP impact from the buildings entire 80 year life cycle including residential energy use (Table 1).

4 Discussion

In general, the results indicate that taking the future background system into account leads to lower GWP impacts. By considering the background system when the building is constructed (2023), the impact is reduced by approximately a third compared to using a conventional LCA approach. This is largely attributed to the fact that the majority of a building's impacts come from operational energy use. However as several studies highlight, it is important to consider dynamic elements of energy use—especially that the energy mix changes significantly during the buildings lifetime (Su et al. 2019, Su et al. 2021). By implementing such dynamism in the background system at 10-year intervals, the total GWP is reduced by almost 75%. In reality this might be lower if using non-electric energy sources such as gas or oil. A significant decrease was expected based on (Karl et al. 2019) and (Roux et al. 2016), however we expected it slightly lesser in magnitude. It should also be noted that since the SSP scenarios that fees into the future projections, are closely connected to political agreements and scenarios. Hence our results reflect a possible future, which is in line with certain political goals. The SSP2-base scenario applied in this study corresponds to extrapolation of historical trends as well as a political mitigation scenario of 3.5 C (Riahi et al. 2017). Other results can be evaluated with the same methodologies as applied in this study.

The study only changed the background system (via using future-projected versions of ecoinvent). Several studies highlight the importance of doing so (Arvidsson et al. 2018, Cox et al. 2018, Mendoza Beltran et al. 2020). However to provide sound decision support, the foreground system should be changed accordingly as well. In this study it was omitted, but relevant changes could, e.g. be lower energy use due to better insulation after renovation, etc.

5 Conclusions

This study follows up on 10 questions and answers (see all questions and answers in Bruhn et al. 2023), that were raised in a previous study concerning prospective LCA for decision support in the built environment. We explore some of the methodologies that are deemed most powerful to conduct prospective LCA. By using *premise*, the background database for a single-family house is changed, which shows significant changes in the GWP results. The results support other studies, which finds that pLCA gives favourable results (lower impacts) compared to conventional LCA. Furthermore, our case study proves that considering a dynamic inventory in the pLCA, the results are significantly more favourable—up to 75% reduced emissions compared to a conventional LCA. Addition of foreground system changes would further increase accuracy of the results, providing important decision support for the built environment.

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Evaluation of Sustainable Developments of Railway Corridors: Infrastructural Characteristics of Railway Freight Corridor 3 in Italy

Corrado Rindone and Luciano Amodeo

Abstract

Railway transport is a sustainable travel option for medium-long distance trips of freight. European Commission is developing Trans European Network (TEN-T) and Railway Freight Corridors (RFC) with the aim to increase sustainable freight mobility. However, the current railway infrastructures have not homogeneous physical and functional characteristics along the corridor. This constitutes a limit for realizing railway transport services for freight mobility. The main objective of the research is to investigate the current characteristics and then the bottlenecks along the Scandinavian Mediterranean commercial corridor (RFC3). In particular, this paper focuses the portion of the RFC3 corridor that crosses the Italy from north to south. The heterogeneous infrastructural characteristics influence the performances railway services (e.g. flows and travel time). The obtained results show the main limits of Italian RFC3, in relation to the European standards. The analyzed bottlenecks represent a constraint for the development of railway freight transport in the perspective to increase the sustainable mobility. The work is useful for researchers, in their role of railway mobility analysts, and decision-makers and takers for supporting the transportation planning process.

Keywords

Railway transport · Freight transport · Railway corridor · RFC · Infrastructural characteristics · Train length

1 Introduction

Rail represents one of the main sustainable option for moving freight at national and international mobility. For this above reason, it is necessary to investigate the current and future asset of the Trans European Network—Transport (TEN-T) (European Commission 2013; European Commission 2021) and the Railway Freight Corridor (RFC) (Woroniuk et al. 2013). The general objective of this research is to identify TEN-T/RFC strengths and weakness in the context of international supply chain. The specific objective of this paper is to identify the functional capacity railway constraints belonging to TEN-T/RFC in relation to freight mobility. According to the EU legislative proposals of the revision of the TEN-T (European Commission 2021), the constraints regard nodes (e.g. railway terminals), links and corridors. This paper regards the physical constraints at the link level that influence the performance of railway services along a commercial corridor.

The physical constraints limit the RFC's potentialities in the European market for promoting sustainable solutions. In particular, the case study of this paper is the portion of the RFC3 corridor that crosses the Italy from south to north to, using the available information of the national railway infrastructures.

After this introduction, the paper has three sections. Section 2 recalls the main characteristics required for freight railway transport at the European level. Section 3 reports the obtained results of the analysis for the Italian case study. Section 4 discusses and interprets the obtained results with some final remarks and future perspectives of the research.

C. Rindone (✉) · L. Amodeo
DIIES, Università degli Studi Mediterranea di Reggio Calabria, Reggio Calabria, Italy
e-mail: corrado.rindone@unirc.it

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2 The Main Requirements for Freight Railway Transport and Interoperability

Europe intends to enhance intermodality and interoperability of the international supply chain through TEN-T networks in order to increase sustainable freight mobility. With this aim, the TEN-T regulations indicate the technical specifications for interoperability (TSI) of the railway network (Sect. 2.1). The proposed analytical formulation allows the identification of the bottlenecks that limit the potentialities of the Rail Freight Corridors (RFC) (Sect. 2.2).

2.1 The European Technical Specifications for Interoperability

The physical characteristics influence the RFC's performances and the achievement of sustainable objectives at the European scale (Russo 2021; Russo et al. 2023). However, the following constraints limit the development of interoperability at the European scale: (a) diversity of signalling systems, towards the ERTMS standard that should replace national signalling systems; (b) different electrification systems between Member States and, sometimes, within the same Member State; (c) differences in maximum train lengths; (d) different axle load categories; (e) absence of a common standard gauge across European rail.

The technical specifications for interoperability (TSI) indicate the technical and operational characteristics and relative essential requirements for ensuring the interoperability of the railway system of the European Union (European Commission 2014). The requirements are defined with the aim of removing trade barriers for industry and consumers within the European Union (EU).

The TSI are defined in relation to the mobility component (people and freight); the following subsystem supply components:

- infrastructure (physical and immaterial);
- management;
- rolling stock.

Railway freight transport is influenced by different supply components. This paper focuses on the TSI for infrastructures defined by the European regulations (UE) n. 1299/2014 and named "INF TSI". Table 1 reports the most common traffic codes for classifying the RFC's links, in relation to the physical characteristics and relative parameters for freight transport. This includes four characteristics indicated with the index i and classified on: "hard" characteristics, as the gauge ($i = 1$) and the axle load ($i = 2$) and "soft" characteristics, as the line speed ($i = 3$) and train length ($i = 4$). The traffic code "F1" indicates the greatest values and then the best performances for interoperability along the RFC's links. These targets values must be considered for upgrading or renewing existing railway lines in terms of gauge, axle load, line speed and train length.

2.2 An Analytical Formulation for the Bottleneck's Individuation

The following analytical formulation individuates the bottleneck for railway freight transport at the link level, along a generic RFC corridor. The formulation uses the following symbols:

RFC	is one of the nine generic rail freight corridor, as defined at the European level;
l	is the generic railway link belonging to one RFC;
k_{RFC}	is the generic path k_{RFC} that links two terminals along the same RFC corridor, defined as a sequence of links l;
$F(l)$	measures the performance of the link l; by comparing the physical link's characteristics with the values reported in Table 1, the variable assumes the traffic code that has the worst value; for instance, if along an RFC the link has a gauge GB, an axle load 20 t, a line speed 120 km/h and a train length 740 m, $F(l) = F3$;
$\mathbf{F}(k_{RFC})$	measures the performance the path k_{RFC}; in a general case, this is a matrix with a number of rows equal to the quantity of railway

Table 1 Performance parameters for freight traffic

Traffic code	Hard characteristics		Soft characteristics	
	Gauge ($i = 1$)	Axle load [t] ($i = 2$)	Line speed [km/h] ($i = 3$)	Train length [m] ($i = 4$)
F1	GC	22.5	100–120	740–1050
F2	GB	22.5	100–120	600–1050
F3	GA	20	60–100	500–1050
F4	G1	18	n.a.	n.a.

Source (European Commission 2014)

Table 2 RFC3 infrastructural characteristics for freight transport ($b_{k,\,\mathrm{RFC3},\,4}$): max train length

Max train length (metres)	Tyrrenian axis		Adriatic axis	
	Spatial extension (km)		Spatial extension (km)	
	v.a.	%	v.a.	%
F1	0	0.0	0	0.0
F2	77.7	23.9	339.05	24.0
F3	771.0	60.0	937.55	66.3
F4	339.1	16.1	136.51	9.7
Total	1415.8	100.0	1413.1	100

links forming the path k_{RFC} and a number of columns equal to the four physical characteristics of Table 1; each element assumes the $F(\mathrm{l})$'s value;

$\mathbf{km}_{F(\mathrm{l}),\,i,\,k,\,\mathrm{RFC}}$ is the vector of the spatial extensions of the railway links for which $F(\mathrm{l}) \neq \mathrm{F4}$, limiting the path k_{RFC} with the physical characteristic i.

For each of the four INF TSI physical characteristics (Table 1), the following indicator measures the total spatial extensions that limits the performances of the path k_{RFC}, in relation to the physical characteristic i and constituting a bottleneck:

$$b_{k,\mathrm{RFC},i} = \left(\mathbf{km}_{F(l),i,k,\mathrm{RFC}}\right)^{T} \quad (1)$$

3 Results

The Italian portion of the RFC3 operates along the ScanMed TEN-T corridor. The current extension on this European corridor connects northern and southern territories from Brennero–Verona to Gioia Tauro–Sicily.

The physical characteristics of the railway infrastructures belonging to the RFC3 are not homogeneous and they do not respect the TSI INF standards. There are different bottlenecks along the Italian portion of the European corridor.

In this paper the total extension of bottlenecks related to the train length are measured by applying the Formula (1), using data obtained with a desk on line survey (RFI 2023). The analyzed path k_{RFC3} connects the Gioia Tauro gateway terminal and the Brenner railway station. Table 2 reports the total spatial extension of bottlenecks ($b_{k,\,\mathrm{RFC3},\,4}$) along the two RFC3's axes in Italy, in relation to the max train length.

4 Discussion and Final Remarks

Some physical characteristics of railway infrastructures limit the potentialities of RFC corridors, as alternative route for freight transportation. The train length, focused on this paper, influences the volumes of freight transported by rail. For instance, the railway line from Perpignan to Luxembourg allow a train length of 850 m, bringing the maximum load to 2400 tonnes instead of 1800 (UIRR 2022).

Railway services along the RFC3 could be of potential interests for production and consumption processes located and distributed in the Italian territories (Russo and Musolino 2012). This paper quantifies the main bottlenecks related to one physical characteristic of a north–south path along the RFC3 corridor. The current physical configuration of Italian rail network generates discontinuity limiting the performance of railway corridors in terms of capacity, speed, and volumes of a freight transportation by rail. Consequently, rail freight is uncompetitive in comparison with conventional transportation modes (e.g. freight by road). An investment to increase the maximum length of a train on approximately 24% of the analyzed path allows the upgrading to the F4 standard. This would lead to an increase in volumes that can be transported with a consequent transfer of traffic from road to rail by about 20%. This produces environmental benefits, in accordance with international guidelines on sustainability.

Future perspectives of this paper regard the analysis of bottlenecks related to the other physical characteristics.

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Evaluation of Sustainable Developments of Railway Corridors: People Accessibility to New HSR Line in the Calabria Region

Corrado Rindone and Paola Panuccio

Abstract

Transport infrastructures and services allow people and business to perform their daily activities (jobs, health, …). This implies the necessity to increase sustainable mobility not only in relation to the economic and environmental components but also for social issues. Enhancing accessibility contributes significantly to the increase of social sustainability. In this context, this paper focuses on the passenger accessibility evaluations of transport nodes belonging to the Trans-European Network (TEN-T) and relative core corridors. The main objective of the research is to investigate the potential accessibility improvements produced by High-Speed Rail (HSR) along the Scandinavian Mediterranean core corridor (Scan Med), focusing on the national connections from/to the Calabria region. The paper applies the consolidated daily accessibility indicator for measuring the potential effects of a new HSR line. The case study compares two alternative hypothetical routes of HSR in Calabria: the first assumes that the new line follows the route of the conventional line; the second assumes that the HSR line follows an internal route. The obtained results show a current situation of connections unbalanced on unsustainable travel options. The presented analyses and results show some problems related to the integration of information, transport, and method of payments. The main interpretation concerns the results in terms of accessibility in the two routes. It emerges that the internal route that should allow greater accessibility, in fact, implies a worsening compared to the connections given by the direct route with the capital of Italy. The proposed work is useful for the transport system designers, as decision-makers and public authorities as decision-takers, in an integrated transportation planning process.

Keywords

Railway corridors · TEN-T · Transportation planning · Social sustainability · Accessibility

1 Introduction

The transport system plays a relevant role in the economic, social, and environmental pursuing sustainability (United Nation 2015). Transport infrastructures and services have an essential function in a territory, allowing people and businesses to perform economic, social, cultural, professional, or personal activities. However, conventional planning tends to evaluate transport system performance-based primarily on motor vehicle travel conditions using indicators such as roadway level-of-service, traffic speeds, and vehicle operating costs; other accessibility factors are often overlooked or undervalued. In this regard, transport planning should aim for a proper balance between the economy and the environment while addressing social issues at the same time (Lucas 2012). The realization of the transportation infrastructures and services should achieve sustainable objectives by respecting the constraints. Mobility and accessibility contribute to the different Sustainable Development Goals (SDGs) of the Agenda 2030. In particular, accessibility contributes to increasing equity, and reducing disparities in different territories (Camporeale et al. 2017). Economic, territorial, and social cohesion constitute a priority of the European Union by improving transport connections allowing the "free movement of persons, goods, capital and services" (European Commission 2022). With this aim, European Commission is promoting and implementing Trans-European Networks—

C. Rindone (✉) · P. Panuccio
Università degli Studi Mediterranea di Reggio Calabria, Reggio Calabria, Italy
e-mail: corrado.rindone@unirc.it

P. Panuccio
e-mail: paola.panuccio@unirc.it

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Transport (TEN-T) (European Commission 2013, 2021). High-Speed Railway (HSR) transport increases accessibility, contributing at the same time to environmental (Russo 2021) and economic (Russo et al. 2023; Russo and Musolino 2012) sustainability. The current practices show the potentialities of HSR for improving the connections of urban agglomerations, reducing at the same time the carbon dioxide emissions (Zhu et al. 2022). The aim of this research is to focus on the accessibility component and the potential contribution provided by HSR lines. The specific objective of this paper is to propose some measures to quantify national accessibility in relation to HSR potential development. The case study is the Calabria region and its connections to the Italian capital. To this end, after the introduction, the paper has three sections. Section 2 recalls some accessibility measures useful for evaluating social sustainability at the national level by focusing on passenger mobility. Section 3 illustrates the results of a comparison between two alternative routes of HSR Salerno-Reggio Calabria planned line. Section 4 discusses the obtained results, reporting some conclusive remarks.

2 Accessibility Measures for National Passenger Mobility

2.1 Accessibility Measures

A classification of accessibility measures is proposed by Geurs et al. (2009) that consider: two perspectives in relation to infrastructures and services performances (*infrastructure-based*) or the spatially distributed activities (*location-based*); four components in relation to the opportunities at each destination (*land-use)*, the travel disutilities from origin to destinations (*transportation*), the temporal constraints for performing a specific activity (*temporal).* Literature offers different specifications for in relation to the two perspectives and the four components, providing assessment measurement of accessibility. The accessibility indicators measure both the ease of a user to reach from his residence the opportunities located in the area to perform his activities (active accessibility), and the ease with which an activity located in a certain area (e.g. tourism) can be reached by its potential users (passive accessibility) (Cascetta 2013).

2.2 Daily Accessibility Indicators for Measuring HSR Performances

As far as concerns the national mobility of people by rail, it is possible to measure the daily accessibility in terms of the quantity of people that can be reached from a place by performing a day's round trip or the quantity of people that can play activities in a place within a day's round trip. A possible analytical formulation is (ESPON 2012):

$$A_i = \sum_j P_j * t \tag{1}$$

with

$t = 1$ if $t_{ijm} \leq t_{\max}$.
$t = 1$ if $t_{ijm} > t_{\max}$.

where

A_i is the daily accessibility measure of the zone i;
P_j is the quantity of residential population in the zone j;
t_{ijm} is the minimum travel time between the zone i and the zone j by transport mode m;
$t_{\max}$ is the time threshold value for the maximum travel time between the zones i and j.

Literature proposes different values for the time thresholds for measuring daily accessibility. For instance, at European level, $t_{\max} = 5$ h.

3 Daily Accessibility Comparisons for the Calabria Region

This section focuses on the Calabria region case study. The objective is to compare the daily accessibility of the region in relation to the trips by rail with destination the national capital. The current configuration of the Italian HSR serves a limited portion of the entire national territories, along the Scandinavian–Mediterranean TEN-T core corridor, starting from the north (Milan) to the south (Salerno). The regional territories located in the extreme south of the country (Basilicata, Calabria, and Sicily) are not served by the HSR. For overcoming this gap, in recent year, the Italian Government is promoting the realization of the Salerno–Reggio Calabria HSR line. For their realization, two alternative routes have been proposed:

- the first "route A" follows a new railway line with the HSR standard;
- the second "route B" follows the conventional railway line, updated to HSR standard.

This paper compares the values of the daily accessibility indicator obtained by applying the formula (1), for the two proposed routes. The analysis is limited to the connections between the major cities in the Calabria Region and the city of Rome, national capital. Figure 1 depicts the travel times from one of the selected city of the Calabria region to the national capital, calculated for the two routes (A and B) of the designed Salerno–Reggio Calabria HSR line.

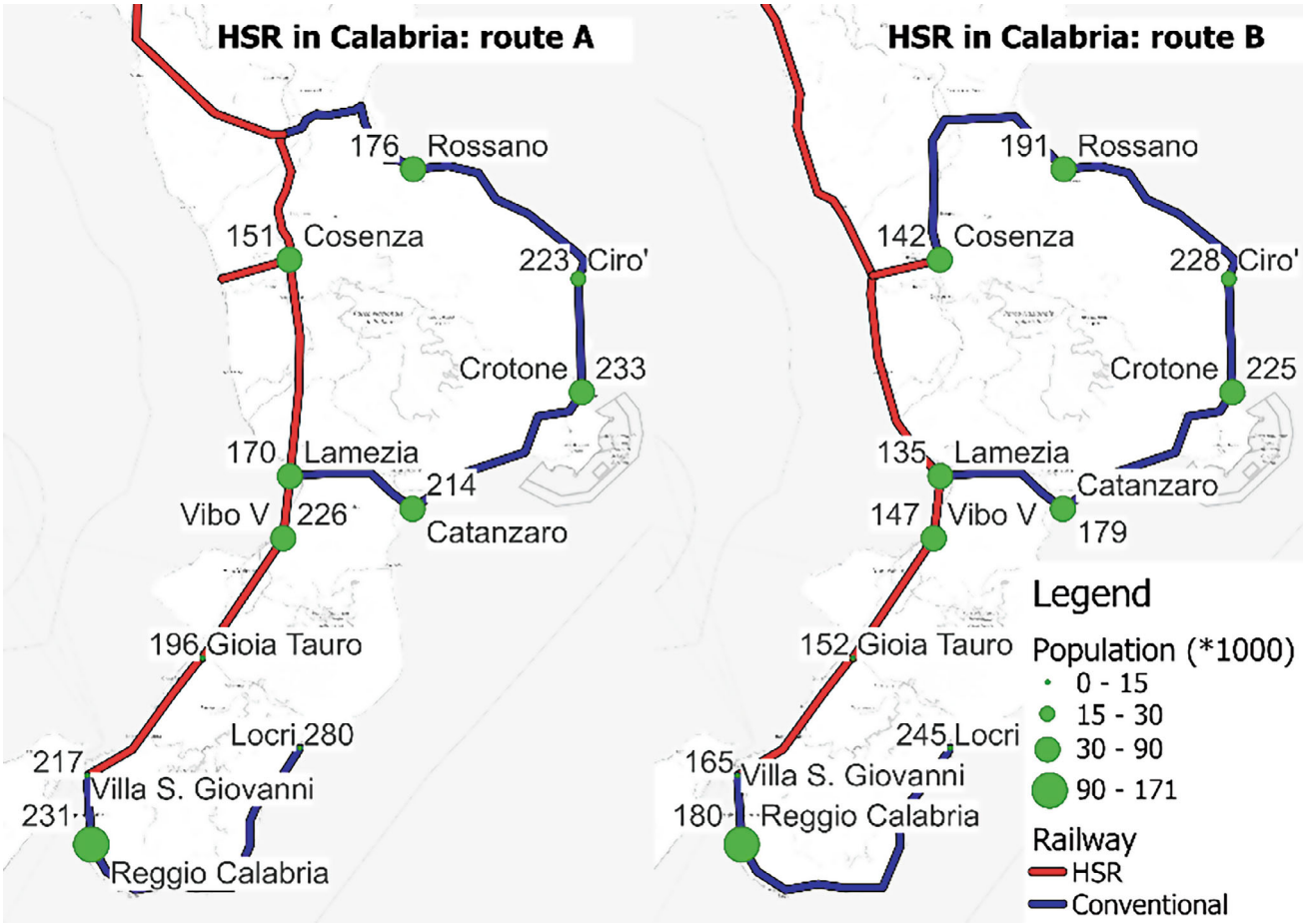


Fig. 1 Travel times along the two routes of the planned Salerno–Reggio C. HSR line

4 Discussion and Conclusion

The development of high-speed railway networks represents a possible solution to achieve a balance between the three components of sustainability. The obtained results show the relevance of the accessibility for measuring the social sustainability component. The case study offers a comparison of two routes for realizing the planned Salerno–Reggio Calabria HSR line. The social effects produced by the two alternative routes are measured adopting the daily accessibility concept. As far as concerns the daily accessibility to the capital of Italy, the route A has a lower performance than the route B. In fact, by adding the products between the resident population in each zone of the region and the relative travel times to Rome, the option B produces a 14% increase in daily accessibility respect to the option A. The proposed analysis therefore makes it possible to use the most correct formulation in relation to the problem to be faced. The work briefly presented is important for public decision-makers who have the two networks at their disposal and want to implement hybrid passenger services. The strengths and weaknesses of the mixed exploitation HSR model are highlighted. The work is also useful for technicians, in their role as planners and designers, because it allows them to use the most advanced transport system analysis models.

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Sustainability Challenges and Opportunities in Arab Communities with the Use of Multiple Rating Systems

Iman Ibrahim

Abstract

To attain environmental equilibrium in Arab communities, it is necessary to first comprehend their distinct sustainability challenges. Therefore, the purpose of this study is to investigate how international and national rating systems can be utilized effectively to achieve multiple dimensions of sustainability. The research's initial analyses investigate specific obstacles to sustainable development, such as accelerated urbanization, resource scarcity, population growth, and climate change. The highlighted areas denote those in need of innovative thought and eco-friendly solutions consistent with the aims associated with a greener planet. The following section emphasizes the function of internationally recognized frameworks such as LEED, BREEAM, SAFAT, ARZ, M, and ESTIDAMA, among others. These provide a standardized framework for evaluating the sustainability performance of buildings, infrastructure, and communities. They test ratings for energy efficiency, water conservation, and refuse management, among others. This information enables us to develop plans that promote environmentally responsible decision-making. The research emphasizes the importance of adapting these sustainability rating systems to regional Arab culture and context-specific knowledge/practices. This encourages local participants to recognize and develop new sustainable solutions, identify best practices for energy conservation, and adhere to relevant eco-friendly policies while preserving their cultural heritage. It is essential for researchers, policymakers, and community members to collaborate across disciplines to realize the full potential of international and national sustainability rating systems when addressing environmental challenges unique to Arab communities. By investing in these tools, we can identify regional context-specific strengths, develop innovative solutions, and improve long-term sustainability performance across an increasingly interconnected urban landscape, thereby fostering a more sustainable future on a global scale. When it comes to achieving sustainable growth, you can't say enough about how important it is for Arab communities to understand and deal with sustainability problems. The study points out major problems that need to be fixed right away, such as rapid urbanization, population growth, lack of resources, and climate change. For these problems to be solved, it's important to have a uniform framework that evaluates green performance for certification. Adding culturally specific values and local knowledge to these systems makes it easier to find sustainable practices and build solutions that fit the situation.

Keywords

Sustainability · Rating systems · Arab communities · Sustainable cities

1 Introduction

Different systems of rating have been created since the 1990s to define and assess ecologically responsible building design. Since the 1970s, "green architecture" has been used to refer to ecologically friendly buildings. Sustainability is concerned with environmental issues, and its implementation alters communal habits. Due to their need to adjust to the new era of dwindling natural resources, regional nations confront social and environmental difficulties. The area uses a variety of rating systems (Deloitte 2015).

Estidama by the Abu Dhabi Urban Planning Council, ARZ by the Lebanese Green Building Council, and GSAS

I. Ibrahim (✉)
University of Sharjah, Sharjah, United Arab Emirates
e-mail: iibrahim@sharjah.ac.ae

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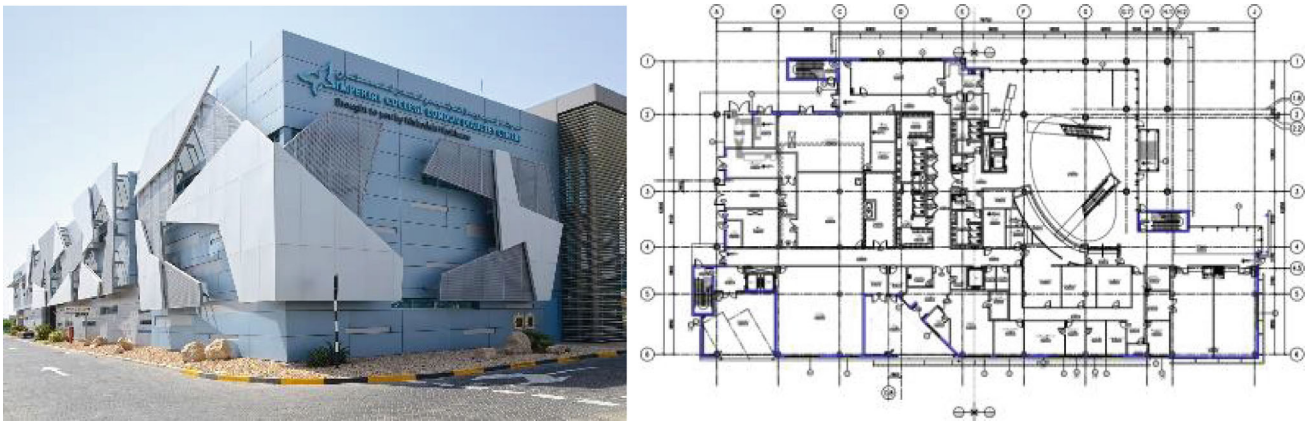


Fig. 1 The imperial college London diabetes **a** exterior shot and **b** center plan

by the Qatari government are the most well-known rating systems in the region that have already begun to be accredited by new projects. This research is willing to analyze three of them with an accredited project from each rating system, as the total value of infrastructure and capital projects planned and underway in Gulf Cooperation Council (GCC) countries in 2015 is valued. According to the GCC Powers of Construction 2015 report, construction is the region's economic barometer (http://www.thebig5.ae).

To create a built environment that is sustainable and has a minimal ecological impact, it is crucial to incorporate concepts that encourage the development of healthier and more habitable urban spaces. This entails a comprehensive strategy that integrates green infrastructure, sustainable transportation, energy-efficient buildings, and community-focused public spaces. Green infrastructure, including urban parks, green roofs, and vertical gardens, is vital in alleviating urban heat islands, diminishing air pollution, and granting citizens the opportunity to connect with nature. Utilizing sustainable modes of transportation such as walking, cycling, and public transit effectively mitigates carbon emissions and alleviates traffic congestion, all the while fostering better lifestyles. These strategies not only promote environmental sustainability but also enhance the overall livability and health of urban areas (Bonet-Avila et al. 2023).

2 Estidama

Estidama is a framework for environmentally friendly design, building, and operation in the Emirate of Abu Dhabi. It is a sustainability program connected to the Abu Dhabi Urban Planning Council. All new communities, buildings, and villas are required by the Abu Dhabi Executive Council to attain a minimum 1 Pearl rating, with government-owned and managed structures being obliged to earn a minimum 2 Pearl rating (Abu Dhabi Urban Planning Council 2015).

The Imperial College London Diabetes Centre in Abu Dhabi is the first Estidama Pearl-rated construction project in the UAE. The building's design was inspired by the center's work and the complex hexagonal helical molecular structure of insulin. The hexagonal hexagons in the screening panels provide solar shading and privacy, reflecting traditional musharabiya screens in the region's vernacular architecture. The center's medical team was closely involved in understanding their operational needs and passion for solar shades, energy-efficient MEP services, gray water treatment, waste management, water-conserving landscaping, solar heating, and locally sourced materials (AE7 2014) (Fig. 1).

3 ARZ

To enhance living conditions and lessen negative environmental effects associated with the building industry, the Lebanese Green Building Council (LGBC) created the ARZ as a recognized grading system in Lebanon. The goal is to promote environmentally friendly, resource-efficient, and cost-effective living environments that improve user comfort and health. This includes the design, planning, construction, and usage of new and existing buildings (Lebanon Green Building Council 2014).

The BLC Bank Head Quarter Landmark in Beirut has received praise from ARZ for establishing a landmark structure that integrates urban design, height, and shape. The building's purpose as a bank is represented by parametric lines in the design, which also integrates street views. The bank headquarters are a notable landmark in the twenty-first century due to their unique design, integration of existing buildings, sustainability, forward-thinking social amenities, and daring structural solutions. The project's innovative social

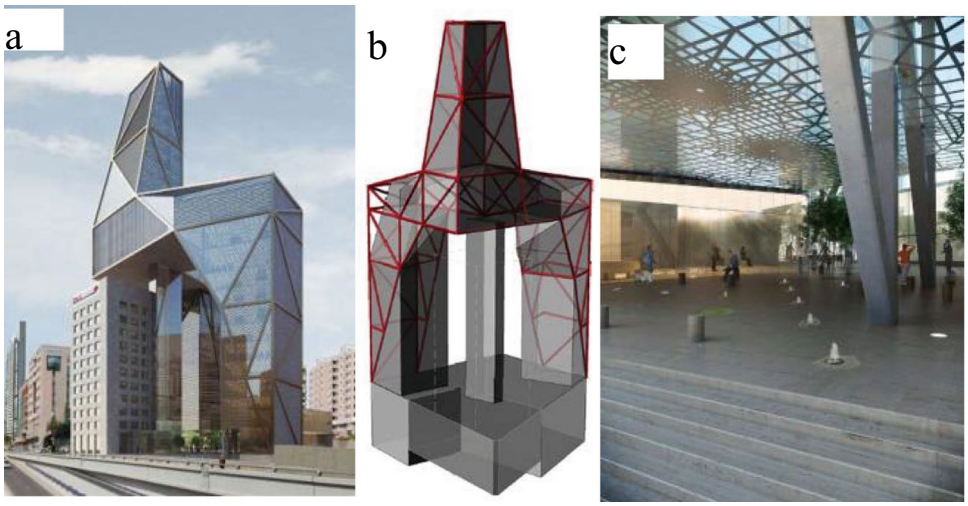


Fig. 2 **a** BLC bank headquarter landmark in Beirut exterior; **b** new extension emphasis the landmark corner; **c** inner spaces

facilities and audacious structural solutions support its ARZ rating (Arch Daily Website 2015) (Fig. 2).

4 GSAS

In order to produce a sustainable constructed environment with a low ecological effect, GORD created the Qatar Sustainability Assessment System (QSAS). It emphasizes cutting operational expenses, raising asset value, minimizing waste, utilizing less energy and water, and promoting a safer and healthier environment. The method, which is recognized by the majority of new buildings, provides points for performance in eight categories, culminating in a single overall score between 1 and 6 stars. Eight areas make up the GSAS certification requirements (GORD 2016).

The completion of a multipurpose hall with a GSAS accreditation by Qatar's Lusail Sports Club ensures conformity with regional and global standards. The sustainability features include 100% recycling of gray water, improved glazing efficiency to 70, 20% recycled content materials, 27% responsibly sourced materials, 90% utilization of local resources, 35% material disassembly, 75% recycling of waste, low-water landscaping, low-pollution interior finishes, heat reduction techniques, and increased sustainability management practices. The location is easily accessed by foot and has links to public transit (KEO International Consultant Web 2014; Global Sustainability Assessment System 2014) (Fig. 3).

5 Discussion

The ability to sustain life for future generations is increasingly important. Governments are creating new grading systems to satisfy society's social and environmental concerns. This global demand motivates nations to develop green building grading systems that consider social and cultural requirements. The UAE is ranked ninth out of the top 10 countries by the US Green Building Council, which reflects the rising popularity of sustainability as a lifestyle. It isn't easy to impart this idea in communities with strong traditional values (EERE 2012; Kriss 2015). To enhance the scientific validity of our research on sustainable built environments with minimal ecological impact, it is crucial to integrate principles of urban design that foster healthier and more habitable urban



Fig. 3 Multipurpose hall at Lusail sports club by KEO international consultant that earned 4-star GSAS

settings. This part will include knowledge from recent books to enhance the conversation.

Creating healthier and more livable urban settings necessitates a comprehensive strategy that encompasses green infrastructure, sustainable transportation, energy-efficient buildings, and community-focused public spaces. Green infrastructure, including urban parks, green roofs, and vertical gardens, is essential for counteracting the effects of urban heat islands, decreasing air pollution, and granting citizens the opportunity to connect with nature. This strategy not only improves the natural equilibrium of metropolitan areas but also helps the physical and emotional well-being of residents by providing leisure spaces and fostering social interactions (Bonet-Avila et al. 2023).

It is crucial to have sustainable mobility options such as walking, cycling, and public transit to decrease carbon emissions and alleviate traffic congestion, while also encouraging healthier lifestyles. The primary focus of urban design should be on establishing pedestrian-friendly streets and comprehensive bike networks to guarantee secure and easily accessible transport choices for all inhabitants. These approaches promote environmental sustainability and improve the overall quality of life and health in urban populations (Hartig et al. 2021). Integrating energy-efficient building designs and technology is a crucial element in the development of sustainable urban environments. By employing passive solar architecture, high-performance insulation, and smart energy management systems, it is possible to greatly diminish energy use and carbon footprints. Implementing energy-efficient upgrades and integrating renewable energy sources into existing structures are essential measures for achieving sustainable urban development (Bonet-Avila et al. 2023).

Public places that prioritize the community promote social unity and inclusiveness by providing locations for social engagement, cultural events, and physical fitness. Public plazas, community gardens, and recreational facilities should be created to be easily accessible and inclusive to people from all demographic groups. This will help to foster a stronger feeling of community and belonging among inhabitants (Hartig et al. 2021).

Ultimately, the attainment of sustainable and habitable urban settings necessitates a holistic strategy that incorporates green infrastructure, sustainable transportation, energy-efficient structures, and community-focused public areas. By considering and tackling these factors, we may develop urban environments that not only reduce ecological harm but also enhance the physical and mental health, as well as the social liveliness, of the people living in them. Integrating these concepts into urban design will facilitate the progression toward a more sustainable and habitable future.

Sustainability rating system	Managing organization	Issues/areas of focus
The Global Sustainability Assessment System (GSAS)	Gulf Organization for Research and Development (GORD), Qatar	Energy, water, indoor environment, cultural and economic value, site, urban connectivity, material, management and operation
ARZ	The Lebanese Green Building Council (LGBC), Lebanon	Energy performance, thermal energy, electrical energy, building envelope materials, indoor air quality, water conservation, operations and management
Pearl rating system (Estidama)	Abu Dhabi Urban Planning Council, UAE	Integrated development process, natural systems, livable communities, precious water, resourceful energy, stewarding materials, innovating practice

6 Conclusion

The capacity of Middle Eastern nations to develop novel rating systems that respect the customs of their populations and attain sustainability in three dimensions—environmental, economic, and social—has been proved. These nations have established accreditation points for new construction associations and developed their grading systems that cater to the demands of their local communities. This strategy is essential since the community is the intended client and has cultural values that can increase public participation in the design process. To emphasize the significance of social issues in the MENA area, previous rating systems have earned more attention as a reference manual for creating rating systems and inspiring other nations to adopt similar systems. To create sustainable and habitable urban settings, it is necessary to combine green infrastructure, sustainable transportation, energy-efficient buildings, and community-focused public spaces. Research indicates that these approaches improve the quality of urban living by effectively tackling both ecological and social aspects. By prioritizing these factors, cities can create an environment that reduces ecological consequences and improves the health and well-being of citizens, thus promoting a sustainable and livable future.

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Advancing Sustainable Buildings: An Optimal Control Approach of Dynamic Thermal Mass of Walls

Alaa Alaidroos

Abstract

Despite existing studies on the thermal mass of building envelopes, limited work has been done to integrate optimal-based controls for the dynamic regulation of building's thermal mass. Hence, this research study is focused on developing an optimal control algorithm to dynamically adjust the thermal mass of the building's walls in order to enhance energy efficiency and promote sustainable built environments. Specifically, optimal control algorithm has been developed to adjust the heat capacity of a building's external walls for buildings in Saudi Arabia's hot climate. This study conducted extensive hourly simulation analyses using a calibrated energy model of an existing residential building, which explores the effects of varying heat capacity values on cooling energy consumption. A co-simulation-optimization environment is developed in MATLAB in addition to an optimal-based control strategy to adjust the walls' heat capacity at each hourly time step for selected days. Moreover, the optimal control system is evaluated across several Saudi Arabia's climate conditions to assess the ability of the optimal control system in improving the energy efficiency of the building. Based on the results, the optimal control algorithm delivered promising outcomes, demonstrating moderate cooling energy savings, particularly for climates characterized by large outdoor temperatures differences between early day and nighttime such as Tabuk's and Abha's climates. Consequently, the results suggest that optimal-based controls can effectively regulate a building's thermal mass, while improving the cooling energy efficiency of buildings, especially in climates with high diurnal temperature fluctuations. In conclusion, the proposed optimal control is expected to deliver intelligent real-time decisions, optimizing buildings' thermal behavior for superior energy efficiency of buildings. The study's findings contribute to the evolution of sustainable, high-performance buildings responsive to their environments and promoting optimal energy use.

Keywords

Dynamic thermal mass · Optimized controls · Genetic algorithm · Energy efficiency · Saudi Arabia

1 Introduction

Responsive building envelopes have demonstrated their ability to reduce energy consumption in buildings by offering adaptive passive cooling and heating mechanisms. Specifically, thermal mass of building structures serves as a form of free thermal energy storage while providing a mean of load shifting. Therefore, the potential of enhancing the benefits of building thermal mass (i.e., heat capacity of the building elements) as a driver of energy efficiency offers considerable promise (Kuczyński and Staszczuk 2020). Several recent research studies investigated the potential benefits of thermal mass especially when regulated with advanced control strategies to optimize the thermal performance of buildings. However, model-based approaches were the most control techniques that have been discussed thoroughly in the recent literature. For instance, one study introduced a model-based control strategy for recovering stored cooling energy in commercial buildings (Shan et al. 2019). Another research study explored model predictive control (MPC) algorithms applied within a simulation framework to manage dynamic heating operations and structural thermal mass for load shifting (Wolisz et al. 2020). In contrast, the cooling system's energy flexibility is examined through simulation-based methodologies and

A. Alaidroos (✉)
King Abdulaziz University, Jeddah, Saudi Arabia
e-mail: aalaidroos@kau.edu.sa

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a rule-based control strategy in nearly zero-energy office buildings (Lu et al. 2021). Innovations extended to specific system designs, such as wall systems incorporating active insulation and thermally activated storage for active cooling energy (Iffa et al. 2022). Furthermore, a linear relationship is assessed between effective thermal capacitance and building areas while identifying the effective thermal capacitance values through the particle swarm optimization algorithm (Ding et al. 2022). Another study proposed a demand-based control rule developed based on demand analysis to control responsive building envelopes that include thermal energy storage and active insulation layers (He et al. 2022). Price responsive MPC is also used to adjust the energy storage in buildings based on dynamic demand pricing to reduce the total energy cost (Wei and Calautit 2022; Wei and Calautit 2023). Recent studies present contradictory conclusions regarding the role of thermal mass in varying climates, suggesting the complexity of its impact on energy demand and emphasizing the need for nuanced control strategies (Alayed et al. 2022). For instance, research showing that thermal mass can lead to increased energy consumption under certain conditions in hot climates like Saudi Arabia challenges the notion of its universal benefit (Alayed et al. 2022). Another study highlights the synergy between thermal mass and intermittent renewable energy sources, demonstrating how optimized thermal storage within buildings can enhance district heating systems' efficiency (Dominković et al. 2018). The potential of thermal mass to contribute to demand-side management, especially in combination with renewable electricity generation, underscores its role in improving grid stability and optimizing energy use (Reynders et al. 2013). Moreover, integrating HVAC systems with the internal thermal mass has been identified as a critical strategy for providing demand response resources, offering peak-load reduction and grid-responsive support (Chen et al. 2020). The few most recent research studies summarized earlier demonstrated the benefits of model-based and demand-based controls in addition to MPC in enhancing the potential of thermal mass. However, it is worth to investigate the ability of optimal-based controls in regulating the heat capacity of walls to minimize the cooling energy of buildings. Therefore, this study aims to develop and evaluate an optimal genetic algorithm-based control to dynamically adjust the heat capacity of the building walls in order to reduce the cooling energy demand each time step.

2 Methodology

A calibrated building energy model is developed in EnergyPlus of an existing residential building for a detailed analysis on the impact of the heat capacity of the exterior walls on the cooling energy consumption of buildings. In addition, a MATLAB code was developed for an optimal control algorithm to adjust the thermal properties of the exterior walls of the building each time step and assigning an optimal heat capacity representing optimal density and specific heat of the wall. The genetic algorithm (GA) optimization has been used in the developed optimal control system to optimize the heat capacity each time step to deliver the lowest cooling energy consumption, which represent the objective function of the GA optimization. Figure 1 illustrates the flowchart of the optimal control algorithm sequence employed to adjust the heat capacity of the wall by selecting optimal density and optimal specific heat that should deliver the lowest cooling energy. In the control algorithm, first initial thermal properties of the wall are assigned in the EnergyPlus

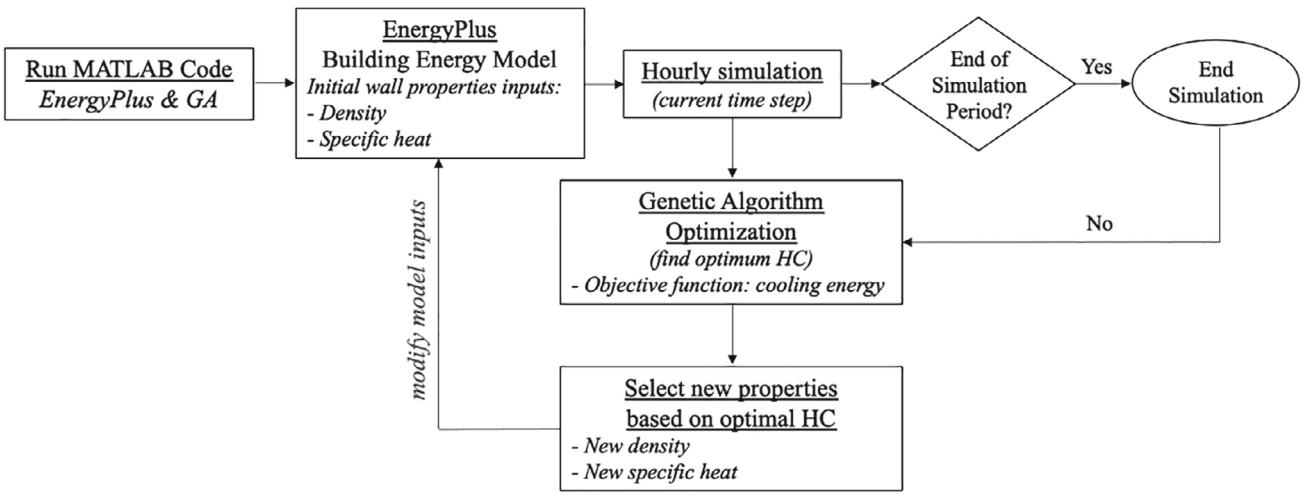


Fig. 1 Flowchart diagram of the simulation-optimization process

building energy model. The GA optimization works simultaneously with the energy model to determine the optimum heat capacity of the wall by evaluating a wide range of heat capacities ranging from 200 to 2500 kJ/m^3 K.

Based on a detailed analysis, the effect of the exterior wall's heat capacity is found to be most significant for buildings located in climate characterized by a high diurnal temperature most of the year. Diurnal temperature, denoted as ΔT in this study, is the temperature difference between the highest outdoor air temperature during the day and the lowest outdoor air temperature during the night. High diurnal temperatures help in storing thermal energy within the wall during the day and release it during the night. Therefore, two cities in Saudi Arabia were selected, Tabuk and Abha, that is known to have large difference in temperatures between day and night, hence, could be suitable for the analysis conducted in this study. According to the temperatures analysis, the average ΔT during the year for Tabuk is around 15 °C, while the maximum ΔT is found to be 20 °C. While, on the other hand, Abha's temperature data shows an average and maximum ΔT of 11 °C and 14 °C respectively. These outdoor climate conditions make these two cities a perfect candidate for this study.

3 Results

3.1 Impact of the Heat Capacity on Cooling Energy

Sensitivity analysis is carried out to estimate cooling energy consumption across thermal properties (density and specific heat), spanning wall heat capacities from 200 to 2500 kJ/m^3·K. Notably, a thermal conductivity of 1.5 W/m K, typical of conventional concrete walls (Clarke et al. 1991), is employed. Simulation results are shown for a representative day (the 15th) of each month in Abha, with normalized cooling energy for easy comparison. Figure 2 illustrates how the optimal heat capacity value for the wall varies with outdoor climate conditions. Highlighted in red, April, May, July, and September exhibit optimal heat capacities ranging from 400 to 1000 kJ/m^3 K. Conversely, other months show a clear trend: increased heat capacity leads to decreased cooling energy. Notably, higher heat capacity is often needed on the selected days (the 15th of each month) to reduce cooling energy. In contrast, lower heat capacities perform better in certain months like April and May (400–500 kJ/m^3 K). These normalized cooling energy patterns in Fig. 2 fluctuate with varying days and climate conditions. The above-described optimal control system aids in optimizing wall thermal behavior, adjusting thermal energy discharge and recharge to minimize heat gains through walls, ultimately reducing building cooling energy demand.

3.2 Evaluation of the Optimal Control System

To evaluate the effectiveness of the control system, the optimal control algorithm presented in Fig. 1 is used to find the optimum heat capacity for each time step. Three simulation scenarios were investigated: 1—Tabuk's climate, May 16th to 20th; 2—Tabuk's climate, April 16th to 20th; 3—Abha's climate, average monthly simulations for April, May, July, and September. As illustrated in Fig. 3, varying exterior wall heat capacities were selected in response to outdoor conditions. For instance, in the first scenario, the optimum heat capacity on the 17th of May is 200 kJ/m^3 K, while it reaches 2500 kJ/m^3 K for the 20th of May. Similarly, in the second scenario 200 kJ/m^3·K is selected for April 19th while 2500 kJ/m^3 K for both 17th and 18th of April. Indeed, averaging the simulation results could affect the accuracy of the control

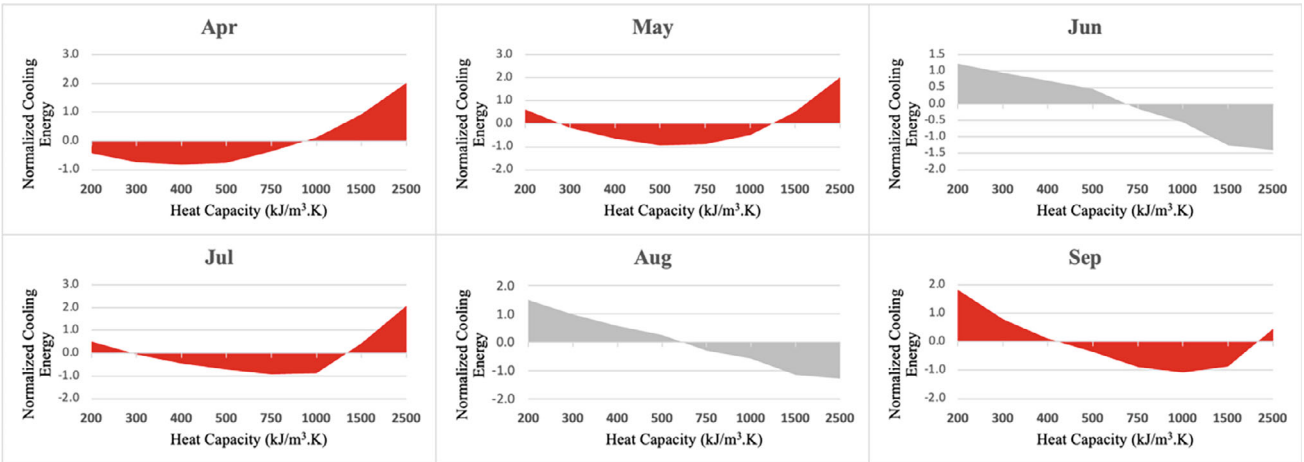


Fig. 2 Sample results of the normalized cooling energy for several heat capacities for Abha (the 15th of selected months)

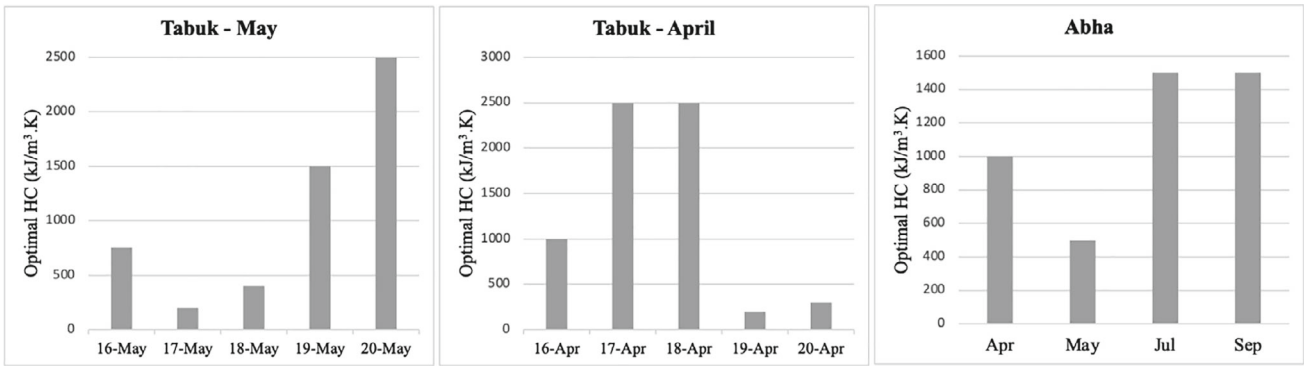


Fig. 3 Optimum heat capacities determined by the optimal control system

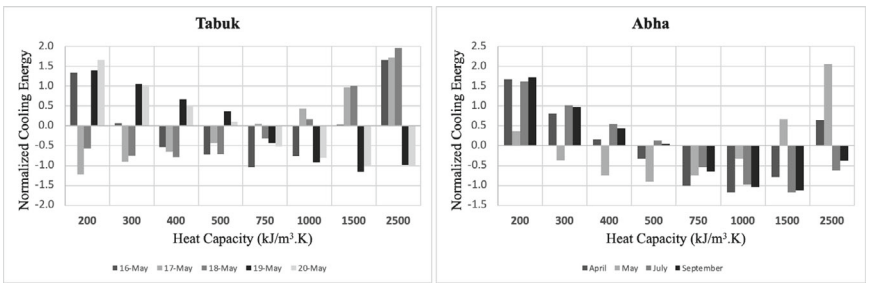


Fig. 4 Performance of the optimal control algorithm for selected days in Tabuk and Abha

outputs due to the averaging of the outdoor conditions. Hence, the third scenario presents the average monthly simulations for Abha's climate for selected months. Nevertheless, varied heat capacities were identified, with May at 500 kJ/m^3 K, April at 1000 kJ/m^3 K, and July and September at 1500 kJ/m^3 K. Figure 4 demonstrates a sensitivity analysis for Tabuk and Abha on the same days evaluated by the optimal control system to validate the effectiveness of the control algorithm. According to Fig. 4, the lowest cooling energy observed for each day is delivered by the exact same heat capacity values presented in Fig. 3, confirming the effectiveness of the optimal control algorithm.

4 Discussion

The analysis findings presented above highlight the complex relationship between exterior wall heat capacity and cooling energy consumption and the performance of the developed optimal control algorithm. While the results demonstrate clear correlations, it is essential to critically evaluate the achieved energy savings and the broader implications of the algorithm's performance. Hence, it is necessary to note that the analysis of the selected days has shown moderate cooling energy savings when implementing the optimal control algorithm. The highest recorded cooling energy savings was approximately 5.5% for a specific day (April 19th) in Tabuk. While this outcome might raise questions about the algorithm's practical significance, it is important to note that energy savings can vary greatly depending on numerous factors, including the outdoor climate conditions, building characteristics, and specific days of analysis. Notably, the reported energy savings are based on a specific day's analysis. Given the dynamic nature of outdoor climate conditions and their interaction with building thermal behavior, evaluating the optimal control algorithm on a comprehensive hourly basis throughout the entire year could yield more comprehensive insights. Therefore, even though the percentage of energy savings for individual days might not be significant, cumulative energy savings over the entire year could be considerably more substantial. However, the findings of this study may offer practical implications for building energy management strategies, particularly in regions with significant diurnal temperature variations. The proposed optimal control algorithm can be implemented in real-time building management systems to dynamically adjust thermal mass based on real-time outdoor conditions. By improving the optimal control algorithm, buildings might achieve substantial energy savings and enhance overall energy efficiency.

5 Conclusions

This study demonstrated the effectiveness of an optimal genetic algorithm-based control in dynamically adjusting exterior wall heat capacity to minimize the cooling energy of buildings. The analysis was conducted for representa-

tive days of different months in Tabuk and Abha, known for their significant diurnal temperature variations. Additionally, the results highlighted the critical influence of outdoor climate conditions, mainly diurnal temperature variations, on the optimal heat capacity values. While the control algorithm did not deliver substantial single-day energy savings, it could potentially demonstrate a significant long-term impact when applied over the course of an entire year. Further research investigation is required to comprehensively analyze the performance of the optimal control algorithm over extended periods. Conducting annual simulations with hourly time steps could offer a clearer perspective on the algorithm's potential. Nevertheless, the proposed algorithm has promising implications for sustainable building practices, contributing to energy savings and reduced environmental impact.

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Using Fuzzy AHP Approach in Environmental Sustainable Management of Euro-Mediterranean Contemporary Wineries

Ana Stanojević Brankov, Mimica Milošević, Ljiljana Jevremović, Dušan Milošević, and Borjan Brankov

Abstract

The environmental dimension of sustainability is mainly present in the contemporary wineries' design process, given the specifics of technological wine production. The paper's subject is the sustainable environmental management of contemporary wineries. Given the longest tradition of winemaking and favourable climatic conditions for growing vines, this research selected the wineries built after 2000 in different rural areas of countries of the Euro-Mediterranean region. In the first stage of the research, selected wineries were classified into several models based on theoretically defined environmental indicators related to urban and architectural design. Environmental indicators are divided into five groups: sustainable urban planning, materials and resources conservation, indoor environmental quality, water management, and energy conservation. The indicators are ranked in the second stage using the fuzzy Analytic Hierarchy Process (AHP) approach. The proposed multi-criteria decision-making methodology points to the crucial environmental indicators for sustainable management of contemporary wineries in the Euro-Mediterranean region. In the last stage of the research, applying the triangular fuzzy AHP method, the study aims to evaluate selected winery models to identify facilities with the best practices from the perspective of the environmental dimension of sustainable management. The results show that the most crucial indicators are site selection for a winery, energy performance of the envelope, transportation plan, use of the terrain in the wine production process, and use of smart energy management. The proposed methodology can be successfully applied in the decision-making process related to the environmentally sustainable management of industrial architecture. Finally, the criteria may be refined and applied locally, considering different industrial uses or geographical regions.

Keywords

Contemporary wineries · Environmental sustainable management · Euro-Mediterranean region · Triangular fuzzy AHP method

1 Introduction

Buildings are often regarded as one of the biggest polluters on earth, with 40% of CO_2 production on a global scale (https://architecture2030.org/why-the-built-environment/), and ecological and environmental design is increasingly recognized as an approach to sustainable management of industrial architecture, especially regarding sustainable development goals of the UN Agenda 2030 (https://sdgs.un.org/2030agenda).

The winemaking process long ago regarded as a traditional/family activity, has grown into a significant industry sphere that needs a complex space for production systems, tourism, manifestations, etc. Europe is one of the oldest and undoubtedly diverse grounds for vineyards, representing about 45% of all the world's vineyards (https://wineriesandvineyards.com/europe/). The EU area of Europe had 2.2 million vineyard holdings in 2020, with most vineyards

A. Stanojević Brankov (✉) · L. Jevremović
Faculty of Civil Engineering and Architecture, University of Nis, Nis, Serbia
e-mail: stanojevicana1991@gmail.com; ana.stanojevic@gaf.ni.ac.rs

M. Milošević
Faculty of Information Technologies, Alfa BK University, Belgrade, Serbia

D. Milošević
Faculty of Electronic Engineering, University of Nis, Nis, Serbia

B. Brankov
Institute of Architecture and Urban & Spatial Planning of Serbia, Belgrade, Serbia

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located in three Mediterranean countries: Spain, Italy, and France (74%) (https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Vineyards_in_the_EU_-_statistics#cite_note-1). This industry's growth required more energy, space and buildings, leading to more renewable winery design in the twenty-first century.

2 Materials and Methods

The methodological framework of the research consists of the following five steps:

Step 1—Defining indicators for environmentally sustainable management;
Step 2—Classification of winery ecological design models in the Euro-Mediterranean region from the aspect of environmentally sustainable management;
Step 3—Defining and implementing the triangular fuzzy AHP method;
Step 4—Identification of priority indicators for environmentally sustainable management of contemporary wineries;
Step 5—Ranking winery design models using the fuzzy AHP approach.

2.1 Defining Indicators for Environmental Sustainable Management of Contemporary Wineries

Given the previous studies on environmental sustainable management in architectural design, the indicators are divided into five groups (López Chao et al. 2020; https://www.wbdg.org/resources/measuring-performance-sustainable-buildings): indicators for sustainable urban planning (S), indicators for materials and resources conservation (M), indicators for water management (W), indicators for indoor environment quality (I), and indicators for energy conservation (E).

Indicators for sustainable urban planning (S) consist of (Varsei and Polyakovskiy 2017): site selection for winery design (S_1), greenery and roof design (S_2), transportation plan and use of the terrain in the wine production process (S_3), and connectivity of the site with vineyards and distribution centres (S_4). Materials and resources conservation indicators (M) include the use of recycled materials (M_1), the use of natural materials from the surroundings (M_2), green products (M_3), and sustainable waste management during the wine production process (M_4) (Abdel-Basset et al. 2021). Water management is an indispensable part of environmentally sustainable management in architectural design. Indicators for water management (W) in contemporary wineries refer to rainwater harvesting possibilities (W_1), irrigation of wine landscape (W_2), and water reduction and recycling in the wine production process (W_3) (Howell and Myburgh 2018).

Indicators for indoor environmental quality (I) are related to different comfort conditions in the interior of the building. This group contains the following sub-indicators (López Chao et al. 2020; https://www.wbdg.org/resources/measuring-performance-sustainable-buildings): external attractive views from the winery (I_1), indoor air quality (I_2), indoor thermal comfort in both production and visitors spaces (I_3), CO_2 monitoring and control in the wine production process (I_4), air exchanging systems for natural and artificial ventilation in wine production space (I_5), and internal noise level (I_6). Energy conservation indicators group (E) refers to the intelligent energy management approach and application of energy-efficiency measures, including using renewable energy sources (RES). This group includes (López Chao et al. 2020): use of RES in winery design (E_1), use of intelligent metering in vineyards (E_2), use of innovative energy management in the wine cellar (E_3), energy-efficiency verification (E_4), energy performances and insolation of envelope (E_5), and harvesting natural light (E_6).

2.2 Winery Ecological Design Models in the Euro-Mediterranean Region

For this research, 70 wineries built after 2000 in rural areas of the Euro-Mediterranean region were selected. The most chosen wineries were built in Italy, Spain, France, and Portugal. All the wineries have their ecological design in common, which, among other things, resulted from the Mediterranean area's specific climatic characteristics favouring vine cultivation. Based on the representation of indicators related to environmentally sustainable management, a comparative analysis of the selected facilities was conducted. As a result of comparative analysis, following their common characteristics, selected wineries are classified into five models:

Model 1—"terraced wineries"—design is focused on the use of terrain, green roofs, natural materials, and passive systems creating cascades (i.e. Antinori winery in Italy);
Model 2—"buried wineries"—design is focused on the maximum use of terrain, green roof, natural materials, and minimal use of technologies creating buried form (i.e. Beronia winery in Spain);
Model 3—"high-tech green wineries"—semi-underground wineries whose design is focused on the use of new technologies and RES (i.e. Treviso winery in Italy);

Model 4—"envelope wineries"—semi-underground wineries whose ecological design is based on envelope characteristics (i.e. Dellas Freres in France);
Model 5—"sustainable materials wineries"—semi-underground wineries whose design is based mainly on natural and recycled materials (i.e. LA winery in Turkey).

2.3 Fuzzy AHP Approach—Triangular Fuzzy AHP Method

The combined effect of fuzzy set theory and the Analytic Hierarchy Process (AHP) approach is provided by the fuzzy AHP as a more effective method for multi-criteria decision-making. When it is impossible to quantify the impact of indicators on the decision problem precisely, the fuzzy AHP method can be used to solve the multi-criteria analysis problem. The introduction of the fuzzy AHP approach also enables the reduction of subjective influences on decision-making.

The special fuzzy sets $\Phi = \{(x, m_\Phi(x)), x \in \mathbb{R}\}a$ re the fuzzy numbers where m_Φ: $R \to [0, 1]$ is a continuous function. The membership function of the triangular fuzzy number (TFN), represented by $\tilde{F} = (a, c, b)$, is as follows:

$$m_{\tilde{F}}(x) = \begin{cases} \frac{x-a}{c-a}, & x \in [a, c) \\ \frac{b-x}{b-c}, & x \in [c, b] \\ 0, & \text{otherwise} \end{cases}. \quad (1)$$

The triangular fuzzy numbers (TFNs) contain denotations and meanings and common fuzzy arithmetic operations using TFNs. ((TFNs) $F_1 = (a_1, c_1, b_1)$ and $F_2 = (a_2, c_2, b_2)$ and scalar $k > 0$, $k \in \mathbb{R}$)), present in Table 1.

The following is how the method is put into practice:

Step 1—Creating the problem hierarchy; identifying the primary aim, the criteria, and the sub-criteria that contribute to the overall goal.
Step 2—Creating the fuzzy comparison matrices. A pairwise comparison is produced by utilizing the rating scale in FAHP, as shown in Table 1. For a fuzzy pairwise comparison of criteria, we create a decision matrix $\tilde{D} = \left(\tilde{D}_{ij}\right)_{n\times n}$ using TFNs, where $\tilde{d}_{ij}$ is a fuzzy value that indicates the relative relevance of one criterion for another. The averaging approach is used to calculate the summation of the expert opinions.
Step 3—Analyzing the consistency of the comparison matrix. For the matrix $\tilde{D} = \left(\tilde{D}_{ij}\right)_{n\times n}$, we compute the consistency index CI and consistency ratio CR using the formulas $\text{CI} = \frac{\text{l}_{\max}-n}{n-1}$, $\text{CR} = \frac{\text{CI}}{\text{RI}}$, where $\text{l}_{\max}$ denotes the maximal eigenvalues, and RI denotes an accepted random index of a matrix. If $\text{CR} \leq 0.10$, it is assumed that we can take the evaluated fuzzy matrix elements; otherwise, we must eliminate the causes of unfavourable high estimates and repeat pairwise comparisons until the degree of consistency falls within acceptable bounds.
Step 4—The fuzzification and the defuzzification processes.
Step 5—Obtain the vector for each criterion and normalize the weight vector.
Step 6—Decision ranking and selection.

Table 1 Meaning of TFNs and common fuzzy arithmetic operations (Dimić et al. 2018; Srdjevic and Medeiros 2008)

Rating scale	Meaning	Explanation
$\tilde{1} = (1, 1, 3)$	Equal importance	Both elements have the same effect
$\tilde{3} = (1, 3, 5)$	Moderate importance	One element has a slight advantage over other
$\tilde{5} = (3, 5, 7)$	Strong importance	A strong advantage of one element over other
$\tilde{7} = (5, 7, 9)$	Demonstrated importance	One element has a very strong advantage over
$\tilde{9} = (7, 9, 9)$	Extreme	One element has a full advantage over other
$\tilde{2} = (1, 2, 3)$, $\tilde{4} = (3, 4, 5)$, $\tilde{6} = (5, 6, 7)$, $\tilde{8} = (7, 8, 9)$	Intermediate values	When compromise is needed
Operators	*Math. expression*	*Results*
Addition	$\tilde{F}_1 \oplus \tilde{F}_2 = (a_1, c_1, b_1) \oplus (a_2, c_2, b_2)$	$(a_1 + a_2, c_1 + c_2, b_1 + b_2)$
Scalar multiplication	$k \cdot \tilde{F}_1 = k \cdot (a_1, c_1, b_1)$	$(k \cdot a_1, k \cdot c_1, k \cdot b_1)$
Multiplication	$\tilde{F}_1 \otimes \tilde{F}_2 = (a_1, c_1, b_1) \otimes (a_2, c_2, b_2)$	$(a_1 \cdot a_2, c_1 \cdot c_2, b_1 \cdot b_2)$
Inverse	$\tilde{F}_1^{-1} = (a_1, c_1, b_1)^{-1}$	$\left(\frac{1}{b_1}, \frac{1}{c_1}, \frac{1}{a_1}\right)$

Table 2 Final ranking of indicators using triangular fuzzy AHP method

Indicator name	$\lambda = 1$			$\lambda = 0$		
	W_i	W_{si}	W	W_i	W_{si}	W
Site selection for winery—S_1	0.3179	0.4368	0.1389	0.3021	0.4236	0.1280
Envelope performances—E_5	0.2896	0.3217	0.0932	0.2927	0.3440	0.1007
Use of the terrain—S_3	0.3179	0.2804	0.0891	0.3021	0.3127	0.0945
Use of energy management—E_3	0.2896	0.2343	0.0679	0.2927	0.2192	0.0642
Greenery and roof design—S_2	0.3179	0.2106	0.0669	0.3021	0.1841	0.0556
Waste management—M_4	0.1235	0.4863	0.0601	0.1119	0.4843	0.0542
Indoor thermal comfort—I_3	0.1738	0.2885	0.0501	0.1907	0.2911	0.0555
Irrigation of landscape—W_2	0.0952	0.5051	0.0481	0.1025	0.5471	0.0561
CO_2 monitoring and control—I_4	0.1738	0.2717	0.0472	0.1907	0.2855	0.0544
Use of RES—E_1	0.2896	0.1516	0.0439	0.2927	0.1431	0.0419
Smart metering in vineyards—E_2	0.2896	0.1327	0.0384	0.2927	0.1368	0.0401
Rainwater harvesting—W_1	0.0952	0.3696	0.0352	0.1025	0.3192	0.0327
Use of recycled materials—M_1	0.1235	0.2277	0.0281	0.1119	0.2086	0.0233
Energy-efficiency verific.—E_4	0.2896	0.0893	0.0259	0.2927	0.0816	0.0239
External attractive views—I_1	0.1738	0.1468	0.0255	0.1907	0.1303	0.0248
Connectivity of the site—S_4	0.3179	0.0722	0.0230	0.3021	0.0796	0.0241
Use of natural materials—M_2	0.1235	0.1851	0.0229	0.1119	0.1944	0.0218
Indoor air quality—I_2	0.1738	0.1300	0.0226	0.1907	0.1247	0.0238
Harvesting natural light—E_6	0.2896	0.0704	0.0204	0.2927	0.0753	0.0220
Air exchanging systems—I_5	0.1738	0.1132	0.0197	0.1907	0.1191	0.0227
Green products—M_3	0.1235	0.1008	0.0124	0.1119	0.1127	0.0126
Water reduction—W_3	0.0952	0.1253	0.0119	0.1025	0.1337	0.0137
Internal noise level—I_6	0.1738	0.0497	0.0086	0.1907	0.0494	0.0094

Table 3 Final ranking of wineries models

Model	$\lambda = 1$	$\lambda = 0.5$	$\lambda = 0$
Model 1	0.6891	0.6904	0.6932
Model 2	0.8111	0.8119	0.8142
Model 3	0.8217	0.8248	0.8323
Model 4	0.5568	0.5620	0.5749
Model 5	0.7088	0.7121	0.7192

3 Results and Discussion

The triangular fuzzy AHP method ranks indicators according to the pessimistic, moderate, and optimistic attitudes towards risk (Srdjevic and Medeiros 2008). Table 2 represents the final ranking of indicators for environmental sustainable management in contemporary wineries according to optimistic and pessimistic attitudes. Table 3 represents the final ranking of classified models of selected wineries in the Euro-Mediterranean region.

4 Conclusions

The results show that the most crucial indicators are site selection for the winery, energy performances of the envelope, transportation plan, and use of the terrain in the wine production process, and use of smart energy management in production. The highly ranked facilities (Model 3) give an advantage in using new technologies.

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H2020ReSET: Using a Low-Cost Urban Microclimate Monitoring Network to Evaluate Potential Green Investments for Urban Heat Management in Bologna, Italy

Sophia Burke, Mark Mulligan, Arnout van Soesbergen, Margherita Ascari, and Raffaele Giordano

Abstract

ReSET (Restarting Economy in Support of Environment, through Technology) is an H2020 research and development (EIC) project focused on future and emerging technologies (FET) in environmental intelligence. As part of ReSET, we are developing and deploying distributed networks of in-field sensors to monitor urban and peri-urban microclimate around Bologna, Italy, in order to assess the potential of green investments for mitigating the human heat stress impact of urban heatwaves. A monitoring plan has been developed that uses a space-for-time approach by deploying monitoring in existing green and non-green areas that are representative of areas where green investments will be considered by the local municipality. The monitoring is focused on three urban typologies: urban with buildings, urban-open and peri-urban. Within each of which a "green" area and a "non-green" area is being monitored, which are similar in character except the amount of vegetation. We are using microclimate sensor networks built from designs published at FreeStation.org, which are low-cost, internet-connected environmental sensors and data loggers which provide locally specific evidence for the impact of urban greening investments in different locations and are logging microclimate variables every 10 min at locations across the city. This experiment permits analysis of the effectiveness of previous urban greening investments in helping cool Bologna's streets. The data could be used to help develop the urban plan for future urban regeneration projects. Urban greening investments have the potential to provide heatwave respite areas and cooler walking routes around the city, but significant effort will be required to reach the level of investment that will be needed.

Keywords

Heatwaves · Urban greening · FreeStation · Monitoring · ReSET

1 Introduction

The area of Bologna, particularly the urban area, shows a general trend of rising temperatures over the last 30 years (Spano et al. 2021). Moreover an average increase in minimum and maximum temperatures of between 1.2 and 3 °C is expected for the period 2021–2050 compared to the 1961–1990 climate reference period (Piano Urbanistico Generale 2020). Heatwaves are among the main risks for the urban area of Bologna. Urban heatwaves can negatively affect human health, vegetation, water supply and energy demands. A number of studies have been conducted to formulate a microclimate classification as a support tool for urban regeneration to combat the impact of heatwaves (Nardino et al. 2021; Nardino et al. 2022) including a microclimate fragility map (Piano Urbanistico Generale 2020) which identifies higher temperatures in high-density urban blocks. Ecosystem services mapping is useful for urban spatial planning (Córdoba Hernández and Camerin 2023). As part of the EU H2020 ReSET project, we deployed low-cost sensor networks to improve the "Environmental Intelligence" and provide better information to guide green investments such as urban regeneration and urban tree

S. Burke (✉)
AmbioTEK CIC, Essex, UK
e-mail: sophia.burke@ambiotek.com

M. Mulligan · A. van Soesbergen
Department of Geography, King's College London, London, UK

M. Ascari
Advanced Design Unit, University of Bologna, Bologna, Italy

R. Giordano
Consiglio Nazionale delle Ricerche—Istituto di Ricerca sulle Acque, Bari, Italy

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canopy cover to mitigate heatwaves and provide respite areas and cooler walking routes within the city.

2 The Bologna FreeStation Microclimate Sensor Network

Using a space-for-time substitution approach, we deployed microclimate monitoring in existing green and non-green areas that are representative of areas where green investments have been made and will be considered. The monitoring focused on three urban typologies; urban with buildings, urban-open and peri-urban, within each of which a green area and a non-green area is being monitored, which are identical in all ways apart from vegetation.

The three green areas, where green investments have already taken place are: Giardino del Cavaticcio (urban with buildings); DumBO (Distretto Urbano Multifunzionale di Bologna) Green (urban-open) and finally the riverside green space Lungo Reno (peri-urban). The three non-green areas are: Giardino Lorusso (urban with buildings) an area with administrative buildings surrounding a square, DumBO Parking (urban-open) which is a large open derelict area associated with disused railway sidings, due for redevelopment and Lungo Reno (peri-urban) which is a residential area with a mix of high-rise and low-rise housing (Fig. 1).

The green investments that the municipality wishes to scope out in these non-green areas are the improvement of the whole DumBO area as cultural centre with vegetated areas that will be heatwave respite areas; and that Lungo Reno, a riverside location, will be developed as a heat respite area and is currently under-used as such. There are no green investments considered for Giardino Lorusso at present, but this area represents the microclimate of other built up areas in Bologna that are being considered for green investments. Parco della Resilienza near Giardino Lorusso provides greenery and usable small green spaces between existing buildings, which will create continuity in terms of public green with Giardino Lorusso.

In each of these six locations, two replicated dataloggers were installed (for failover), totalling 12 dataloggers altogether. Ten measure temperature and humidity, and two measure wind speed and direction. We are using microclimate sensor networks built from designs published at FreeStation.org, which are low-cost, internet-connected environmental sensors and data loggers and are logging microclimate every 10 min across the city.

Table 1 Air temperature (deg. C) for 30/06/2023, 21:00 to 17/07/2023. 1894 records

Results	Urban built green (L359)	Urban built green (L360)	Urban built non-green (L361)
Mean	30.27	29.82	29.79
Minimum	5.92	6.07	6.04
Maximum	43.03	43.07	43.5

3 Results

To date, only the preliminary monitoring data from Spring 2023 has been analysed and is presented here; further data from Summer 2023 will be analysed to determine the impact of urban greening on microclimate. The results show a small difference in concurrent air temperature between the stations (e.g. Table 1).

4 Discussion

Table 1 shows that air temperature differs between urban buildings "green" and "non-green" with the lowest and highest recorded temperature in the "green" area during a period from 30th June 2023 and 17th July 2023. There is

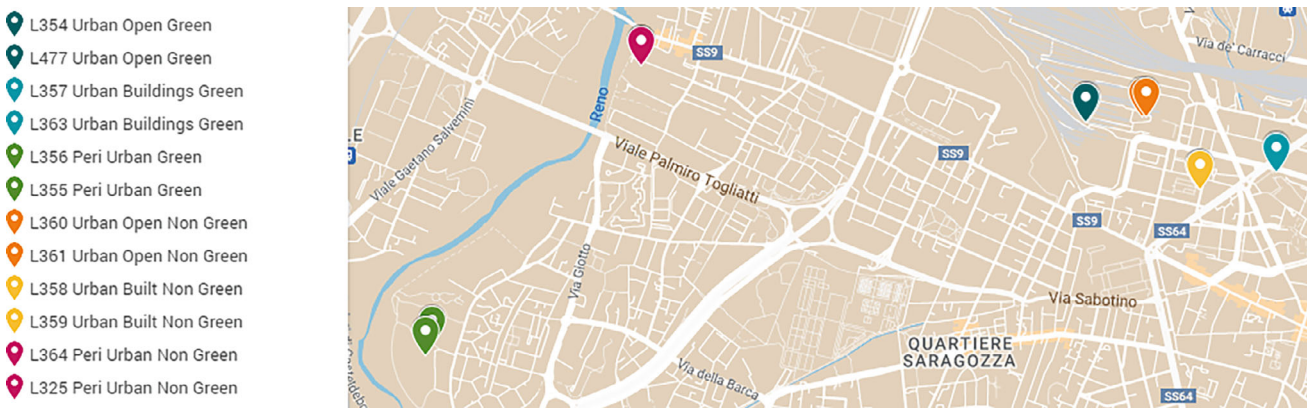


Fig. 1 Locations of the 12 loggers in the 6 typologies represented by different colours

also some variation between the two stations in urban open green. This highlights how much air temperature is influenced by the surroundings, concrete versus open soil and tree cover. These first monitoring data shows that microclimate varies between different urban typologies. Further data from Summer 2023 will be analysed to determine the impact of urban greening on microclimate. We will then be able to use the results from each of the urban typologies to estimate the impact of heatwaves across the city.

One of the main challenges we faced was finding and obtaining permission for suitable installation locations. The sensors should be sited in locations that are secure and accessible for maintenance. The site must be representative of the larger area (i.e. similar elevation from the ground and without shading from nearby walls and buildings). A weather station should be in the open and unobstructed at all sun angles, see WMO standard (https://www.campbellsci.com/weather-station-siting). Instrumentation is prone to vandalism so should ideally be surrounded by a deterrent fence or be sited on flat roofs of buildings, but the fence should not shadow or obstruct the instruments. Being on private land and in close proximity to dwellings will minimise the risk of vandalism. We have found schools to be a good home for FreeStations since they then also provide a direct educational benefit to the school. We have also successfully installed FreeStations on urban light columns (lamp posts) at heights above approximately 2.4 m (to deter vandals) as these are often unobstructed by walls and buildings, but permission to install sensors on urban street furniture can be difficult to obtain.

5 Conclusions

Low-cost sensors have been deployed to identify small differences in air temperature, relative humidity and solar radiation, although further data analysis is needed, including a comparison between these data that are measured in the streets of Bologna and the official Bologna meteorological data collected for the same period. Due to the high variability a larger network is needed to fully understand the variability of microclimate within each urban typology.

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Development of a Reference Matrix Based on Morpho-Energy-Efficient Indicators, Suitable for Southern Mediterranean Countries

Khadidja Rahmani and Lakdar Kairouani

Abstract

The severity of climate change, the scarcity of fossil fuels and the economic crises experienced, are the origin of the emergence of many current issues, affecting the energy and the environment directly or indirectly, or, the urbanized space constitutes the heart and the key factor, for which particular attention is increasingly praised, and it could present beautiful opportunities in the face of the disaster and the anxiety of the observed situation, in particular, in terms of sustainable development requirements. The aim of this work is to develop an approach based on morpho-energy indicators, enabling designers to steer towards efficient and successful urban projects in southern Mediterranean cities. To do so, our approach addresses several urban portions in different climate regions and then evaluates these portions using indicators of a conceptual, energy and environmental type. This evaluation will result in the development of a reference matrix. This work uses real data, which is supplemented by a series of simulations using building thermal dynamic simulation software, to fill the occasional data gap. In addition, GIS tools are used for data visualization in the form of morpho-energy mapping. This research has made it possible to evaluate the impact of the use of indicators in the design of urban complexes in economic and ecological terms, and the use of this method, has proven that a well-thought-out urban design can make a significant contribution to improving the quality of the urban environment in relation to reducing the energy demand of the entities that make up this environment.

Keywords

Energy consumption · Morpho-energy indicators · Comfort · Urban area · Simulation tools · GIS

1 Introduction

Urban morphology of cities plays an important role in addressing the problems of climate change and energy consumption, it can be a factor key in the energy transition of cities and the promotion of renewable energies (Eicker et al. 2015). Until now, much research has shown that the impact of urban form on household energy consumption and emissions remains unclear (Chao and Qing 2011). The research results in (Allegrini et al. 2015), show that there is a complex interaction between buildings and the local microclimate, each urban morphology has its own different behaviour. Certainly, there are studies in the Mediterranean context that have already tried to determine the relationship between urban form and energy efficiency. The authors of this work (Grifoni et al. 2016; Poggi et al. 2017) have tried to present an approach based on parametric analysis of building design by combining urban form. Authors in (Lin et al. 2017; Sarralde et al. 2015; Braulio-Gonzalo et al. 2015) have found that some indicators in its context can be useful for improving energy efficiency and thermal comfort of cities, e.g. wide streets and medium-rise buildings in areas with low wind speed.

Urban areas have an important role to play in the realization of the principles of sustainability.

Nevertheless there is not yet a single tool or method for obtaining the morpho-energetic relationship of urban areas (Koutra et al. 2018), for this reason this work aims to develop

K. Rahmani · L. Kairouani
Université Tunis EL Manar, Ecole Nationale d'Ingénieurs de Tunis, Unité de Recherche Energétique et Environnement, Tunis, Tunisie

K. Rahmani (✉)
Department of Renewable Energies, University Saad Dahlab -Blida 1, Blida, Algeria
e-mail: khadidja.rahmani@enit.utm.tn

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a morpho-energetic matrix, which can be considered as a relevant tool for transitioning the city towards sustainable urban development.

2 Materials and Methods

Proposed methodology aims to evaluate urban entities by using morphological indicators such as building density (B_D), mineralization (M), rugosity (R_m), compacity (C_f), prospect (P_e) and correlated it with energy consumption (C), in order to bring out a linear relationship, between urban morphological indicators and energy consumption, and its impact on thermo-aerolic comfort. To be done, it requires providing data about built environment (green area, building height, distribution system, building geometry, envelope shape, real consumption, climate data, etc.).

After data collection, it is necessary to use computer tools, firstly for calculation of morph-energetic indicators and graphs generation, secondly simulation software for thermo-aerodynamic comfort assessing, and finally geographic information system (GIS) for specialization and visualization of the results in the form of mapping cards (Fig. 1).

To be realizable of this work, it is necessary that architects, planners and engineers collaborate between them, to establish and test this method feasibility. In this work the selected morphological indicators are defined in (Wang et al. 2017), for the calculation of this morphological indicators, we used Eqs. (1–5).

$$\mathrm{B}_D = \sum_{i=1}^{i=n} Ap_i \div A_s \tag{1}$$

B_D: Building density—Ap: Building floor area i—A_s: Total area—i: Number of buildings.

$$M = S_t - \left(\sum_{i=1}^{i=n} S_{Ve} + \sum_{i=1}^{i=n} S_{Ea}\right) \div S_t \tag{2}$$

M: Mineralization—S_t: Total area of urban portion—S_{Ve}: Surface of the plant element—S_{Ea}: water surface.

$$R_m = \frac{\sum_{i=1}^{i=n} A_i \times h_i}{\sum_{i=1}^{i=n} A_i + \sum_{i=1}^{i=n} A_j}[m] \tag{3}$$

R_m: Rugosity—A_i: Area outside the building i—H_i: Building height i—A_j: Outside surface j.

$$C_f = \sum_{i}^{N} \frac{A_{\mathrm{ext},i}}{V_i^{2/3}} \tag{4}$$

C_f: Compacity—A_{ext}: Outer surface of non-contiguous building envelope—V_i: Building volume i—N: Building number.

$$P_e = H_m / L_p \tag{5}$$

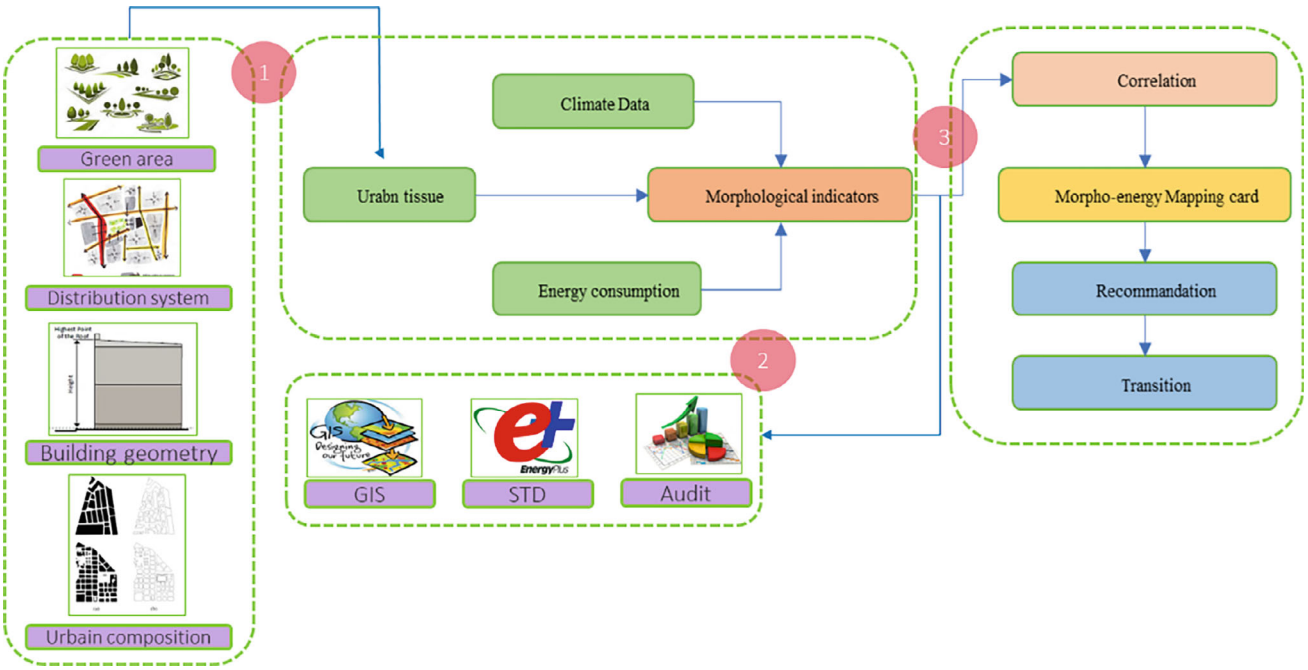


Fig. 1 Urban morpho-energetic development process

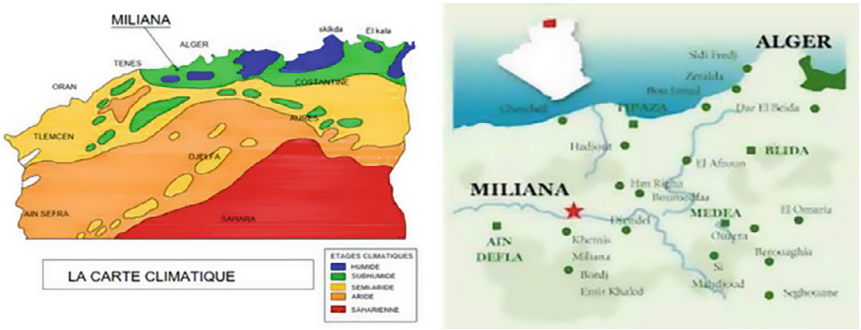
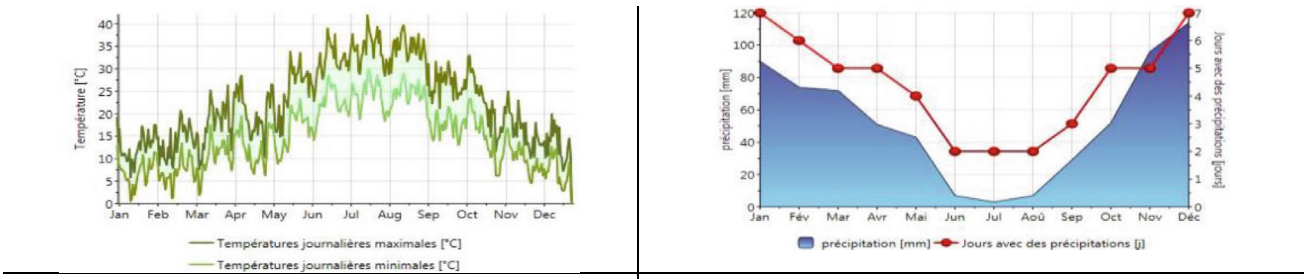


Fig. 2 Location of the selected area



Daily tempratures min and max (°c) | Yearly and daily rainfall (mm)

Fig. 3 Climate data of the study area

P_e: Prospect—H_m: Average height of space—L_p: Small width of space or street.

3 Case Study Description

This section presents a case study in Algeria to closely examine the practical application of the methodology within a specific context. A brief introduction of the Algerian urban system is given, followed by a description of energy consumption models used in Algeria.

Miliana is a town in Algeria that is located 199 km southwest of Algiers, at an altitude of 720 m (Fig. 2).

Using the aridity index and the climate data regenerated by the metronome tool, and presented in the table below deduces that the climate of the chosen study area is sub-humid, whose aridity index is 25[1] (Fig. 3).

4 Results

4.1 Morphological Indicators

The chosen urban tissue was divided into zones, according to the hierarchy of the main, secondary and also the directions of the extensions of the city. The vocation of the area is also determined according to the historical evolution and the characteristics of the buildings (Table 1).

According to the analysis of the different types of islets, there are in the city three types of islets, pre-colonial islets, colonial, current islets. Land cover, is either planar, linear, punctual. Each zone was divided into islands which are neighbourhoods to calculate the different indicators (Fig. 4).

4.2 Morpho-energy Indicators Correlation

After calculating the indicators for different points in each zone, we calculated the average for each zone, and this to correlate the average indicator with the energy consumption of each zone (Fig. 5).

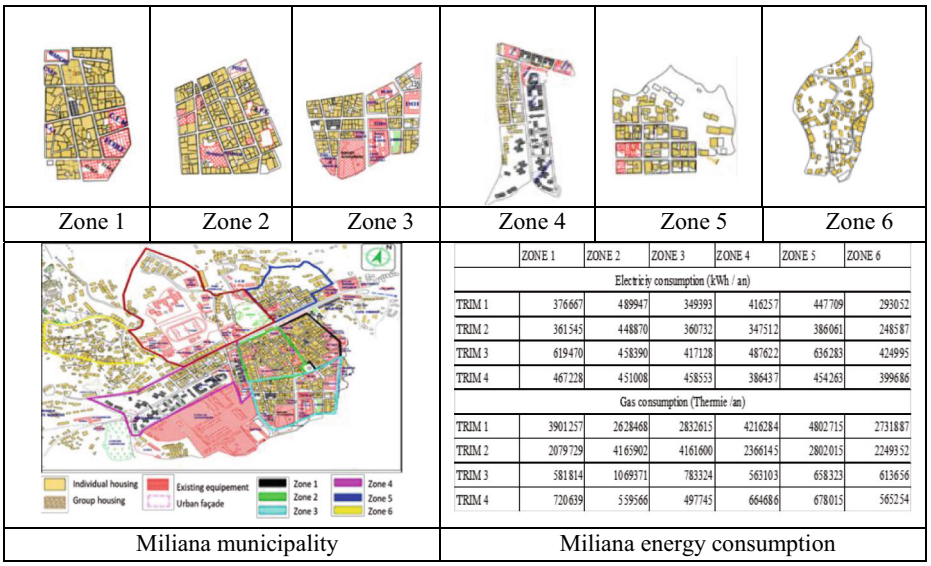
5 Discussion

In this work, we chose to work on the quarter 2 gas consumption, which represents the winter period, so the use of heating since the main source for heating in Algeria is gas. For air conditioning, we chose quarter 4 for electricity consumption, which represents the summer period.

For the summer period, where we need energy for cooling, we deduce that some indicator has a positive relationship with consumption such as density prospect, compactness,

[1] Average annual precipitation mm is 50-Average annual temperature °c 14.

Table 1 Miliana municipality data



	ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 5	ZONE 6
Electricity consumption (kWh / an)						
TRIM 1	376667	489947	349393	416257	447709	293052
TRIM 2	361545	448870	360732	347512	386061	248587
TRIM 3	619470	458390	417128	487622	636283	424995
TRIM 4	467228	451008	458553	386437	454263	399686
Gas consumption (Thermie /an)						
TRIM 1	3901257	2628468	2832615	4216284	4802715	2731887
TRIM 2	2079729	4165902	4161600	2366145	2802015	2249352
TRIM 3	581814	1069371	783324	563103	658323	613656
TRIM 4	720639	559566	497745	664686	678015	565254

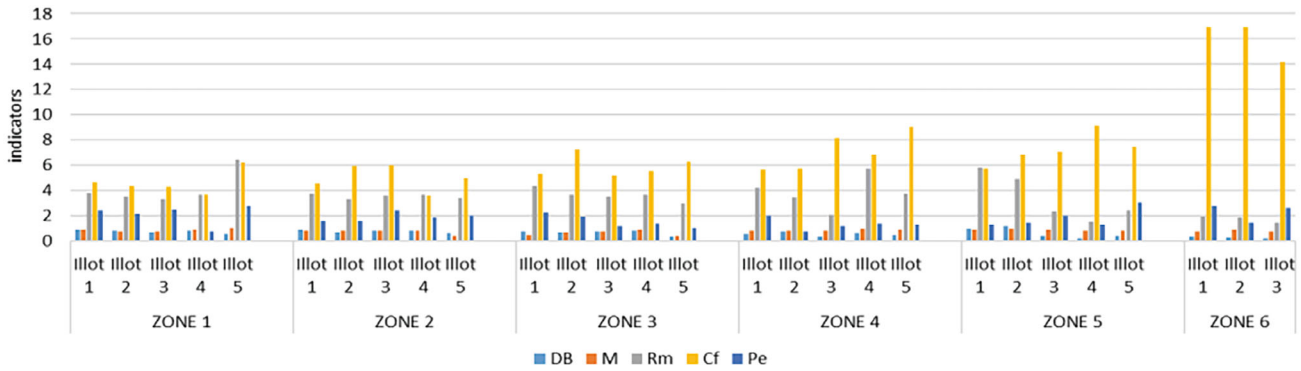


Fig. 4 Morphological indicators for different points in each zone

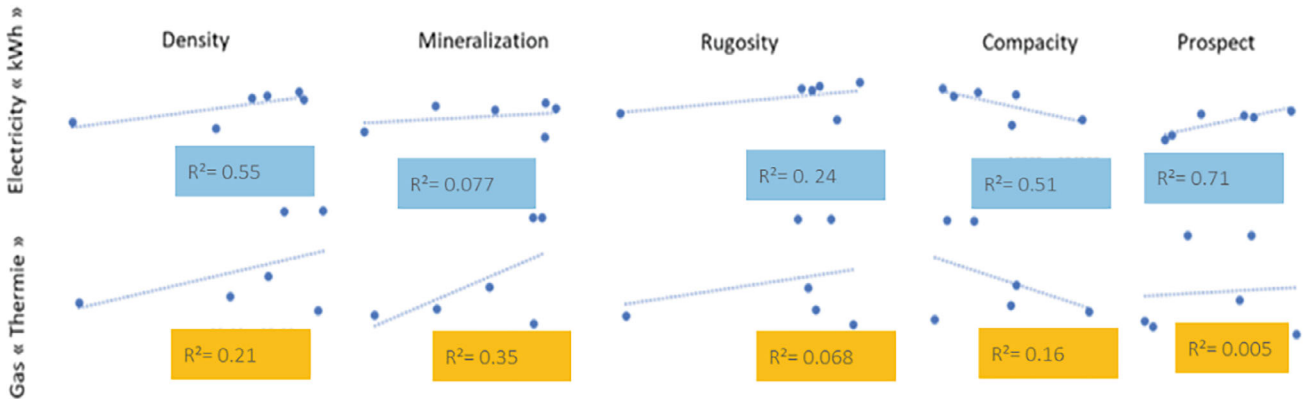


Fig. 5 Linear regression between morphological and energetic indicators

some have had an inverse relationship such as mineralization, rugosity. For the winter period, the influence of morphological indicators on consumption is not very readable.

6 Conclusions

The urban form has an importance in the control of our energy balances, which requires developing an approach to help designers; in this paper, it was not possible to really detail the approach, nevertheless the result presented shows the importance of this type of research.

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Simulation Study of a House Insulated with Date Palm Fiber in the Climatic Conditions of Marrakesh City

Farah Eddib, Aicha Moumni, and Abderrahman Lahrouni

Abstract

Morocco's vocation to use natural materials, and to reuse waste from natural products, is becoming more and present, given the country's strong interest and commitment to minimizing the production of greenhouse gases, and increasing the efficiency of buildings. Products made from date palms have been the subject of much research, including studies of their mechanical and morphological aspects, their performance alone or in combination with other products, and their life cycle. However, its use as an insulator remains largely unexplored in the literature. In April 2023, a study was made on the effect of date palm fiber as an insulator in the meteorological conditions of the city of Casablanca for a house (R + 1), on the heating/air-conditioning load and the evolution of temperatures in the different zones. As a complement to this work, we carried out dynamic simulations with TRNSYS software, on the effect of date palm fiber on heating/air-conditioning loads, as well as occupant's indoor comfort, in the weather conditions of the city of Marrakesh for a house (R + 1). The obtained results are compared with those obtained with a non-insulated house built with standard materials used in Morocco. The results show that date palm fiber insulation has a major effect on the indoor air temperature and the cooling and heating loads of the house. By comparing results to the reference house, the insulated house achieves better comfort conditions, in winter the air temperature has increased by up to 4.5 °C, and decreased by up to 6 °C in summer. In addition to that, annual heating and air-conditioning requirements were reduced by 26% and 30%, respectively, by insulating only walls.

Keywords

Date palm fibers · Insulation · Thermal comfort · TRNSYS · Dynamic simulation · Heating load

1 Introduction

With the aim of achieving thermally efficient buildings, researchers are taking an increasing interest in bio-composite materials, with a great deal of scientific research in recent years. Bio-composite materials are lightweight, purely natural blocks or composites based on continuous solid matrices reinforced with ecological additives. Among bio-composite materials is date palm fiber, considered one of the most accessible natural fibers in the world (Alotaibi et al. 2019; Asim et al. 2021). Date palms account for 4.8% of all palms in Morocco, and occupy an area of 50,000 ha. This ranks the country sixth in the world in terms of palm acreage and 11th in terms of date production (faostat3.fao.org). Many studies have been carried out on the thermo-physical properties of the material, citing several references (Saba et al. 2019; Chikhi et al. 2013; Benmansour et al. 2014; Asim et al. 2020; Agrebi et al. 2020; Oushabi et al. 2015; Mlhem et al. 2022), but we found only one study on the effect of date palm fiber on an R + 1 house in the city of Casablanca in Morocco (Belhous et al. 2023). In this work, we will study the effect of date palm fiber (P-DPF) on an R + 1 house in the climate of the city of Marrakesh, using a dynamic simulation with TRNSYS software.

F. Eddib (✉) · A. Lahrouni
Faculty of sciences Semlalia, Cadi Ayyad University, Marrakech, Morocco
e-mail: farah.eddib@edu.uca.ac.ma

A. Moumni
Université Caen Normandie, ENSICAEN, CNRS, Normandie Univ, GREYC UMR 6072, F-14000, Caen, France

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Table 1 Thermo-physical of construction materials

Material	Specific heat (kJ kg^{-1} K^{-1})	Thermal conductivity (W m^{-1} K^{-1})	Density (kg m^{-3})
Cement mortar	1	1.15	1700
Concrete block	0.65	1.15	1800
Red clay brick	0.878	0.963	1300
Plaster	1	0.57	1300
Granite cladding	1	2.8	2700

Table 2 Thermal properties of insulation (date palm fiber P-DPF) (Belhous et al. 2023)

Material	Thickness (cm)	Thermal conductivity (W m^{-1} K^{-1})	Density (kg m^{-3})
P-DPF	3	0.033	121

2 Materials and Methods

2.1 Building Description

The studied building, located in Marrakesh (Morocco), is a two-floor house with four façades. Its area is 80 m^2. The maximum house's height is 6 m. The first floor consists of one hall, one living room, one dining room, one kitchen, one utility room, and one bathroom. The second floor is composed of three bedrooms, one bathroom, and a hall. The main entrance is located in the south façade. The windows are simple glazed ($U = 5.74$ W m^{-2} K^{-1} and g-value $= 0.87$). Thermo-physical properties of the house construction materials are listed in Tables 1 and 2 displays the thermo-physical characteristics of the insulator.

2.2 Building Numerical Modeling

Dynamic multi-zone numerical modeling is based on the principle of dividing the studied house into several thermal zones (Zi). In our case, it allows us to distinguish between the two floors, in order to represent existing rooms and spaces. This division gives us five zones on the ground floor and three on the first floor. Some zones include more than one room, and we have assumed that they have the same conditions, and therefore the same temperature. The simulations are performed using TRNSYS software, with a time step of one hour.

The following assumptions are adopted:

- The thermal zones are described by an air node representing the temperature of the zone volume.
- All doors and windows are closed.

3 Results

3.1 Thermal Analysis

Simulations were carried out over a period of one year, for our two studied configurations, insulated and uninsulated houses, studying the change in temperatures for the first and second floors. For the uninsulated house (A), temperature fluctuations on both floors are very significant, and much less for the insulated house (B) (Fig. 1).

3.2 Heating and Cooling Loads

Based on the results obtained with TRNSYS software in the climatic conditions of the city of Marrakesh represented in Table 3, we compared the results of an uninsulated house and another insulated with date palm fiber (P-DPF) as shown in Fig. 2.

As shown in Table 3, the heating consumption of the insulated and uninsulated houses is 5175 and 7401 (kWH), respectively, and the air-conditioning consumption of the insulated and uninsulated houses is 14,910 and 20,240 (kWH), respectively.

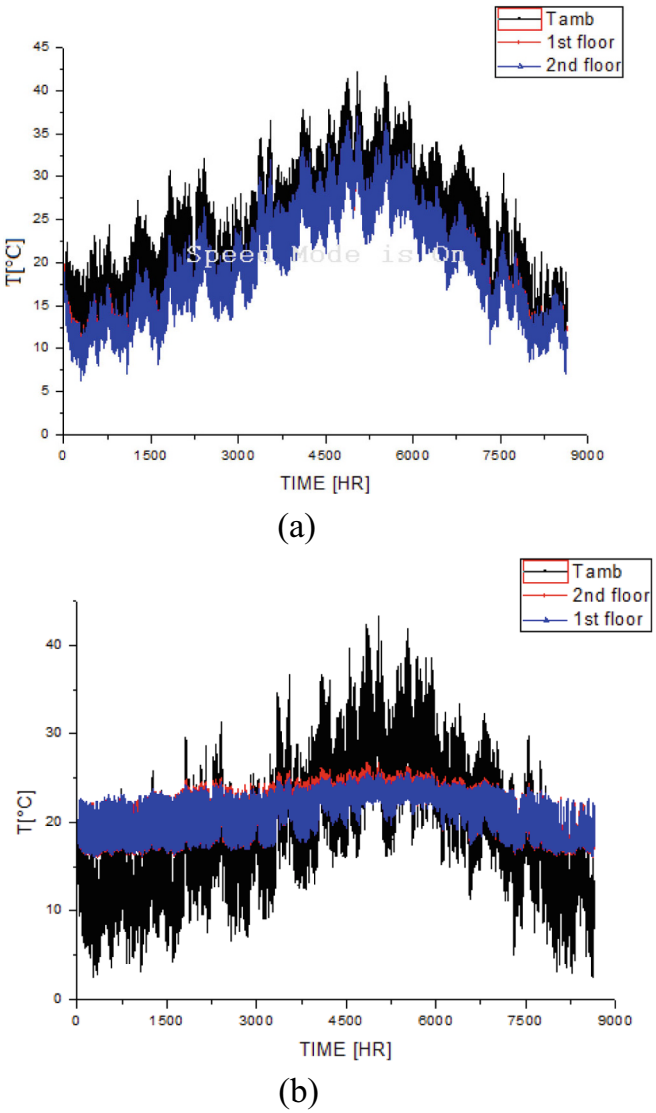


Fig. 1 Hourly air temperatures over a year for uninsulated house (**A**) and insulated house (**B**)

Table 3 Heating and cooling loads for insulated and uninsulated house

	Heating (kWH)	Cooling (kWH)
Insulated house	5175	14,910
Uninsulated house	7401	20,240

4 Discussion

Date palm fiber is a natural, biodegradable insulator that is the focus of our study. The results showed that by insulating only the exterior walls, we were able to raise internal temperatures by 4.5 °C in winter, and lower them by 6 °C in summer. This enabled us to reduce the heating load by 26%, and the air-conditioning load by 30%.

In a study carried out in the city of Casablanca (Belhous et al. 2023), the authors found that by insulating the roof and external walls with date palm fiber, they were able to reduce heating and air-conditioning loads by 18% and 25%, respectively.

The continuation of this work will consist in deepening this study to have the best possible configuration in the climatic conditions of the city of Marrakesh.

5 Conclusions

The study we carried out focused on the effect of date palm fiber on internal temperatures, heating and air-conditioning loads in the climate of Marrakesh city in Morocco. By insu-

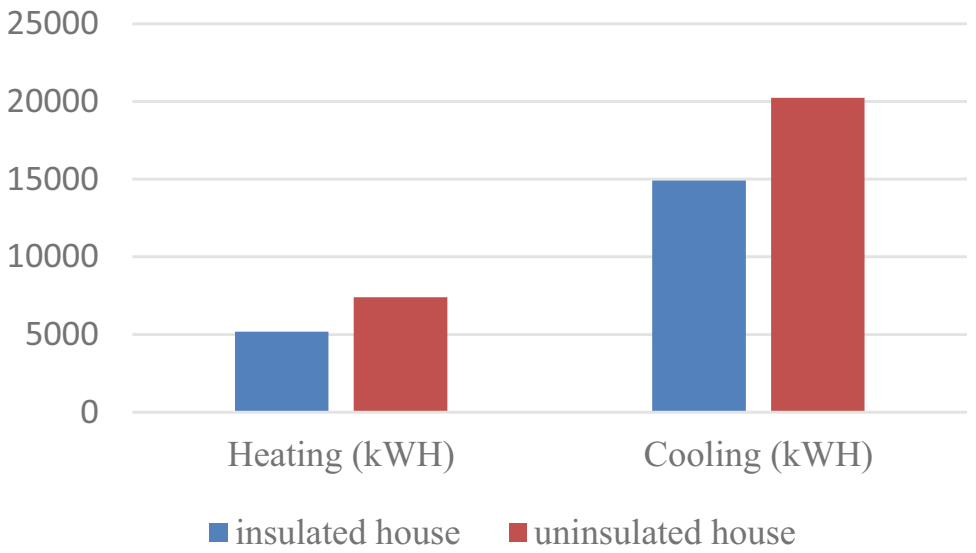


Fig. 2 Heating and cooling loads for insulated and uninsulated house

lating only walls, we were able to achieve better comfort conditions, in winter the air temperature has increased by up to 4.5 °C, and decreased by up to 6 °C in summer. In addition, to save respectively 26% and 30% on heating and cooling loads.

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Automatic Damage Detection of Moroccan Architectural Heritage Based on Deep Learning

Oumaima Khlifati, Khadija Baba, and Sana Simou

Abstract

Heritage sites are sensitive to damage resulting from environmental, anthropological, and social factors. Consequently, this deterioration doesn't only diminish the quality of these structures but also poses significant safety risks. Hence, it is imperative to regularly visually inspect heritage structures to ensure their maintenance and preservation. Damage assessment of building surfaces typically necessitates the involvement of qualified professionals, who dedicate substantial time and effort to the task. In order to surpass these limitations, this research introduced an innovative method for automated damage detection employing a deep learning network to ensure rapid investigation and effective detection of damage to Rabat's architectural heritage. The dataset utilized in this work includes images of Rabat's historic monuments, which were captured manually using a camera Canon 700D. After the labeling process, the dataset was employed for training and testing using the YOLOv5 technique. The model utilized in this study has the capability to detect and classify different types of damage present on the exterior walls of different historic monuments. These damages include: crack, delamination, lichens, partial collapse, rising damp, and spalling. Validation experiments demonstrate the model's high precision and recall, with performance improving at higher confidence levels. The automated system significantly enhances the efficiency and accuracy of damage detection, ensuring timely maintenance and preservation of heritage sites.

Keywords

Deep learning · Damage detection · Architectural heritage

1 Introduction

Rabat, the imperial city and capital of Morocco, proudly shelters an abundance of ancient landmarks. These remarkable sites stand as enduring symbols of the civilizations that have significantly shaped during the Roman and Islamic periods. Among these historical treasures, several date back to the eighth century, with Chellah being one of the most notable.

Chellah's appeal draws an increasing number of visitors. Despite its allure, this unique site is subject to relentless natural forces, experiencing both physical and chemical degradation. The main factors contributing to the physico-chemical deterioration of historical monuments in Chellah include climatic elements, such as rainwater runoff and humid air carrying salts from the Atlantic Ocean. These elements infiltrate the materials through processes like infiltration or capillary action.

In order to protect this historical monument from deterioration, it is vital to carry out frequent assessments of these buildings to guarantee their preservation and conservation. Swiftly identifying and categorizing any damages will facilitate timely interventions and maintenance endeavors. The most common approaches to detect surface damage in historic heritage sites primarily depend on on-site visual inspection methods, supported by specialized equipment (Gattulli and Chiaramonte 2005; Santos et al. 2013; Reyno et al. 2018; O'Byrne et al. 2013; Flores-Colen et al. 2009). However, thanks to the swift advancement of deep learning methodologies, the previously mentioned issues can be addressed. Numerous Convolutional Neural Networks (CNN) have arisen, showcasing exceptional accuracy in

O. Khlifati (✉) · K. Baba · S. Simou
Civil and Environmental Engineering Laboratory (LGCE), Mohammadia Engineering School, Mohammed V University in Rabat, Rabat, Morocco
e-mail: khlifatioumaima@gmail.com

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classification and recognition. Several authors have adopted CNN algorithms to detect various damages in civil engineering (Cha et al. 2018; Khlifati and Baba 2023). The detection technology that was previously limited to modern civil applications presents compatibility challenges. This study employs the You Only Look Once (YOLO) (Redmon et al. 2016) technique for detecting and classifying various damages present in Chellah.

2 Data Collection and Methodology

The data collection used in this research consists of images captured at Chellah with a digital camera. A collection of 117 pictures was acquired, each with unique dimensions due to the varying sizes of the scenes captured. These images focus on different types of damages at Chellah, including cracks, delamination, lichens, partial collapse, rising damp, and spalling.

This study utilizes YOLOv5l as the chosen model for the object detection task. Table 1 details the architecture of YOLOv5. The YOLOv5 algorithm mainly split into three key sections: the backbone network, the bottleneck layer network which is called "Neck," and the detection layer named "Head." The backbone network comprises a standard convolution layer (Conv), a spatial pyramid pooling fast module (SPPF) and a C3 module. The neck component is comprised of essential elements such as convolution layer (Conv), an upsampling process, concatenation, and a C3 module. The head contains a detect module made up of three convolutional layers (Fig. 1).

Table 1 YOLOv5l architecture (Jocher 2020)

Module	Stride
Backbone	5*Conv
	4*C3
	SPPF
Neck	4*Conv
	2*Upsample
	4*Concat
	4*C3
Head	3*Conv
C3	3*Conv
	BottleNeck
	Concat
Bottleneck	2*Conv

3 Results and Discussion

The provided figure features two essential plots for evaluating the YOLOv5 algorithm's performance in identifying damages in the context of Chellah: a precision-confidence curve (Fig. 2a) and a recall-confidence curve (Fig. 2b). The precision-confidence curve illustrates that as the confidence threshold increases, precision generally improves, indicating more reliable predictions at higher confidence levels across different damage types such as crack, delamination, lichens, partial collapse, rising damp, and spalling. The aggregated performance across all damage types shows a trend toward high precision at elevated confidence levels, emphasizing the model's general reliability. Conversely, the recall-confidence curve shows that recall typically decreases with higher confidence thresholds, reflecting the expected trade-off as some true positives are filtered out. This curve demonstrates the model's ability to maintain high recall at moderate confidence levels, with varying performance across different damage types. The analysis highlights the YOLOv5 model's effectiveness in distinguishing between various damages, balancing precision and recall for practical applications. Overall, the curves underscore the model's proficiency and reliability in accurately identifying and localizing anomalies, with performance improving as confidence increases.

To evaluate the model's results, Fig. 3 displays the detected bounding boxes for each type of damage. These results show that the system exhibits a remarkable ability to differ-



Fig. 1 Examples of dataset images

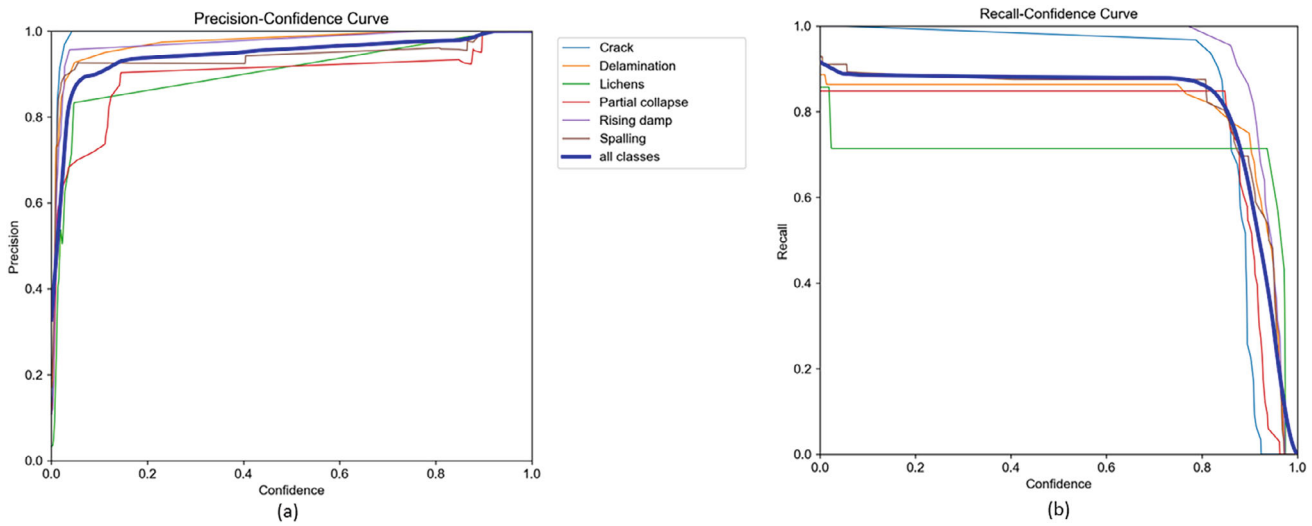


Fig. 2 **a** Precision-confidence graph of the model for all damage types, **b** recall-confidence graph of the model for all damage types



Fig. 3 Example depicting anticipated bounding boxes using the YOLOv5l model

entiate among the various forms of degradation present in Chellah, confirming its proficiency in effectively identifying and accurately locating various anomalies on the examined surfaces.

4 Conclusions

Chellah's captivating charm attracts a growing number of tourists from various backgrounds and age ranges, establishing its status as a top tourist spot. Despite its allure, this historic site faces continuous natural wear and tear, including both physical and chemical damage. Traditionally, assessing these damages involves the expertise of skilled professionals who invest significant time and energy to the evaluation process. To address these challenges, this study introduces an innovative automated damage detection approach leveraging a deep learning technique. By using the YOLOv5l, this approach aims to accurately identify and categorize the different types of degradation affecting the Chellah. The results demonstrate the model's capability to detect and precisely pinpoint all deterioration in Chellah.

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Estimating the Sustainable Mobility Index in Tunisian Cities

Emna Khammassi, Ferid Rehimi, and Adel Kalboussi

Abstract

Transportation is a crucial issue with a major impact on the environment, the economy and society. The aim of this study is to construct a composite index of transport sustainability based on a set of indicators considered relevant to measure the gap between Tunisian cities in terms of mobility. To achieve this objective, a total of 92 indicators of transport sustainability were identified from relevant research literature, covering Tunisian cities as a case study. These indicators encompass the three dimensions of sustainability, namely, environmental, social and economic, with each dimension being further subdivided into separate subdivision. The indicators were standardised, weighted using principal component analysis (PCA)/FA, and then combined to produce a composite index for each subdivision and then for each dimension. Finally, the dimensional composite indices were combined to establish the composite index of mobility sustainability for each Tunisian city. The most sustainable cities in descending order are Mahdia, Sousse, Manouba, Ariana, Tunis, Ben Arous and Monastir. Meanwhile, the least sustainable cities are Kasserine, Tozeur, Siliana and Le Kef. The regional development index was employed to explain this finding. The study showed that certain Tunisian cities rank higher in transport sustainability. This study not only helps decision-makers identify regional mobility disparities in Tunisian cities but also allows measuring transport sustainability.

Keywords

Transportation sustainability · Indicators · Composite index · Tunisian cities · Gap

1 Introduction

Sustainable development is a key consideration in local, national and regional policy-making (Siksnelyte et al. 2018). In order to achieve financial viability, social equity and environmental sustainability, it is essential to assess the sustainability of transport systems (Illahi and Mir 2020).

Sustainability indicators are highly appropriate for assessing the improvements towards a more sustainable transportation system (Epa 2011). These measures are quantifiable and help in the assessment of the impact of the different factors on the three pillars of sustainable development within the transport system (Verma 2015).

The elaboration of combined indices is a required approach and insight to achieve sustainability of mobility (Illahi and Mir 2020). OECD has released guidelines for the calculation of such composite indices (Joint Research Centre-European Commission 2008).

Different methods have been employed by various studies to assign weights to the indicators. The commonly used weighting methods fall into three groups: equal weighting methods, weighting methods based on expert opinion and statistical weighting methods (Saisana 2011). Among these, principal component analysis is a highly appreciated method that is so superior to previous weighting methods used in the literature (equal weighting and weighting based on expert opinion) (Reisi et al. 2014; Mahdinia et al. 2018).

Several studies have concentrated on assessing and appraising the sustainability of transportation.

Haghshenas and Vaziri conducted a study of 100 global cities using a synthetic metropolitan transport index with an equal-weight approach (Haghshenas and Vaziri 2012).

E. Khammassi (✉) · A. Kalboussi
LEM laboratory, Faculty of Science, Monastir University, Monastir, Tunisia

F. Rehimi
Department of Civil Engineering, Taibah University, College of Engineering, Madinah, Saudi Arabia

LESTE Laboratory, ENIM, Monastir University, Monastir, Tunisia

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Gruyter et al. also investigated sustainability of public transport systems by applying 15 transport indicators with equal weighting (Gomez-Limon and Riesgo 2008). Reisi et al. applied a similar methodology in Melbourne to assess the sustainability of transport. A composite sustainability index was generated by employing PCA (principal component analysis) techniques to weight the indicators (Reisi et al. 2014).

2 Methodology

The methodology used in this study follows the approach developed by Mahdinia et al. (2018), with some adaptations made to the process of calculating pollutant emissions and greenhouse gases.

In fact, all of the indicators of sustainable mobility have been chosen according to the relevant scientific literature (Mahdinia et al. 2018) and, based on the data provided by Tunisia (National Institute of Statistics (INS), Technical Agency for Land Transport ATTT, Ministry of Equipment, Housing and Infrastructure, National Agency for Energy Management ANME), several indicators have been added ('time needed to reach a university hospital', 'overall length of paved roads per VKT', 'overall length of unpaved roads per region', 'overall length of urban roads') and some have been omitted. Indicators used during this study are presented in Fig. 1.

For the calculation of the environmental indicators associated with air pollution, the COPERT method was applied (Ntziachristos and Samaras 2019). Furthermore, when calculating greenhouse gas (GHG) emission indicators, all pollutants were converted into CO_2 equivalents.

As described above, indicators were standardised and then weighted through principal component analysis, followed by aggregation into a combined index (see Fig. 2).

2.1 Phase 1: Standardising Indicators

As part of the standardisation of indicators, the max/min method was applied (Reisi et al. 2014; Mahdinia et al. 2018).

$$I_N^+ = \frac{I^+ - I_{\min}^+}{I_{\max}^+ - I_{\min}^+} \text{ If } I > 0 \tag{1}$$

$$I_N^- = \frac{I_{\max}^- - I^-}{I_{\max}^- - I_{\min}^-} \text{ If } I < 0 \tag{2}$$

I is the sustainable transport indicator; I_N is the standard indicator; I (+) is an indicator with a rising value having a positive effect on sustainability; I (−) is an indicator with a rising value having a negative effect on sustainability; I (min) is the indicator's minimum value; I (max) is the indicator's maximum value.

2.2 Phase 2: Calculation of Combined Indices for Subdivision

Indicators are initially assigned a weighting by the principal component analysis (PCA) method, applying the formula below:

$$W_{\text{kjsd}} = \frac{(\text{Factor Loading})_{\text{kjsD}}^2}{\text{Eigenvalue}_{\text{jsD}}} \tag{3}$$

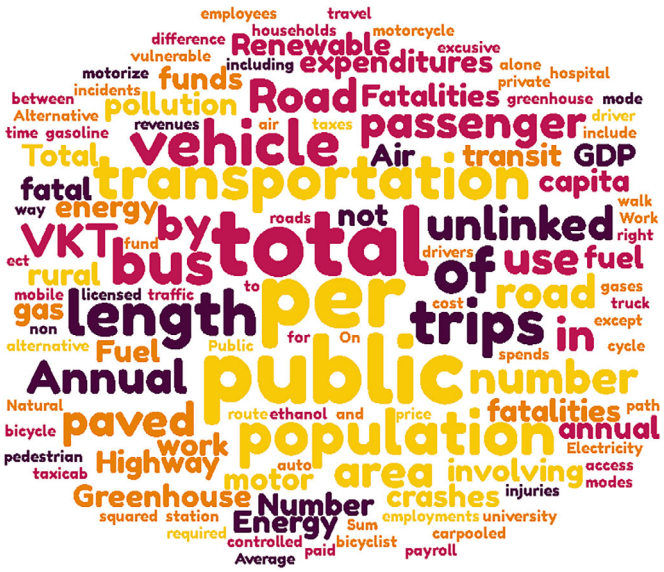


Fig. 1 Sustainable transportation indicators

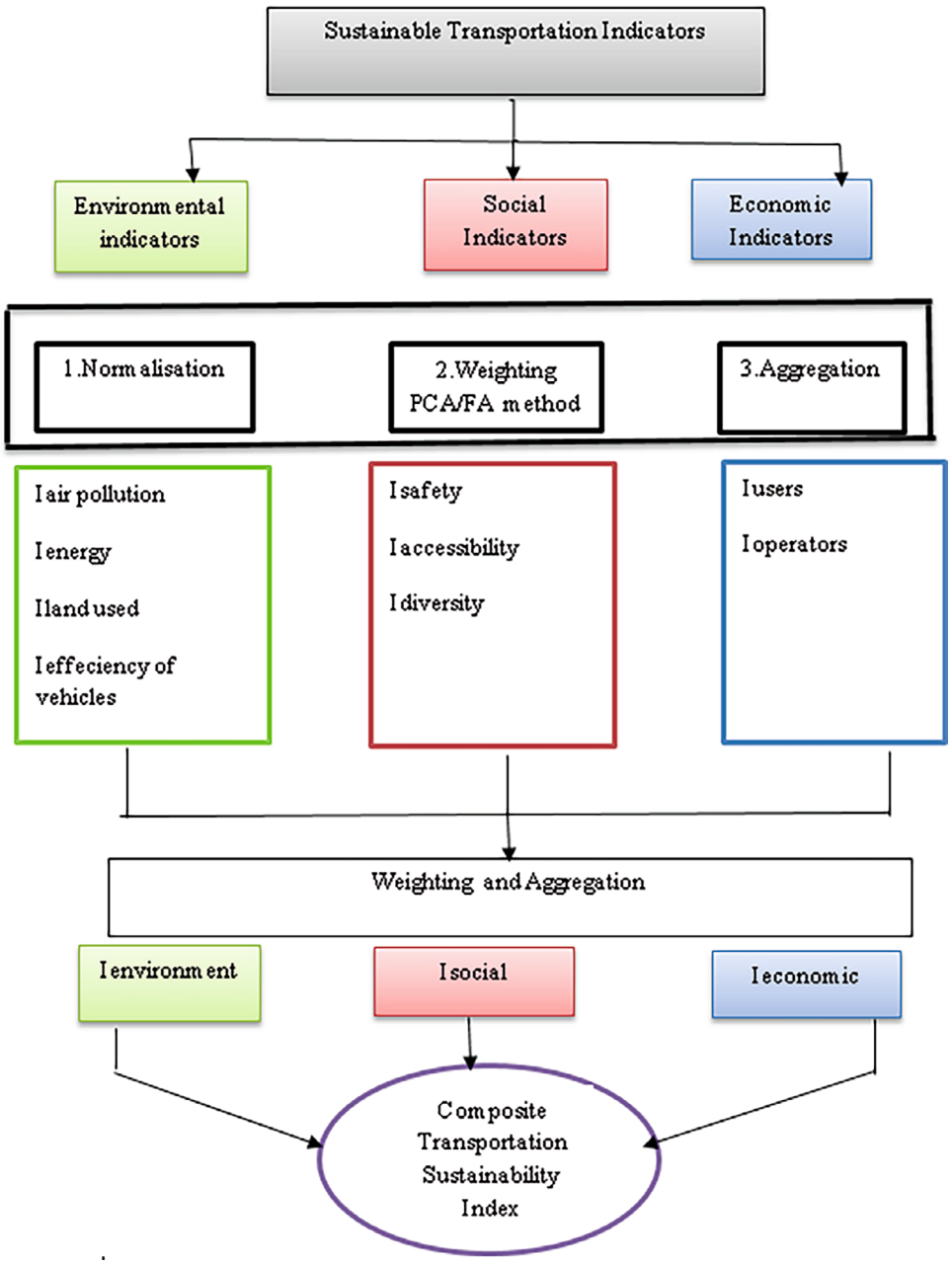


Fig. 2 Calculating steps of the composite transportation sustainability index

(j): latent factors;(k): indicators;(s): subdivision (D): dimension.

Next, a composite factor index (CFI) relative to each of the latent factors (j) was computed:

$$\mathrm{CFI}_{\mathrm{jsd}} = \sum_{k} W_{\mathrm{kjsd}} \times \mathrm{NI}_{\mathrm{kjsd}} \tag{4}$$

W_{kjsd}: The measurement of an indicator's weight based on the hidden component and eigenvalue.

CFI: The aggregate index of the latent component (j), which refers to the dimension d and its subdivision (s).

NI: This represents the indicator's standardised value.

It is important to compute the composite subdivision index after computing the composite factor index (CFI). In order to create the composite subdivision index (CSI), the composite factor index (CFI) was assigned a weight using Eq. (5) and then combined using Eq. (6).

$$\alpha_{\mathrm{jsd}} = \frac{\mathrm{Eigenvalue}_{\mathrm{jsd}}}{\sum_{\mathrm{js}} \mathrm{Eigenvalue}_{\mathrm{jsd}}} \tag{5}$$

$$\mathrm{CSI}_{\mathrm{sd}} = \sum_{j} \alpha_{\mathrm{jsd}} \times \mathrm{CFI}_{\mathrm{jsd}} \tag{6}$$

α: The weight refers to the combined factorial index (CFI); CSI_{sd}: The combined subdimensional index.

2.3 Phase 3: Calculating Combined Dimensional Indices

By combining the combined indices of the previously obtained subdivision, combined indices reflecting each dimension's features were produced in this phase. The following equation was used to determine how much the CSI indices should be weighted:

$$W_{sj'd} = \frac{(\text{Factor loading})^2_{sj'd}}{\text{eigenvalue}_{j'd}} \tag{7}$$

The following equation was then used to obtain the combined factorial index that belonged to the latent factor (j'):

$$\text{CFI}_{j'd} = \sum_s w_{sj'd} \times \text{CSI}_{sd} \tag{8}$$

$W_{sj'd}$: Latent factor (j') and eigenvalue together make up the weight applied to the combined subdivision indice (s).

$\text{CFI}_{j'd}$: A combined factorial index for the dimension d and latent component (j').

These indices were weighted and combined to create the combined dimensional indices (CDI) after generating the combined factor index (CFI).

$$\alpha_{j'd} = \frac{\text{Eingenvalue}_{j'd}}{\sum_j, \text{Eigenvalue}_{j'd}} \tag{9}$$

$$\text{CDI}_d = \sum_{j'} \alpha_{j'd} \times \text{CFI}_{j'd} \tag{10}$$

$\alpha_{j'd}$: The combined factor index's weight; CDI_d: The combined dimensional indices index.

2.4 Phase 4: Determining the Composite Transportation Sustainability Index

During this stage, we aggregated the three combined indices of the dimensions in order to generate the composite transportation sustainability index by assigning them a weighting coefficient equal to 1:

$$I_{TS} = \frac{\sum_d \alpha_d \times \text{CDI}_d}{D} \tag{11}$$

$\alpha_d = 1$ is the combined dimensional indices given weight; I_{TS} is the composite transportation sustainability index.

3 Results

The result shows that the regions of 'Tunis' (0.4472), 'Sousse' (0.4756), 'Monastir' (0.4452), 'Mahdia' (0.4767), 'Manouba' (0.4542), 'Ariana' (0.4540) and 'Ben Arous' (0.4461) are the most sustainable cities while 'Kasserine' (0.3543), 'Tozeur' (0.3630), 'Siliana' (0.3661) and 'Le Kef' (0.3666) are the least sustainable cities (see Fig. 3).

3.1 Composite Environmental Index

In terms of the environmental index, the city of 'Tunis' (0.4183) has the lowest rank, which can be explained by the existence of a fairly large fleet and increased traffic. As a result, indicators related to air pollution and greenhouse gases take on high values.

3.2 Composite Social Index

The composite index of social aspects shows strong regional disparities which can be summarised by the low level of accessibility to means of transport and health services in the cities of 'Kasserine' (0.0792), 'Tozeur' (0.0928), 'Siliana' (0.1068), 'Le Kef' (0.1074) and 'Sidi Bouzid' (0.1415), in contrast to the coastal cities of 'Tunis' (0.4964), 'Mahdia' (0.4581), 'Sousse' (0.4757) and 'Manouba' (0.4386).

3.3 Composite Economic Index

At the level of the economic index, the seaside cities 'Tunis' (0.4271), 'Ariana' (0.3857), 'Sousse' (0.5233) and 'Monastir' (0.4692) are poorly ranked. This inferiority can be explained by the high level of expenditure on transportation system.

4 Discussion

The results of this study show regional inequalities and point to various transportation problems in some Tunisian cities. Indeed, the coastal regions are endowed with a socio-sanitary infrastructure and increased transportation accessibility and diversity. While the social composite index reflects strong disparities in the interior regions in terms of accessibility

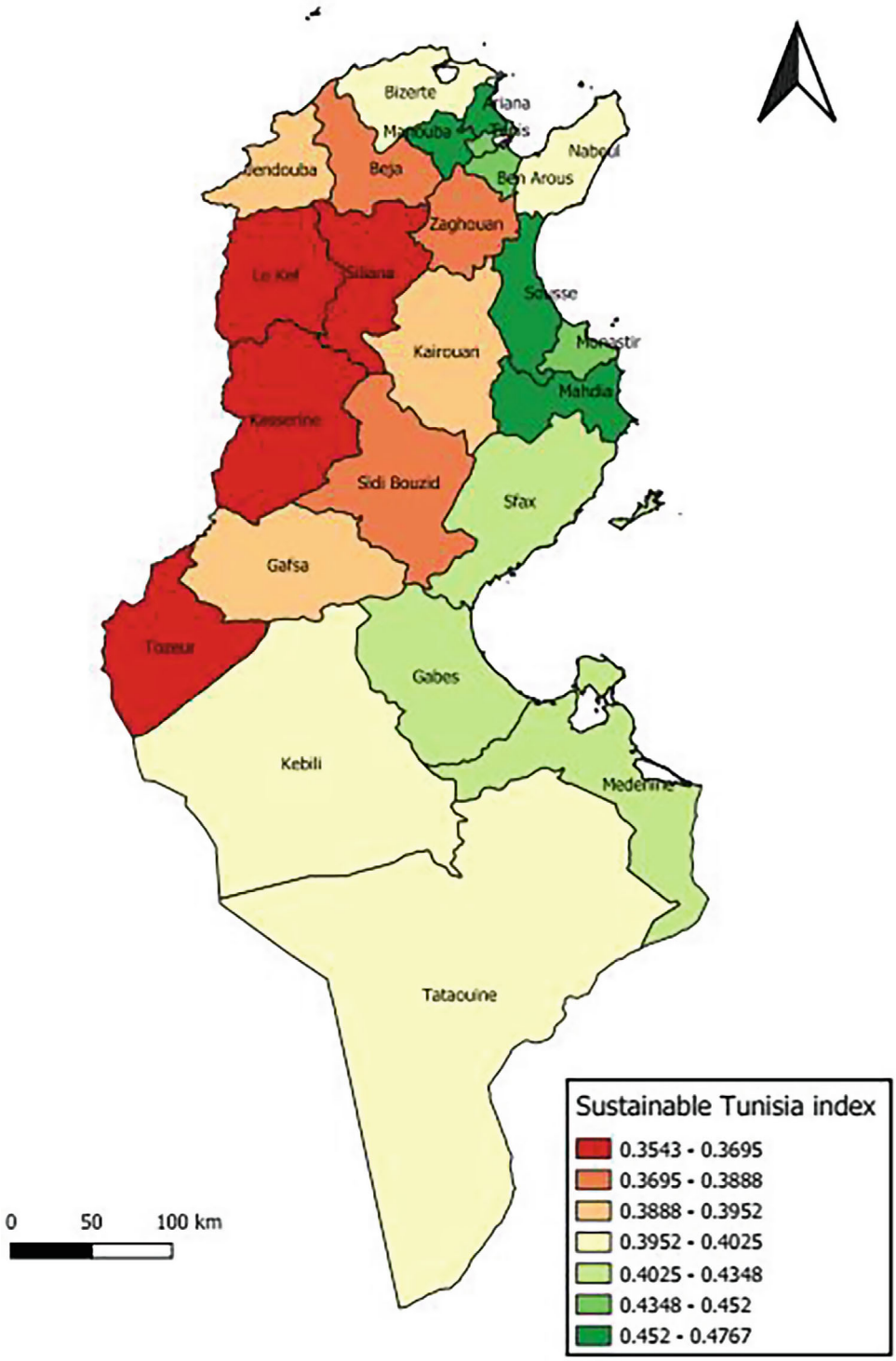


Fig. 3 Composite transportation sustainability index

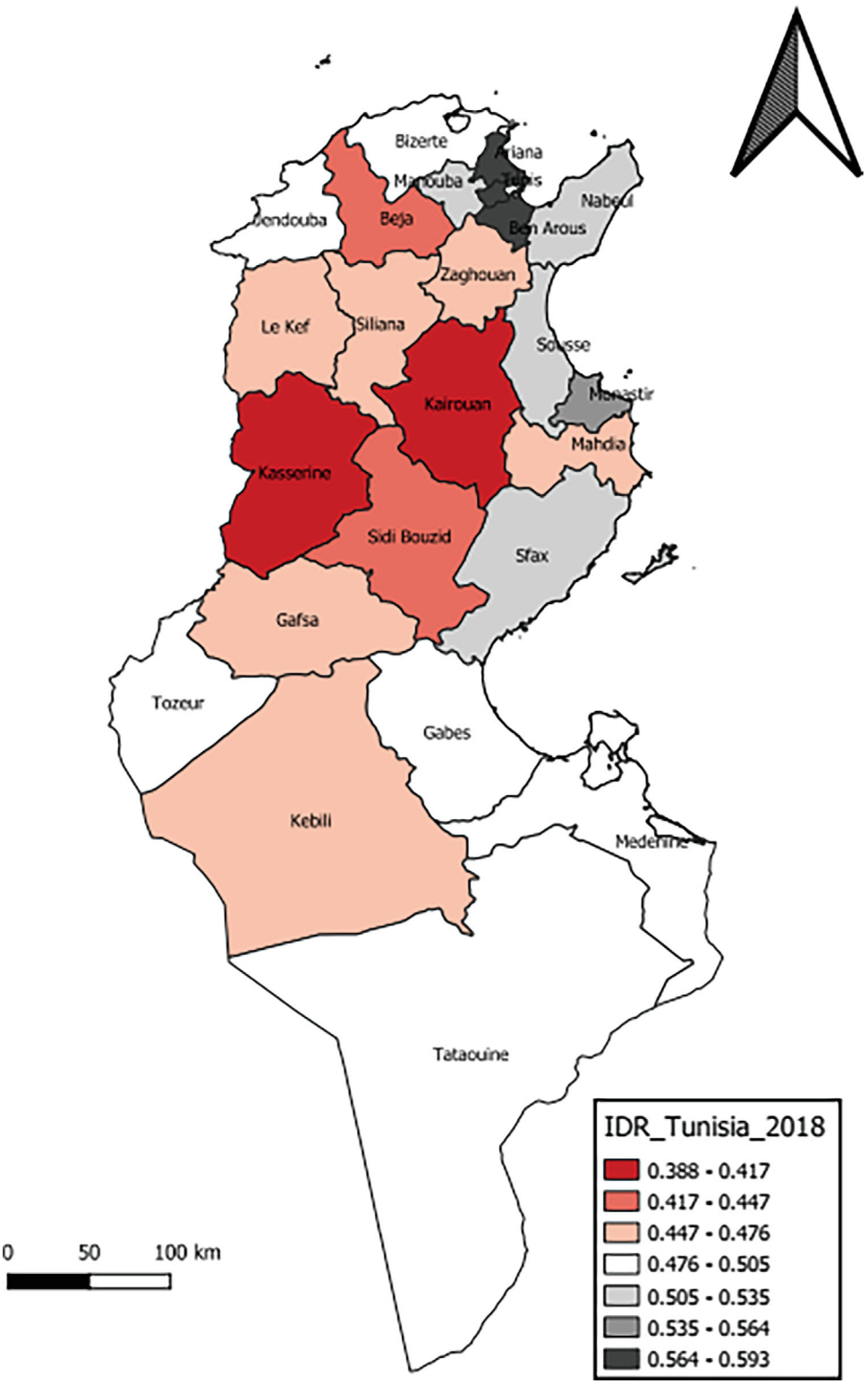


Fig. 4 Regional development indicator Tunisia 2018

to transport and health services. Its cities are affected by poverty due to low economic activity and low levels of investment, attractiveness and inability to absorb job opportunities. The regional development index calculated for Tunisian cities manages to show this disparity ('Tunis' = 0.5931; 'Ariana' = 0.5801; 'Monastir' = 0.5535; 'Bizerte' = 0.4942; 'Gabes' = 0.5011; 'Kasserine' = 0.3881; 'Kairouan' = 0.3984) (ITCEQ 2018) (Fig. 4).

5 Conclusion

In this work, a calculation methodology from the work of Mahdinia et al. (2018) was adopted and modified in order to introduce a composite transportation sustainability index for Tunisian cities based on 92 indicators. This study can be an effective tool to measure the gap between cities and the performance of investment policies in/of transportation systems, in order to mitigate regional disparities and ensure an equitable distribution.

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Numerical Simulation of Road Traffic Noise Propagation Using the French Outdoor Noise Prediction Method Coupled with the First Order Traffic Model

Abdessalem Jbara, Ahmed Komti, Mohamed Houcine Dhaou, and Khalifa Slimi

Abstract

In modern planning, noise protection is one of the fundamental requirements that should be respected before performing any kind of project aiming to install a new infrastructure (roads, railroads, airports, and seaports). Moreover, in the environmental studies, the noise maps are essential for risk assessment, identification of noise sources, simulation of mitigation measures, evaluation of the exposed population, and urban planning. Therefore, this work presents a numerical investigation of road traffic noise propagation in the exposed areas. The first order road traffic model and the French standard road noise prediction method were used to forecast both road traffic conditions and noise levels within the studied area. The findings indicate that installing noise barriers can effectively alleviate the adverse effects of road traffic noise. The main results show that the equivalent sound level gap (between the case without noise barrier and the case with noise barrier) is proportional to the absorption coefficient of the noise barrier.

Keywords

Noise propagation · Road traffic · Numerical simulation

1 Introduction

Noise discomfort represents a significant challenge, particularly in densely populated urban areas, since it poses a substantial threat to the overall quality of life. According to the European Environment Agency (European Environment Agency 2020), about 110 million individuals are daily subjected to noise levels exceeding the established standard threshold of 55 dB(A).

In the same context, the World Health Organization was indicated that 33% of the populations are annoyed during the daytime and 20% have disturbed sleep at night because of traffic noise (World Health Organization 2011).

This paper aims to study road traffic noise propagation by using the standard French road noise prediction method (NMPB-Roads-2008) coupled with the macroscopic first order traffic model (LWR). In the same context, the effect of acoustic reflectors will be presented and discussed.

2 Mathematical Modeling and Numerical Method

A road, of width 6 m, passes through the middle of a rectangular area of dimensions $L \times L = 1 \times 1$ km. Each point belonging to this area is represented by its spatial coordinates (x, y) in a Cartesian coordinate system (o, x, y).

By assuming that traffic is at an equilibrium state, the first order traffic model proposed by (Lightill and Whitham 1955; Richards 1956) is written as follows:

$$\begin{cases} \frac{\partial \rho}{\partial t} + \frac{\partial Q(\rho)}{\partial x} = 0 \\ Q(\rho) = \rho V_{\max}\left(1 - \frac{\rho}{\rho_{\max}}\right) \end{cases} \quad (1)$$

ρ(veh/km) denotes the vehicular density and Q(veh/h) the corresponding vehicular flux. $V_{\max} = 60$ km/h and $\rho_{\max} = 165$ veh/km are the maximum authorized speed and the maximum vehicular density.

According to the NMPB method (Service d'études sur les transports, les routes et leurs aménagements (SETRA) 2009a), the sound levels in the downward-refraction conditions ($L_{i,F}$) and in the homogeneous conditions ($L_{i,H}$) for a

A. Jbara (✉)
University of Sousse, Sousse, Tunisia

A. Jbara · A. Komti · M. H. Dhaou · K. Slimi
University of Monastir, Monastir, Tunisia

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propagation path and in a given third-octave band are written as follows:

$$L_{i,c} = L_{A,\mathrm{wi}} - \left(A_{\mathrm{div}} + A_{\mathrm{atm}} + A_{\mathrm{sol},c}\right) \tag{2}$$

where c denotes F for downward-refraction conditions or H for homogeneous conditions and $L_{A,\mathrm{wi}}$ [dB(A)] is the point source's sound power level which is expressed as follows:

$$L_{A,\mathrm{wi}} = \left[\left(L_{w/\mathrm{LV}} + 10\log Q_{\mathrm{LV}}\right) \oplus \left(L_{w/\mathrm{HV}} + 10\log Q_{\mathrm{HV}}\right)\right] + 10\ \log l_i + R(k) \tag{3}$$

$\mathrm{L_{W/LV}}$ and $\mathrm{L_{W/HV}}$ are the power levels of light and heavy cars per unit of length. Q_{LV} and Q_{HV} are the vehicular flow rates of light and heavy cars. l_i is the ith source line's length and $R(k)$ is the road noise spectrum value standardized at 0 dB and A-weighted. A_{div}, A_{atm}, and $A_{\mathrm{sol},*}$ are the attenuations due to geometric divergence, atmospheric absorption, and soil effect. All these attenuations are given in (Service d'études sur les transports, les routes et leurs aménagements (SETRA) 2009b).

The long-term road noise level due to the point source number i ($L_{i,\mathrm{LT}}$) is obtained by energy summing of the noise levels $L_{i,F}$ and $L_{i,H}$:

$$L_{i,\mathrm{LT}} = 10\log\left(p_o 10^{(0.1L_{i,F})} + (1-p_o)10^{(0.1L_{i,H})}\right) \tag{4}$$

p_{o} denotes the average probability of downward-refraction conditions in a given propagation path (Service d'études sur les transports, les routes et leurs aménagements (SETRA) 2009a).

The total road noise level at the receiver in a specific third-octave band (k) results from combining sound emissions from all point sources (i) and their potential image sources (i') in case of specular reflection:

$$L_{\mathrm{eq,LT}} = 10\log\left(\sum_i 10^{0,1\ L_{i,\mathrm{LT}}} + \sum_{i'} 10^{0,1\ L_{i',\mathrm{LT}}}\right) \tag{5}$$

The total road noise level, in dB(A), is calculated by adding the noise levels of all third-octave bands (k = 1,18) (Service d'études sur les transports, les routes et leurs aménagements (SETRA) 2009a):

$$L_{\mathrm{Aeq,LT}} = 10\log\left(\sum_{k=1}^{18} 10^{0.1L_{\mathrm{eq,LT}}(k)}\right) \tag{6}$$

In this study, the finite difference technique is applied to discretize the traffic model (system (1)). The road is divided into 20 cells ($N_x = 20$), each with a consistent length of Δx = 50 m, and a uniform time increment of Δt = 2.4 s. Within each cell (i) and for each subsequent iteration [$t + \Delta t$], the discretized form of vehicular density is expressed as follows:

$$\boldsymbol{\rho}(\boldsymbol{t}+\Delta\boldsymbol{t},\boldsymbol{i}) = \boldsymbol{\rho}(\boldsymbol{t},\boldsymbol{j}) + \frac{\Delta\boldsymbol{t}}{\Delta\boldsymbol{x}}\left[\boldsymbol{Q}(\boldsymbol{t},\boldsymbol{i}-1) - \boldsymbol{Q}(\boldsymbol{t},\boldsymbol{i})\right] \tag{7}$$

$Q(t, i)$ is the traffic flow exiting each cell i during [t, $t + \Delta t$] given by (Godunov 1959):

$$Q(t,i) = \min\{F_d[\rho(t,i)],\ F_s[\rho(t,i+1)]\} \tag{8}$$

F_d represents the local demand function of the road cell i, while F_s stands for the local supply function of the road cell i + 1 at time t. These two functions are given by the following equations:

$$F_d[\rho\ (t,i)] = \begin{cases} \rho(t,i).V_{\max}\left(1-\frac{\rho(t,i)}{\rho_{\max}}\right) & \text{if } \rho(t,i) < \rho_c \\ Q_{\max} & \text{if } \rho(t,i) \geq \rho_c \end{cases} \tag{9}$$

$$F_s[\rho\ (t,\ i+1)] = \begin{cases} Q_{\max} & \text{if } \rho(t,\ i+1) < \rho_c \\ \rho(t,i+1).V_{\max}\left(1-\frac{\rho(t,i+1)}{\rho_{\max}}\right) & \text{if } \rho(t,\ i+1) \geq \rho_c \end{cases} \tag{10}$$

$Q_{\max}$ = 2475 veh/h is the road capacity and ρ_c = 82.5 veh/h is the critical density.

The area is divided into a grid of uniform cells, with a total of 2000 cells to calculate the total road noise level. These cells have consistent dimensions of Δx = 50 m and Δy = 10 m. Each cell's center is treated as a point receptor, $P(i, j)$.

The iterative numerical method follows these eight steps:

- Initializing variables;
- Solving the traffic model and determination of ρ and Q (Eqs. 7 and 8);
- Computing the point source's sound power level $L_{A,\mathrm{wi}}$ (Eq. 3);
- Computing all attenuations A_{div}, A_{atm}, $A_{\mathrm{sol},F}$ and $A_{\mathrm{sol},H}$;
- Computing the noise levels $L_{i,F}$ and $L_{i,H}$ (Eq. 2);
- Computing the long-term road noise level $L_{i,\mathrm{LT}}$ (Eq. 4);
- Computing the road noise level $L_{\mathrm{eq,LT}}$ (Eq. 5);
- Computing the total road noise level $L_{\mathrm{Aeq,LT}}$ (Eq. 6).

3 Results and Discussion

In this section, we will expose and analyze the simulation outcomes related to noise propagation caused by road traffic.

Figure 1 shows the noise maps and the histograms of cell occupancy rates for different simulation times and for two cases: without noise barrier and with noise barrier. Cell occupancy rate is defined as the ratio of current density, to the jam density for a given road cell i:

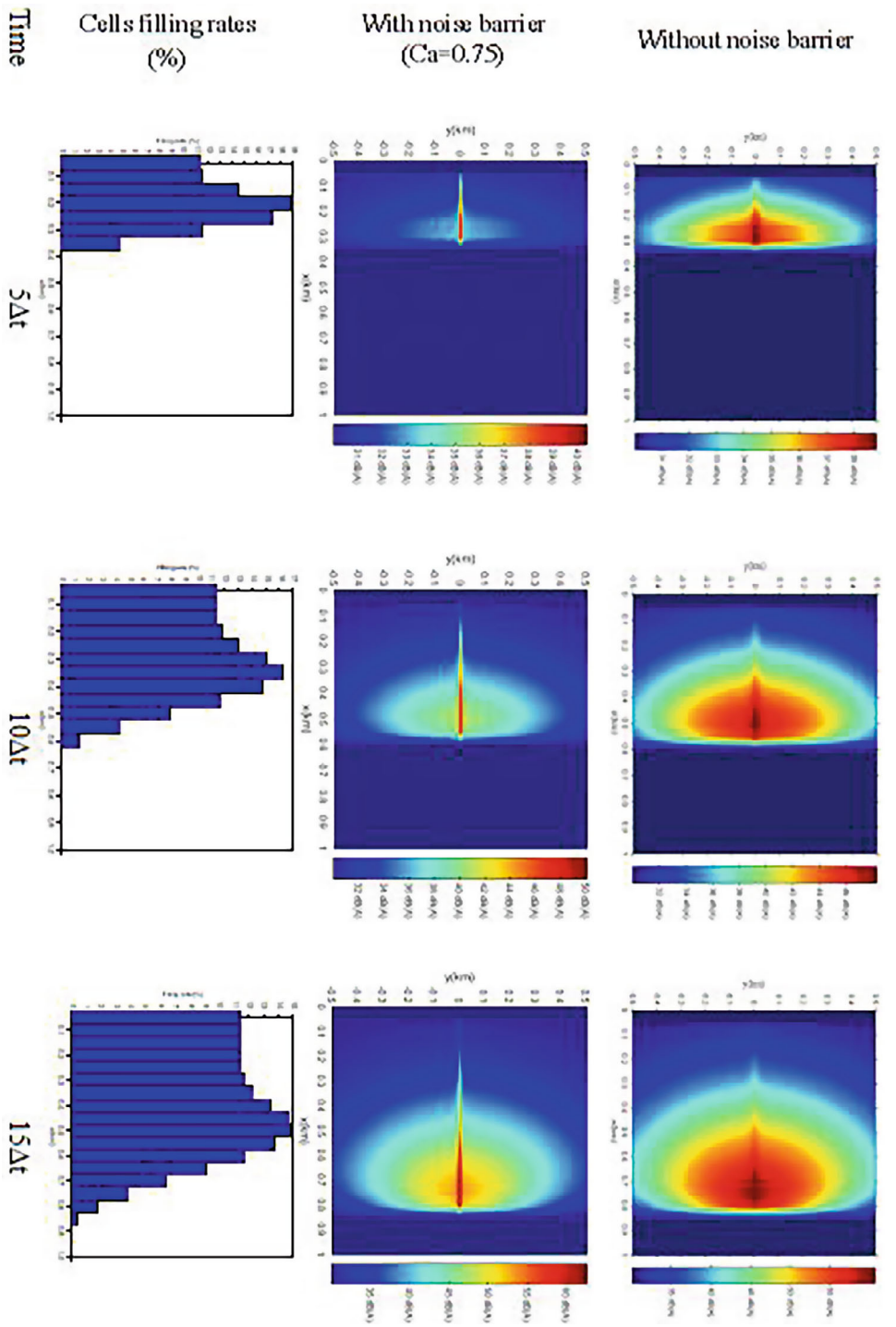


Fig. 1 Noise maps and histograms of cell occupancy rates for different simulation times and for two cases: without and with noise barrier

$$\tau(t,i) = 100\,\frac{\rho(t,i)}{\rho_{\max}}(\%) \tag{11}$$

For the two cases, the sound level distribution is symmetrical with respect to the road axis and the values are proportional to the cell occupancy rates. Moreover, the sound level values are lower in the case of noise barrier. Therefore, the area reached by sound levels that exceed the standard threshold (55 dB (*A*)) is also smaller.

Table 1 shows the acoustic level gaps along the transverse coordinate (y), at $x = L/2$ and for different values of the absorption coefficient (Ca). The acoustic level gap is calculated as follows:

Table 1 Acoustic level gaps along the transverse coordinate (y) at $x = L/2$ and for different values of the absorption coefficient (Ca) of the noise barrier

	Absorption coefficient of noise barrier (Ca)						
y(m)	0.15	0.25	0.45	0.55	0.65	0.75	0.85
10	0,160	1211	3809	5486	7579	10,365	14,547
20	1440	2504	5135	6830	8944	11,752	15,947
30	1470	2540	5184	6887	9009	11,828	16,034
40	1497	2570	5221	6929	9056	11,881	16,093
50	1523	2598	5255	6966	9097	11,926	16,142
60	1548	2625	5287	7001	9136	11,968	16,187
70	1573	2652	5319	7035	9173	12,009	16,231
80	1597	2679	5350	7070	9211	12,050	16,275
90	1622	2706	5382	7104	9249	12,091	16,319
100	1647	2733	5414	7139	9287	12,133	16,364

$$\Delta_L(\%) = \frac{L_{\mathrm{Aeq,LT}}(\text{Without barrier}) - L_{\mathrm{Aeq,LT}}(\text{With barrier})}{L_{\mathrm{Aeq,LT}}(\text{Without barrier})} \times 100 \tag{12}$$

As shown, the acoustic level gap is proportional to the absorption coefficient of the noise barrier and it is more important when moving away from the road axis. It can exceed 16% at 30 m from the road axis in the case of a noise barrier with an absorption coefficient of 0.85.

4 Conclusions

In this study, we explored the noise disturbance originating from road traffic. The outcomes derived from solving the first order traffic model were combined with the French standard NMPB-Roads-2008 model to compute the noise levels around a road segment. The primary findings suggest that the installation of noise barriers has the potential to reduce the adverse effects of road traffic noise discomfort. Furthermore, the reduction in the road noise level is strongly linked to the noise barrier's absorption coefficient.

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Exploring the Significant Causes of Disputes in Green Construction Projects in Palestine

Fadi Fatayer, Mohammed Abunemeh, and Amjad Issa

Abstract

Green construction projects in Palestine frequently encounter disputes among the contractual parties, including owners, designers, and contractors. This study seeks to identify and assess the causes of such disputes. Approximately 33 dispute triggers specific to green construction projects were identified through a combination of literature analysis and expert interviews. Subsequently, a meticulously designed questionnaire was distributed randomly to 50 industry professionals. A five-point Likert scale was employed to rank the significance of each identified cause. The results of the study highlighted several significant causes of disputes, including issues with the management of green construction activities, a lack of awareness within project teams about the unique aspects of green construction projects, and the common occurrence of incomplete bid documents tailored to green construction. These disputes often arise from the unfamiliarity of project teams with the specific requirements of green construction projects. Consequently, unqualified designers and project managers are often assigned to oversee these projects, exacerbating the potential for conflicts. The findings from this study can serve as a valuable guide to improve collaboration and coordination among contractual parties in future green construction projects, aiming to reduce adversarial relationships. Furthermore, these insights are expected to enhance the awareness and familiarity of contractual parties with the distinctive demands of green construction projects.

Keywords

Construction disputes · Green construction · Sustainability · Contract requirements

1 Introduction

Palestine suffers from various forms of environmental pollution. Accordingly, Palestine Higher Green Building Council was established in 2010 to increase awareness about green construction and improve the efficiency of infrastructure to meet future needs (Nguyen et al. 2017). stated that the incorporation of green technologies in construction improves a healthy built environment and maximizes the efficiency of resource utilization (Chakravarthy et al. 2022). confirmed that green construction has attained considerable growth globally. However, it is still in its infancy in Palestine.

(Enshassi et al. 2009) assured that the highlight merit of most construction projects in Palestine is the frequent occurrence of disputes among project teams, and green construction is not an exception. Disputes are unfavorable and problematic occurrences in construction projects, and lead to an adversarial relationship between contractual parties, if not handled and solved amicably (Elghandour 2006). According to (Enshassi et al. 2009), completing a construction project without any disputes is a crucial factor to success. Disputes and their causes in green construction projects have to be well addressed to enhance the adoption of sustainable principles in future projects. Therefore, this research aims to explore the significant causes of disputes in green construction projects in Palestine.

F. Fatayer · M. Abunemeh · A. Issa (✉)
Civil & Architectural Engineering Department, An-Najah National University, Nablus, Palestine
e-mail: amjadissa@najah.edu

A. Issa
Construction and Transportation Unit, Scientific Research Centers, An-Najah National University, Nablus, Palestine

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2 Methods

The research methodology includes four key steps: (1) Initially, a literature review and semi-structured interviews with experts were conducted to identify causes of disputes in green construction projects. (2) Subsequently, a comprehensive questionnaire survey was designed to assess the significance of these causes using a five-point Likert scale. (3) The collected survey data underwent rigorous analysis using the Statistical Package for the Social Sciences (SPSS) platform to derive results. (4) To delve deeper into the top three recurring causes of disputes in green construction projects, interviews with three professionals were conducted, providing valuable explanations for the prevalence of these issues. The significance index (SI) of each cause is calculated using Eq. (1):

$$\mathrm{SI} = \frac{1^{*}X_1 + 2^{*}X_2 + 3^{*}X_3 + 4^{*}X_4 + 5X_5{}^{*}}{5^{*}N}\,100\% \qquad (1)$$

where X_1 is no. of respondents for "not significant"; X_2 is no. of respondents for "somewhat significant"; X_3 is no. of respondents for "significant"; X_4 is no. of respondents for "very significant"; X_5 is no. of respondents for "extremely significant"; and N is the total no. of respondents.

3 Results

3.1 Respondents' Characteristics

About 85% of respondents have more than 5 years of experience in green construction projects. This will offer more reliability to the gathered data and results.

3.2 Impact of Disputes on Green Construction Projects

All respondents confirmed that disputes obstruct achieving project objectives. Figure 1 shows the negative impacts of disputes on green construction projects involving time and cost overruns, poor project performance, and reduced labor productivity.

Table 1 The main significant causes of disputes in green construction projects

Rank	Causes of disputes in green construction	Mean	SI
1	Issues with the management of green construction activities	4.27	85.4
2	Lack of awareness within project teams about the unique aspects of green construction projects	4.12	82.4
3	Incomplete bid documents tailored to green construction	4.09	81.8

3.3 The Main Significant Causes of Disputes in Green Construction Projects

Table 1 presents the mean and SI of the most significant causes that frequently occur in green construction projects, and the common occurrence of.

4 Discussion

Once the significant causes have been determined, interviews with three professional experts have been conducted to explain why these causes frequently occur.

4.1 Poor Management Process

The results revealed that the issues with the management of green construction activities are the most significant cause of disputes in Palestine. This is compatible with (Lokman et al. 2017) who stated that assigning an incompetent project manager by contractual parties is a reason for green construction project failure. Unfortunately, most construction companies in Palestine assign project managers with low experience in green construction projects. Accordingly, disputes will emerge between contractual parties.

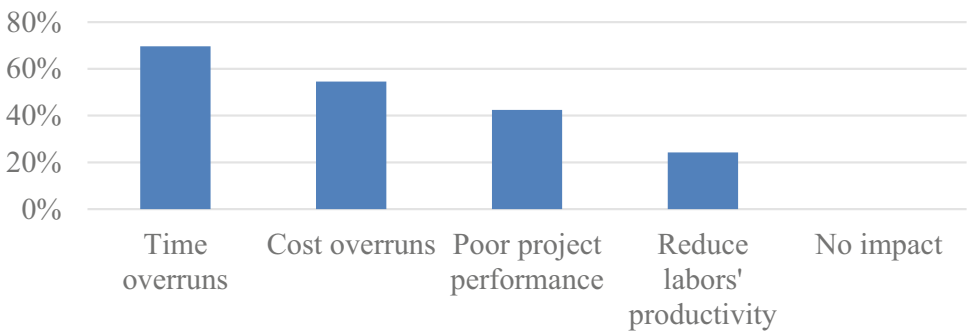


Fig. 1 Impact of disputes on green construction projects

4.2 Lack of Awareness of Project Team with Green Construction

Green construction in Palestine is still in its infancy. Therefore, the majority of project team members do not have adequate knowledge, experience, and technical skills regarding green technologies, methods, and procedures to handle this kind of project. This coincides with (Zhang et al. 2011; Hwang and Ng 2013) who confirmed that the lack of awareness in green construction is an obstacle to the development of project team members.

4.3 Developing an Incomplete Set of Bid Documents

(Hwang et al. 2015) indicated that adequate time and cost should be given to the design team in order to develop a comprehensive set of bid documents that integrate green concepts into the project. Unfortunately, this is not the case in Palestine, due to the unique challenges of these projects and the difficult evaluation of different alternative materials and systems.

5 Conclusions

This paper aims to explore the causes of disputes in green construction projects in Palestine. The results revealed that the disputes in green construction projects have a significant negative impact on the time followed by the cost and quality of the project. Furthermore, the results displayed that the crucial causes of disputes in green construction projects are issues with the management of green construction activities, a lack of awareness within project teams about the unique aspects of green construction projects, and the common occurrence of incomplete bid documents tailored to green construction.

Some recommendations have been suggested to minimize disputes in green construction projects: (1) holding job training, workshops, and short courses about green materials, green design, and green technologies to increase awareness of all construction stakeholders about sustainable green construction; and (2) introducing special courses in green design and standards in academic engineering programs in universities to support the long-term development of sustainability knowledge.

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The Effect of Profitability, Companies' Growth, and Debt Policy Toward Dividend Policy with Free Cash Flow as a Moderating Variable

Arni Surwanti and Eka Bagus Hutama

Abstract

This study looks at how profitability, debt management, and company growth affect dividend policy, with free cash flow acting as a moderating factor. In this study, data from manufacturing companies that were listed between 2015 and 2018 on the Indonesian Capital Market were used. The sample used in this research is non-probabilistic judgement sampling. In this study, moderated regression analysis (MRA) was the analysis technique. This research can also prove that the free cash flow as a moderating variable that strengthen the influence of profitability toward dividend policy. This research can also prove that the free cash flow as a moderating variable can strengthen the influence of profitability toward dividend policy.

Keywords

Dividend policy · Profitability · Debt policy · Company growth · Free cash flow

1 Introduction

The company's objective in financial management is to boost the companies' value. Market value can maximise the shareholders' wealth to shareholders; firms have a market value. The management of the corporation adopts a number of policies, including a dividend policy (AbÃo et al. 2017). According to the Bird in the Hand Theory and the Signaling Theory, a company's dividend policy has an impact on the firm value. Dividend provides certainty of income to the shareholders and gives the good signals of the firm's financial performance in the future.

The business management's dividend policy determines whether a profit will be distributed to shareholders as a dividend or will be kept as retained earnings. One internal source of funding that can be used to fund a company's investment is retained earnings. It was common for shareholders and management to disagree on dividend policies. In general, investors desire higher payouts. Retained earnings will rise if the corporation chooses not to distribute dividends. Because the company is less reliant on outside funding, it will enhance the equity position of the owner.

The corporations must take into account a number of variables that have an impact on the dividend policy when deciding how dividends will be distributed. Diverse elements affect dividend policy. According to earlier studies, a variety of variables, such as liquidity, profitability, indebtedness, tangible characteristics, investment prospects, market ratio, company size, business age, and ownership structure, have an impact on dividend policy (Jung and Mun 2016). The role of foreign investors also had a significant impact on this dividend policy process (Kangarluei et al. 2011; Wijaya and Felix 2017).

Dividend payout is positively influenced by variables like profitability, firm size, investment ratio, asset structure, corporate tax rate, and interest rate, while dividend payout is negatively impacted by leverage and unaffected by operating risk (Lestari et al. 2019). Profitability, cash flow, sales growth, and market-to-book value are the important factors that affected the dividend payout in Ghana (Amidu and Abor 2006). With free cash flow acting as a moderating variable, this study examines the effects of profitability, debt policy, and company growth on dividend policy in manufacturing firms listed on the Indonesian Capital Market.

A. Surwanti (✉) · E. B. Hutama
Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia
e-mail: arni_surwanti@umy.ac.id

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2 Methods

Manufacturing businesses listed on the Indonesian Capital Market between 2015 and 2018 make up the study's population. By establishing specific criteria, the sample approach was carried out using the purposive sampling method. The sample for this study was chosen based on the following criteria: company manufacturers that distribute dividends between 2015 and 2018. Throughout the observation time, the business is profitable. The secondary data used in this study was gathered from www.idx.co.id. The data were analyzed using moderating regression analysis (MRA). To ascertain how the independent and moderating variables affect the dependent variable, moderating regression analysis (MRA) is performed.

The formula used to analyze the data and prove the hypothesis:

$$\mathrm{DPR} = \alpha + \beta 1\mathrm{ROA} + \beta 2\mathrm{FCF} + \beta 3\mathrm{growth} + \beta 4\mathrm{DER} + \varepsilon \quad (1)$$

$$\mathrm{DPR} = \alpha + \beta 1\mathrm{ROA} + \beta 2\mathrm{FCF} + \beta 3\mathrm{growth} + \beta 4\mathrm{DER} + \beta 5\mathrm{ROA} * \mathrm{FCF} + \varepsilon \quad (2)$$

The dividend payout ratio/DPR is used in this study to measure the dividend policy. Dividend per share divided by profit per share represents DPR. The ability of the business to generate a profit is known as profitability (ROA). ROA is measured as net profit/total asset. The tendency of a corporation to grow in size is known as corporate growth. Growth is determined as follows: $[(\mathrm{TA}_t - \mathrm{TA}_{t-1})/\mathrm{TA}_{t-1}]$. TA is total asset. Company practice for getting funds is the debt-to-equity ratio. Free cash flow (FCF) is the amount of money that is available for dividend payments without harming the company's ability to continue operating and generating cash flow in the future (Brigham 2018). Free cash flow is calculated using the NOPAT—Net Investment in Operating Capital formula (Koh et al. 2014).

3 Results

3.1 Descriptive Statistics

According to a descriptive statistical test, dividend payments in manufacturing enterprises have a minimum value of 0.001, a maximum value of 2.639, and an average value of 0.44763. Manufacturing companies' profitability ranges from 0.002 to 0.527, with an average of 0.10418. The ratio of debt to equity is referred as leverage. The values for the manufacturing company are between 0.091 and 2.967, with an average value of 0.73363. With an average value of 0.128177, manufacturing company growth runs from a minimum of −0.1708 to a maximum of 1.9659 (Table 1).

3.2 The Determinant of Dividend Policy

Based on Models 1 and 2, data analysis show :

Profitability has positive significant impact on dividend policy, growth has negative significant effect on dividend policy, but debt policy did not give significant impact to the

Table 1 Descriptive statistics

Variable	Minimum	Maximum	Mean	Std. Dev
ROA	0.002	0.527	0.10418	0.093383
DER	0.091	2.967	0.73363	0.574358
GROWTH	−0.1708	1.9659	0.128177	0.2111085
FCF	−1.311	1.203	0.16832	0.271158
ROAFCF	−0.02	0.57	0.0357	0.08448
DPR	0.001	2.639	0.44763	0.384233

Table 2 Data analysis determinant of dividend policy

Variable	Coefficients	*t*-Statistic	Sig	Explanation
Constants	*0.361*			
ROA	1.281	3.362	0.001	Positive significant
DER	0.070	1.423	0.157	Not significant
GROWTH	−0.489	−3.480	0.001	Negative significant
ROA * FCF	3.050	2.478	0.014	Positive significant
R^2	0.113			Model 1
Adj. R^2	0.092			Model 1
R^2	0.144			Model 2
Adj. R^2	0.119			Model 2

dividend policy. Based on Table 2, free cash flow, a moderating variable ROA which is proxied by ROA*FCF, has a significance value of 0.014 < 0.05 with a positive regression coefficient value of 3.050. So that free cash flow is proven to be able to moderate the positive and significant effect of profitability on dividend policy.

4 Discussion

Profitability's Impact on Dividend Policy Decisions.

Profitability, it turns out, has a favorable and significant influence on the dividend policy. A company's capacity to pay dividends tends to rise with high levels of profitability. The findings of this study support The Bird in the Hand Theory, according to which investors preferred dividend payments than uncertain income sources like capital gains. The results of this study are in line with earlier research, which discovered that profitability greatly influences dividend policy (Azhagaiah and Priya 2008; Koh et al. 2014; Hudiwijono 2018; Ahmed 2015; Krishnamoorthi 2016; Ahmad and Wardani 2014).

Effect of Debt Policy on Dividend Policy.

Debt policy has an insignificant effect in a positive direction on dividend policy. This can happen because there is possibility that the companies can add external financing for investment purposes, so the internal funding can still be used to pay dividends. However, there is another possibility that the company will still use internal financing for investment purposes, so it will reduce the dividend payment. This research is not in accordance with previous research (Amahalu et al. 2016; Farahani and Jhafari 2013).

The Impact of Company's Growth on Dividend Policy.

The results show that firm growth give negative and significant impact on dividend policy. Therefore, it can be claimed that the dividend policy rate will be lower if there is stronger of the company's growth. The growing companies will likely remain the profits to finance the investments, therefore this companies are more likely to pay smaller dividends.

This is consistent with the residual theory, according to which the corporation will pay dividends following the financing of its investment. This study confirms the findings of other studies (Bararoh 2015), which indicate that company growth has a negative and significant impact on dividend policy.

Profitability's Impact on Dividend Policy with Free Cash Flow as a Moderating Variable.

Based on data analysis evaluating how profitability that is moderated by free cash flow affects dividend policy, the findings show that profitability that is moderated by free cash flow has a significant positive influence on dividend policy. Therefore, one might say that free cash flow can make the connection between profitability and dividend policy stronger.

A company with a high free cash flow can be considered to be healthier since it has cash on hand to fund expansion, debt repayment, and dividend payments. As a firm that has both high profitability and free cash flow is better able to pay dividends than a company that merely has high profitability without any free cash flow.

The potential amount of dividends that the company will pay out increases with profitability and free cash flow. The agency theory believes that managers and investors have different priorities, which can lead to conflict between them. In order to lessen this conflict, managers (agents) of companies with excess cash flow will distribute it to their investors in the form of dividends, rather than investing their money in unreliable and counterproductive ventures for shareholders. This is consistent with earlier research findings (Azhagaiah and Priya 2008; Hosein et al. 2014; Hudiwijono 2018; Ahmed 2015; Kangarluei et al. 2011; Krishnamoorthi 2016; Ahmad and Wardani 2014) that profitability, which is moderated by free cash flow, has a positive and significant effect on dividend policy.

5 Conclusions

This study examines how profitability, debt management, and company's growth affect dividend policy in manufacturing firms, with free cash flow acting as a moderating factor. The findings of this study lend support to the agency theory, residual theory, and the Bird in the Hand Theory. This information can be used by businesses as a basis for deciding on their dividend policy and by investors to determine their investment strategy.

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Energy Sustainability Using Dual Skin Façades and Radiant Cold Surfaces Systems

Eusébio Conceição, João Gomes, Mª Inês Conceição, Mª Manuela Lúcio, André Ramos, and Hazim Awbi

Abstract

This numerical work evaluates the application of dual skin façades (DSF) and radiant cold surfaces (RCS) used to improve indoor thermal comfort (ITC) conditions in a virtual chamber, during the summer environment in a Mediterranean climate. This virtual chamber is equipped with three DSFs located in front of three windows facing south and two RCS, one placed on the floor and the other placed on the ceiling. These RCS are made up of cold water pipes used to cool the interior space. DSFs are used to extract warm air from the interior space. A building dynamic response (BDR) research software developed by the authors was used to estimate the air temperature (Tair) and the mass of contaminants in the virtual chamber, as well as the Tair in the different elements of the virtual chamber, DSF and RCS. The BDR numerical model is built with a system of equations of balance of energy and equations of balance of mass. Among the output data, the evolution of the Tair, the index of the predicted mean vote (PMV) and the concentration of carbon dioxide (CO_2) inside the chamber are obtained. The results show that the CO_2 concentration is acceptable and the index of the PMV is acceptable, according to international standards.

Keywords

Building dynamic response · Radiant cold surfaces · Dual skin façade · Numerical model · Indoor thermal comfort

1 Introduction

The DSF is usually made using two glass surfaces divided by a ventilated air space. In this air space can be installed shading devices or photovoltaic cells. More details about the characteristics of DSFs are presented in the work of Ghaffarianhoseini et al. (2016). The interest in RCS has been increasing due to the potential they present in obtaining energy savings and, simultaneously, guaranteeing acceptable levels of ITC. More details on RCS can be seen in the work of Hassan and Abdelaziz (2020).

The indoor air quality (IAQ) is evaluated using the CO_2 concentrations (Asif et al. 2018). In accordance with the ASHRAE Standard 62-1 (2016), an acceptable level of IAQ is obtained when the value of CO_2 concentration is below 1800 mg/m^3 (1000 ppm). The ITC can be evaluated by the index of PMV (Fanger 1970). This index was adopted by ISO 7730 (2005) to establish three ITC categories (A, B and C). In this work, the category C was considered.

This work aims to apply a new ventilation system based on the simultaneous use of DSFs and RCS installed on the floor and on the ceiling in order to improve the IAQ and ITC conditions in a compartment for the summer season.

2 Methods and Materials

In this work, the authors developed the research software. The software evaluates the thermal response of the chamber in a transient environment. It is based on equations of balance of energy, used in the temperature evaluation, and equations of balance of mass, used in the mass evaluation

E. Conceição (✉) · M. M. Lúcio · A. Ramos
Universidade Do Algarve, Faro, Portugal
e-mail: econcei@ualg.pt

J. Gomes
CINTAL, Faro, Portugal

M. I. Conceição
Instituto Superior Técnico, Lisboa, Portugal

H. Awbi
University of Reading, Reading, UK

E. Conceição
Departamento de Engenharia Mecânica, ADAI, Coimbra, Portugal

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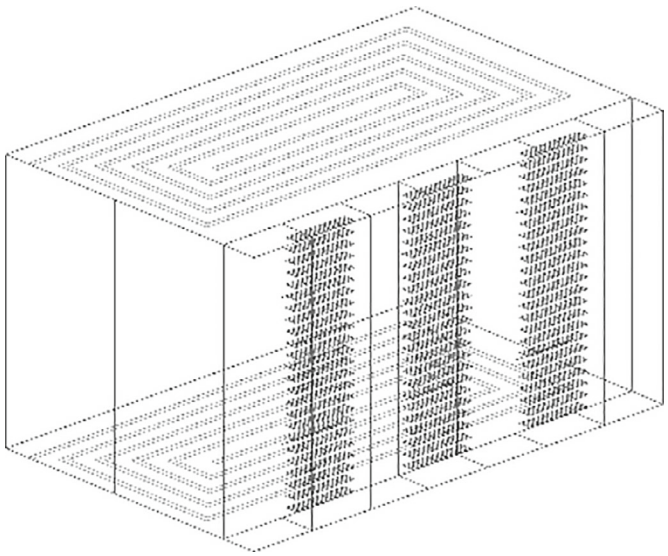


Fig. 1 Chamber equipped with three DSFs installed in the south envelope and RCS installed in the floor and in the ceiling

of water and contaminants. In Conceição et al. (2019), the software and the ITC concepts are presented and applied.

The chamber is equipped with three DSFs located in front of three windows facing south and two RCSs, one installed on the floor and the other in the ceiling (Fig. 1). These RCSs are made up of cold water pipes used to cool the interior space. DSFs are used to extract warm air from the interior space. In the air space of each DSF is installed a shading device, which is used to control the entrance into the chamber of solar radiation. The chamber is 4.5 m long, 2.55 m wide, and 2.5 m high. Eight persons occupying the chamber are considered. It has an occupancy between 8 and 12 am in the morning and between 2 and 6 pm in the afternoon. The airflow rate is 0.0778 m^3/s during occupancy and one air renovation per hour when the chamber is not occupied.

3 Results and Discussion

The results of CO_2 concentration, Tair (Fig. 2a), and the PMV index (Fig. 2b) are presented for a summer day and consider two situations: the use or non-use of the RCS.

The obtained results of the CO_2 concentration are lower than 1800 mg/m^3, so that the level of IAQ is acceptable (ANSI/ASHRAE Standard 62-1 2016).

The use of RCS allowed us to obtain a reduction of the indoor Tair of about 4.6 °C during the occupation cycle. In this case, the average indoor Tair is 31.9 °C, a value close to the average outdoor temperature, 31.0 °C. These are typical values obtained in the area where the building is located, characterized by a Mediterranean climate. As is presented in Fig. 2a, the evolution of indoor and outdoor temperatures is

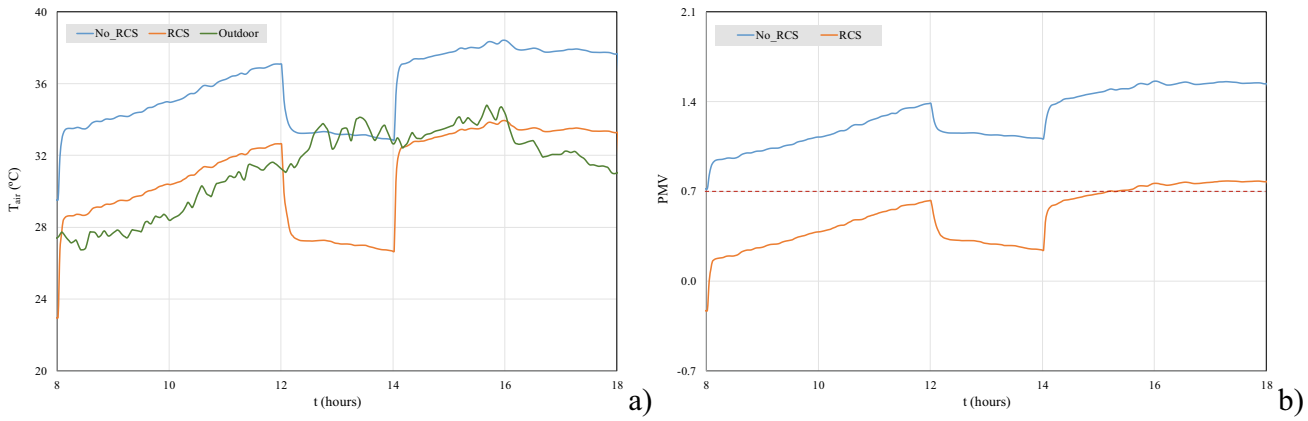


Fig. 2 Results obtained using RCS or not (No_RCS): **a** Tair; **b** index of PMV. The dashed line represents the upper limit of category C (ISO 7730 2005)

very similar during the occupation cycle, which allows for a better adaptation of the occupants to the ITC.

The index of PMV shows that the use of RCS improves the level of ITC by approximately 60%. In this way, it is possible to obtain acceptable levels of ITC with the index of PMV values within category C (ISO 7730 2005) during the entire occupancy cycle. The index of PMV values rises slightly above the limit of +0.7 [category C (ISO 7730 2005)], only during the last 2 h of occupation.

These improvements are achieved using passive technologies, with energy savings by avoiding the use of conventional ventilation systems powered by electrical energy.

4 Conclusions

It was developed a ventilation system built on the use of DSFs and RCS. This system was applied in a chamber with the purpose of improving the IAQ and ITC conditions in the summer season. It obtained an acceptable level of IAQ during all occupation cycle, with values of CO_2 concentration below 1800 mg/m^3 (ANSI/ASHRAE Standard 62-1 2016). It also obtained an acceptable level of ITC conditions with the index of PMV values within category C (ISO 7730 2005) during almost occupancy, except at the end of the afternoon when the index of PMV values was slightly above +0.7.

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Exploring the Effectiveness of Community-Based Conservation Initiatives in Promoting Biodiversity Conservation in Africa

Tlou D. Raphela

Abstract

Purpose: Biodiversity conservation and sustainable ecosystem management are crucial for ensuring the long-term health and well-being of our planet and there has been a growing recognition of the importance of involving local communities in conservation initiatives. Community-based conservation initiatives aim to empower local communities to take an active role in conserving their natural resources and ecosystems. However, the effectiveness of these initiatives in promoting biodiversity conservation and sustainable ecosystem management has not been reported in Africa. *Research Gap*: While there is growing evidence that community-based conservation initiatives can be effective in promoting biodiversity conservation and sustainable ecosystem management, there is a lack of comprehensive research on the factors that contribute to their success or failure. Specifically, there is a need for research that explores the social-ecological outcomes of community-based conservation initiatives and the factors that influence their effectiveness. *Methodology*: The study is purely qualitative and collected data through a systematic literature review approach. Relevant studies in the English language from 2000 to 2022 in the African context were identified from the University of the Free State online library. The study applied deductive and inductive content analysis of the literature identified using NVivo software. The study started with the deductive approach to address the research question and incorporated inductive elements to capture findings. *Results*: The findings indicate that community-based conservation initiatives in Africa frequently result in negative or mixed social outcomes, whereas ecological outcomes tend to be largely positive. Devolution of rights to the local community is significantly associated with community-based conservation outcomes but was not present in many cases, despite this feature being a hallmark of effective Community-Based Conservation. *Conclusion*: The study indicated that community-based conservation initiatives could be effective in promoting biodiversity conservation and sustainable ecosystem management in Africa. However, the rigorousness of the implementation is a major issue hindering their success.

Keywords

Conservation · Environment · Ecosystem · Biodiversity · Communities

1 Introduction

Community-based conservation initiatives (CBCI) have been reported by a lot of studies to include a series of resource management issues, while on the positive side, CBCIs are recorded to have multiple incentives for managing these natural resources (Berkes 2007; Plummer and Armitage 2007; Suich 2010; Morton et al. 2022). However, the effectiveness of CBCI has not been extensively explored especially in Africa where biodiversity conservation is an issue of contention. Several African studies explored community-based conservation and termed it a human development enhancer for communities living directly with nature (Galvin et al. 2018), but literature on the effectiveness of the CBCIs that promote biodiversity conservation is scanty, especially in Africa. In this climate change era, biodiversity reduction is a global concern, partly because of reported natural resource misuse by communities abutting protected areas (Mbaiwa and Kolawole 2013). The Sustainable Development Goal, SDG15 calls for sustainable

T. D. Raphela (✉)
University of the Free State, Disaster Management Training and Education Centre for Africa, Bloemfontein, South Africa
e-mail: RaphelaTD@ufs.ac.za

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management of forests, combat desertification, halting and reversing land degradation, and halting biodiversity loss. Indeed, biodiversity conservation and sustainable ecosystem management are crucial for ensuring the long-term health and well-being of our planet (Mbaiwa and Kolawole 2013). In support of SDG 15, there have been programs to manage natural resources by communities for the sustainable use of these resources (Musavengane, and Simatele 2016). However, literature is more focused on the role of these communities in conserving nature, and studies focusing on the effectiveness of CBCIs are scanty.

This review therefore seeks to explore community-based approaches to promote biodiversity conservation and sustainable ecosystem management in Africa. In addition, the study seeks to identify conditions under which CBCI is likely to be effective and sustainable compared with alternative approaches for conserving biodiversity.

2 Materials and Methods

Data for this study was collected through a literature review conducted between May 2023 and August 2023. A systematic review of the effectiveness of community-based conservation initiatives (CBCI) across Africa was explored to gather data about CBCIs across Africa. The analysis of the scholarly papers reviewed for this study facilitated the comprehension of how factors such as political systems and community participation in coming up with conservation initiatives influence or impact the effectiveness of CBCI in Africa between 2000 and 2022. The focus of this review is on (1) the positive and negative outcomes that are reported in the literature about community-based conservation initiatives, (2) the hindrances of the success of the community-based conservation initiatives as reported in the literature reviewed, and (3) the association of the effectiveness of community-based conservation initiatives with positive or negative socio-ecological outcome. Articles that focused on African community-based conservation were identified and analyzed using NVivo software. The study adopted a content analysis approach and started with the deductive approach to address the research questions and incorporated inductive elements to explore themes beyond the initial research questions.

2.1 Search and Coding Method

This systematic review applied an online database search from the University of the Free State (UFS) online library to select relevant literature. The online library of the UFS draws from several databases including Scopus, Web of Science PubMed, JSTOR, DOAJ, and Science Direct. The study used four criteria to select articles as follows: (1) the study's relevance to community-based conservation in Africa, meaning for inclusion a study must have assessed community-based initiatives in the conservation context; (2) the considered geographical scope included Africa; (3) the language of publication must be English, meaning other studies that were geographically included but were from the Francophone and Lusophone areas published in French and Portuguese, respectively, were excluded from this study; (4) the study's publication date; the search was conducted between May and August 2023, and articles were limited to those published between 2000 and 2022. The year 2000 was selected because the study aimed to capture recent developments in the contribution of conservation initiatives in Africa. (5) only journal peer-reviewed articles were considered, meaning non-peer-reviewed articles were excluded from the study.

2.2 Data Collection Methods

The process of literature selection process for this study is outlined in Fig. 1. The process began by combining the keywords "Community-based conservation," "Conservation initiatives," and "Africa." The results were further refined by limiting the search to the above five inclusion criteria. The study further carefully assessed all article titles and abstracts after identifying the keywords from the listed articles provided by the UFS online library. The article's relevance was established by an entire article examination.

3 Results

The final 16 studies which were reviewed fulfilled the inclusion criteria, The UFS online library data search with specific keywords produced 232 titles including duplicates. The search was then filtered by peer-reviewed, period, and the African geography location (Fig. 1). The study then screened the 235 titles by looking up keywords and abstracts, but the excluded duplicates and the remaining studies were 36 articles. 20 articles were excluded after the full articles were assessed as they lacked rigor in the methodology and some did not provide understandable findings; this narrowed the study to 16 systematically reviewed articles published between 2007 and 2022 (Fig. 2).

3.1 Cases Identified

The review pulled together the identified cases into three African communities, the cases from the Southern African Development Community (SADC), whereby cases from five

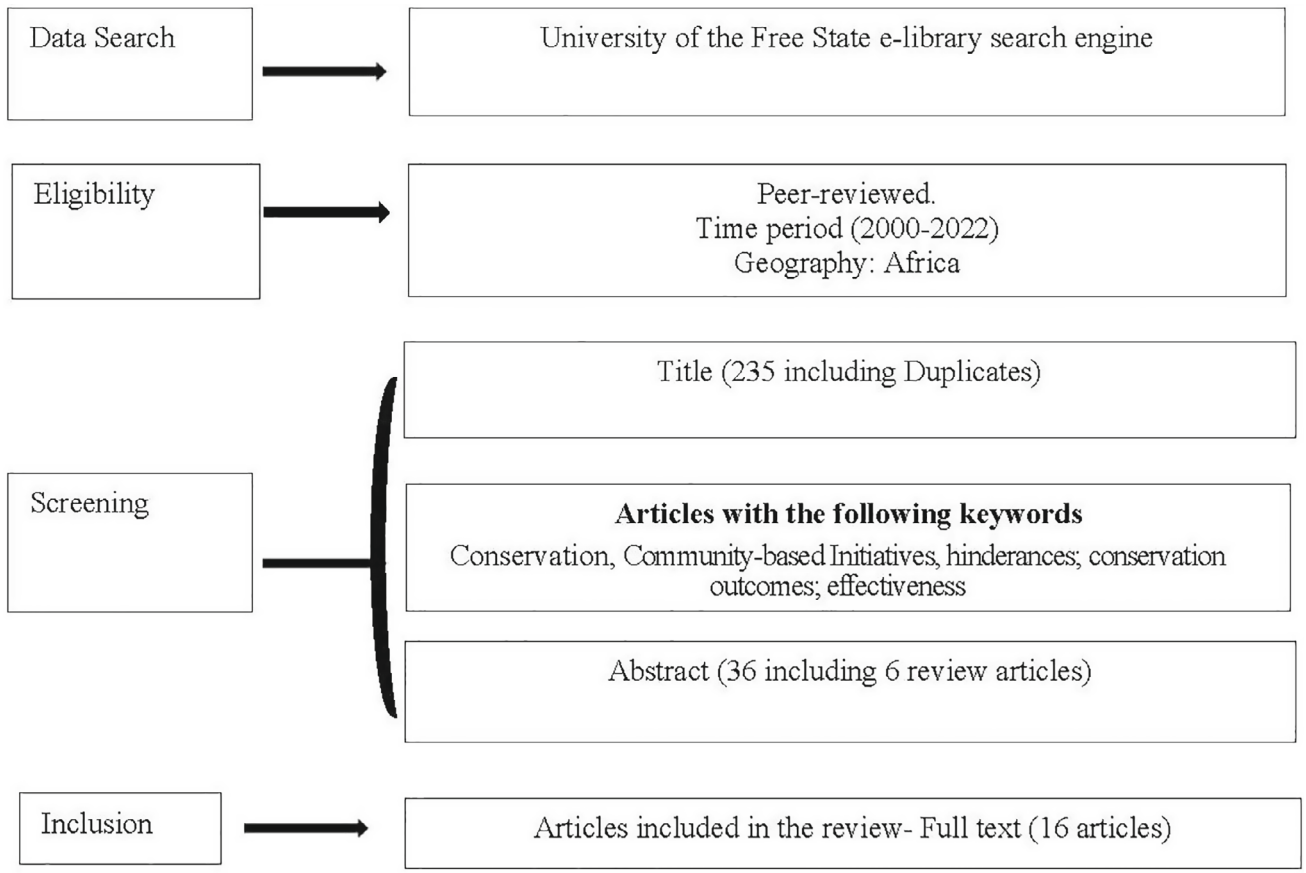


Fig. 1 The methodological flowchart and the research design adopted by this study

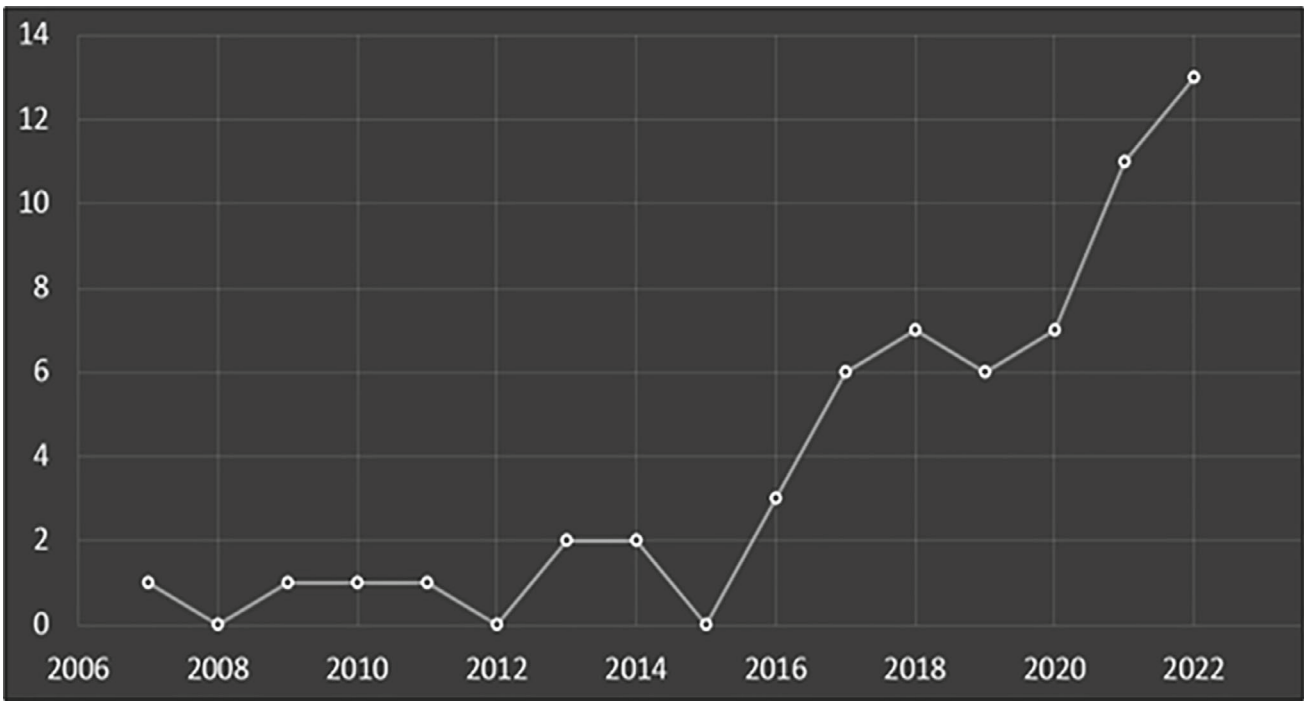


Fig. 2 Years of publications and the number of articles

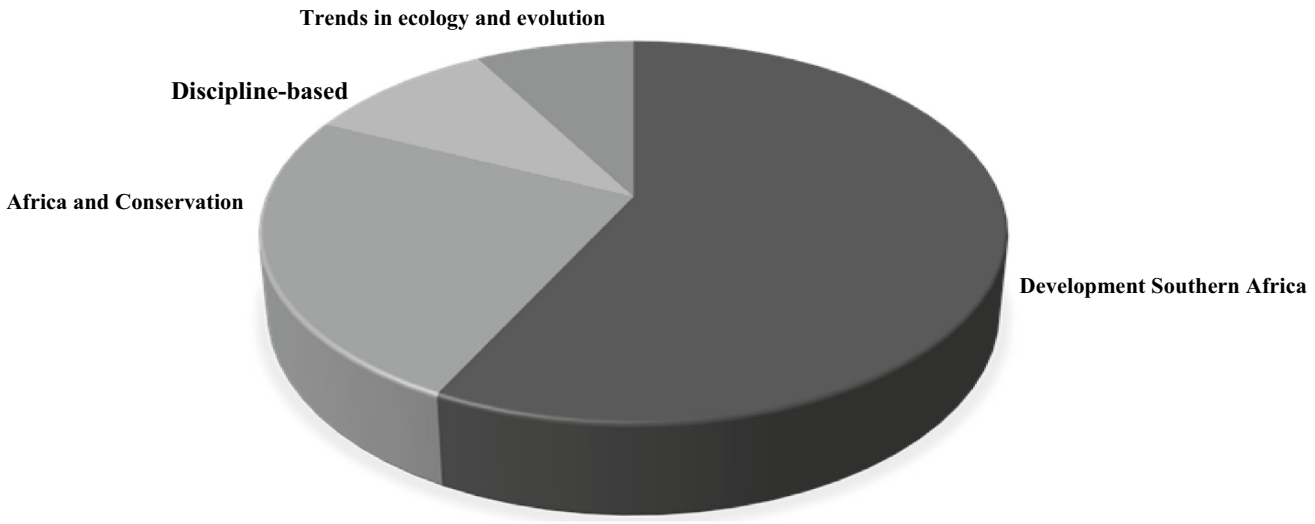


Fig. 3 Journal's discipline

of the 16-member states (Botswana, Namibia, South Africa, Zambia, Zimbabwe) were analysed. The Eastern African Community (EAC) cases whereby three of the seven partner states (the Democratic Republic of Congo; the Republic of Kenya; and the United Republic of Tanzania) were pulled. From the 15 countries forming the Economic Community of West African States (ECOWAS), only one case from Ghana was identified and analysed with the other African communities.

The studies are widely scattered across the continent, with South Africa leading with four articles, followed by Zambia (3). Botswana and Kenya contributed two articles each, while Zimbabwe, Namibia, the United Republic of Tanzania, and the Democratic Republic of the Congo each had one article (Fig. 3).

3.2 Key Findings

The study aimed to systematically analyse peer-reviewed articles on community-based conservation initiatives in Africa. The focus was put on English-speaking African countries where the studies were conducted. The research methodology was applied to collect data and analyse publication trends within the study period (2000–2022) in order to understand developments in conservation initiatives during the new millennium. The review showed mixed results on the question of whether community-based conservation initiatives were effective in Africa. That is, some initiatives were still a success, some were not followed through; and socio-ecological benefits, including funds generated for biodiversity-related community projects. For example, three SADC countries have been implementing community-based conservation initiatives successfully for almost two decades (Mbaiwa and Kolawole 2013). Understanding the entanglements between people, biodiversity conservation, and community-based conservation initiatives was not clear in most papers. Again, several papers did not show research rigor and contribution to knowledge.

4 Discussion

This study found a mixed relationship between people, biodiversity, and conservation. In the three SADC countries, communities have positive attitudes toward biodiversity (Kiss 2004; Meffe et al. 2012; Galvin et al. 2018). These three countries were reported to be more inclined to use natural resources sustainably to promote biodiversity conservation (Mbaiwa and Kolawole 2013).

In the East African Community (EAC), the parks for Kenyans and parks beyond parks initiatives encouraged local conservation initiatives outside parks and promoted ecotourism (Western et al. 2015). The underlying principle of these initiatives lies in lowering the cost of conflict by raising the direct benefits communities could gain from wildlife, and by devolving the rights and responsibilities for conservation action to the lowest effective and accountable levels (Western et al. 2015).

In West Africa, the Sanctuary initiative in Ghana created opportunities for livelihood diversification and generated an additional income stream, as community members collected and sold shea nuts, thereby contributing to the effectiveness of community-based conservation initiatives (Silva and Mosimane 2014). The mixed results reported by this study when it comes to the viability of the CBCIs could imply that there is a potential for the success of CBCIs to promote biodiversity conservation in Africa.

Studies that showed positive conversation outcomes leaned toward living and non-living factors and ecological systems and processes. Wildlife took precedence in what was measured across the study, whereby Sheppard et al. (2010) reported how the Wechiau Hippo Sanctuary developed and resulted in the stabilization of the hippo population. In Namibia, an increase in wildlife population was recorded in the established Torra Conservancy, which also came with a reduction in commercial poaching (Scanlon and Kull 2009).

5 Conclusions

The study finally concludes that community-based conservation initiatives could be effective in promoting biodiversity conservation and sustainable ecosystem management in Africa. However, the rigorousness of the implementation is a major issue hindering their success.

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Snakebite Management in Koulikoro, Mali: Insights from a Household Survey

Sanou Khô Coulibaly, Fatine Hadrya, Faiçal El Hattimy, Boubacar Maïga, Siaka Dembelé, Tidiane Diallo, Abdelmajid Soulaymani, and Hinde Hami

Abstract

Snakebites are not solely caused by nature, as per certain African beliefs. This study aims to evaluate the treatment of snakebites in the Koulikoro region of Mali for a comprehensive understanding of the victims' therapeutic journey. A cross-sectional survey was conducted to investigate households during April 1–June 30, 2022. Questionnaires were distributed to individuals who witnessed, provided assistance for, or were victims of snakebites in the rural municipalities of the Kati and Kangaba prefectures. The survey revealed 211 cases of snakebites, with men accounting for 72% of the cases and a mean age of 34 ± 16 years. Most victims were farmers (46%) or herders (18%). People aged 15 years and older were the most affected, accounting for 93% of the cases. Snakebites mainly occurred during the rainy season, representing 57% of the cases. The lower limbs were the most frequently bitten sites, accounting for 68% of the cases. Before seeking hospital care, 75% of the victims had consulted traditional healers. The primary traditional remedies used consisted of black stones (31%), a mixture of shea butter and snake slough (26%), and tree leaves (14%). The period of conventional treatment spanned from 7 to 21 days, with positive results detected in 38% of cases. Among patients who solely sought contemporary medicine, recovery took less than 14 days in 17% of incidents. These findings emphasize the critical importance of increasing awareness among rural populations about the hazards of snakebites and the need for immediate medical attention. By dispelling misconceptions and offering precise information on snakebite prevention, treatment, and management, it is possible to reduce complications and improve outcomes for victims. The importance of implementing information and health education initiatives for rural populations, which are influenced by traditional beliefs, is obvious. These initiatives raise awareness, dispel misconceptions, and facilitate the adoption of appropriate preventive measures and timely medical interventions.

Keywords

Snakebites · Management · Rural population · Traditional healing · Mali

S. K. Coulibaly · B. Maïga · S. Dembelé
Faculty of Medicine and Odonto-Stomatology, University of Sciences, Techniques and Technologies, Bamako, Mali
e-mail: csanoukho@gmail.com

B. Maïga
e-mail: bmaiga@icermali.org

S. Dembelé
e-mail: siakadembele@gmail.com

S. K. Coulibaly · F. Hadrya · F. El Hattimy · T. Diallo · A. Soulaymani · H. Hami (✉)
Laboratory of Biology and Health, Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco
e-mail: hinde.hami@uit.ac.ma

F. Hadrya
e-mail: fatine.hadrya@uhp.ac.ma

F. El Hattimy
e-mail: elhattimy@gmail.com

T. Diallo
e-mail: tidiallo2017@gmail.com

A. Soulaymani
e-mail: asoulaymani@gmail.com

F. Hadrya
Hassan First University of Settat, Higher Institute of Health Sciences, Laboratory of Health Sciences and Technologies, Settat, Morocco

T. Diallo
Faculty of Pharmacy, University of Sciences, Techniques and Technologies, Bamako, Mali

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1 Introduction

Snakebites present a continual challenge to public health, especially in Africa, where they cause significant harm in terms of mortality and morbidity. The human-snake interaction can be complicated, leading to unintended bites (Chippaux 2005; Chippaux and Goyffon 2006). According to the World Health Organization (WHO), approximately 5.4 million snakebites occur annually, resulting in 1.8 to 2.7 million envenomation cases. These incidents resulted in 81,410–137,880 fatalities and contributed to lasting disabilities, including amputations or blindness. It should be noted that these bites disproportionately affect women, children, and farmers from poor rural communities in low- and middle-income countries (Centre OMS des médias 2023).

A study conducted in Burkina Faso from 1981 to 2000 revealed that in 1190 documented cases of snakebites, 338 resulted in fatalities before medical intervention. Of these cases, modern medical practices successfully managed 388 cases of envenomation, whereas traditional healers treated 464 cases (Somé et al. 2002). Similarly, a comprehensive household survey conducted in Senegal involving 1120 individuals discovered 24 snakebites, one of which tragically resulted in death (Chippaux et al. 2005). In Mali, the availability of centralized data on snakebites is limited, with the knowledge gap primarily filled by isolated studies conducted in various health facilities. In some African countries, snakebite victims still use archaic and inadequate remedies such as constricting tourniquets or talismans, and such incidents are often attributed to causes beyond the natural realm according to certain African belief systems (Chippaux et al. 2005; Moutaouakkil et al. 2018).

This study evaluated the management of snakebites in the Koulikoro Region of Mali. The objective is to understand the therapeutic journey of victims and highlight the challenges and dynamics of snakebite treatment in this specific context.

2 Methods

A cross-sectional survey was conducted from April 1 to June 30, 2022, in the rural communities of the Kati and Kangaba circles, located in Mali's Koulikoro Region.

The Kati Circle, which covers an expansive area of 16,300 km^2, was home to a population of 1,352,419 individuals in 2020 and is located in the southwestern part of the Koulikoro Region. It is located approximately 15 km from the administrative capital. In contrast, the Kangaba Circle spans 5150 km^2 and is home to a population of 120,720 as of 2020. It is located in the southwestern region of Koulikoro (Mali, Recensement Général de la Population et de l'Habitat (RGPH) de 2021 2022).

The study included all individuals who had directly witnessed, provided assistance during, or personally experienced a snakebite incident in the rural communities of the Kati and Kangaba circles. Methodically designed questionnaires were administered to both heads of households and individuals possessing the most profound understanding of snakebite occurrences in the villages.

This study enabled the precise compilation of data related to snakebite incidents within this particular region of Mali, which is severely impacted by this pressing public health issue. The accumulated data were entered into Excel software version 16.0 and subsequently analyzed using SPSS version 20.0.

3 Results

Over a period of three months, 211 snakebite cases were documented in rural communities of the Kati and Kangaba circles, located in Mali's Koulikoro Region. The cases included 15 children under the age of 15 years and 196 adults aged 15 years and above, categorized based on the WHO criteria. On average, the victims were 34 years old with a standard deviation of 16. Males accounted for 72.04% of the entire cohort, resulting in a male-to-female ratio (M/F) of 2.58. The occupational groups most affected by snakebite envenomation were farmers, herders, and housewives, accounting for 46.44%, 18.01%, and 11.85% of cases, respectively.

Most incidents occurred during the rainy season, accounting for 121 cases or 57.35% of the total. Vipers and cobras were the main culprit snakes identified in 131 and 43 cases, respectively, contributing to 82.46% of cases overall. Further investigation uncovered three distinct locations where bites occurred: the lower limbs (144 cases), upper limbs (59 cases), and trunk (8 cases).

Following the incidents, over 75% of the victims sought traditional healers for treatment. These practitioners often used remedies such as black stones (54 cases), a mixture of shea butter (45 cases) and discarded skin, and various tree leaves (24 cases).

The duration of both traditional therapy and combined treatment, which includes traditional therapy followed by medical intervention, ranged from a few days up to 21 days. The duration depended on the victim's condition and the particular treatment regimen used (Table 1). It should be noted that treatment relying only on traditional therapy often lasted a significant amount of time. Among those who received conventional therapy, with or without subsequent medical treatments, 44 of the 100 cases with known outcomes demonstrated healing (Table 2).

Using solely contemporary medical methods led to treatment periods of less than 14 days, allowing for the complete recovery of all participating patients ($n = 36$). Unfortunately,

Table 2 Distribution of victims based on therapeutic outcomes

Therapeutic outcomes		Number of cases	%
Recovery cases ($N = 80$)	Medical treatment only	36	17.06
	Traditional treatment	44	20.85
Fatal cases ($N = 20$)	In-hospital	2	0.95
	Traditional setting	18	8.53
Unknown outcome		111	52.61
Total		211	100.00

two cases went unattended, and their results remain uncertain to this day.

Consequently, the overall recovery rate is 37.91%. Equally significant is the case fatality rate of 9.48%. The number of fatalities resulting from traditional therapy is alarmingly high, accounting for a staggering 90% of all documented fatalities.

4 Discussion

Based on the study findings, snakebites primarily affect males with an average age of 34, and most victims are engaged in farming and herding activities. These results are consistent with those of previous studies on snakebites and venomous snake envenomation, particularly in rural areas (Chippaux and Goyffon 2006; Somé et al. 2002; Chippaux et al. 2005). Adults aged 15 years and older experienced the highest prevalence, with a notable increase during the rainy season, which agrees with previous research (Dabo et al. 2010; Chippaux 2023). The lower extremities were the most commonly targeted body part, which is in agreement with the findings of various studies in this area (Chippaux 2005; Somé et al. 2002).

The study's data indicated that in 82% of incidents, the responsible snake's identity was determined, contrasting with the common issue of species misidentification reported in other studies (Chippaux 2005; Chippaux and Goyffon 2006; Chippaux et al. 2005). Despite this progress, challenges persisted, notably in discerning the exact species of the snake. Most of the victims and their families, who were primarily involved in farming and hunting activities and often without formal education, could only identify the broader family of the snake. In many cases, the snakes were killed and disposed of immediately, which presented a significant hurdle for accurate species identification by herpetologist. This educational gap highlights the critical need for better training in snake species identification and methods for specimen preservation following bites, which are crucial for improving the management and outcomes of envenomation cases.

Victims often initially used traditional treatments before seeking medical care in hospital settings. These traditional approaches included the use of black stones, a mixture of shea butter and discarded skin, and various tree leaves. It is important to note that snakebite victims often turn to traditional therapies for various reasons, often due to factors such as limited access to healthcare centers, as observed in other studies (Dabo et al. 2010; Chippaux 2023).

Among the cases with documented outcomes, positive results were found in 38% of the cases. It is worth mentioning that victims who solely pursued modern medical treatment experienced recovery in less than 14 days in 17% of the cases. Research conducted in similar fields has corroborated these findings, emphasizing that most snakebite cases exhibit favorable outcomes, especially when subjected to suitable medical management (Dabo et al. 2010).

In conclusion, the findings of this study align with those from a retrospective examination of patient records for snakebite consultations and envenomation cases from January 2008 to December 2009 at our study site (Coulibaly et al. 2013). This consistency across time underscores the persistent nature of snakebite incidents and the characteristic profiles of the affected populations, further validating the relevance and continuity of our research findings within this setting.

5 Conclusions

These findings emphasize the significance of implementing information and health education programs customized for the rural population to maintain deep-rooted traditional beliefs. Additionally, enhancing the logistical capacities of healthcare facilities could have a significant impact on culti-

Table 1 Distribution of victims based on treatment duration

Duration in days	Treatment			
	Traditional only (%)	Combined* (%)	Medical only (%)	None
Less than 7	6 (2.84)	60 (28.44)	26 (12.32)	
[7–14]	12 (5.69)	38 (18.01)	10 (4.74)	
[14–21]	40 (18.96)	17 (8.05)	–	
Total	58 (27.49)	115 (54.50)	36 (17.06)	2 (0.95)

Combined treatment*: Sequential application of traditional treatment followed by medical intervention

vating a sense of trust and rapport between the community and healthcare professionals.

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Does Governance Mean Territorial Justice? Study in the Protected Areas of the Marche Region (Italy)

Pamela Esther Degele

Abstract

The Italian territorial-environmental debate is currently fluctuating between the interests of environmental universalism and directives of European policies on the one hand, and the need for development, repopulation, and strong local identity of internal lands, on the other. In this sense, the oscillation of powers and priorities between the national, regional, and local governments leads to various conflicts and tensions. Internationally, governance is postulated as a useful policy to promote dialog between territorial agents and tends toward protected areas and consensual territorial projects. However, does the governance system of Protected Areas (PAs) in force in Italy enable citizen participation? To what extent does this system promote territorial justice? Is there a difference between the case of national and regional parks and reserves? In the Marche region, this debate is especially relevant as parks have been proposed in the last decade as a valuable alternative to boost the economy of internal areas, recently affected by the 2016 earthquake. This paper presents the main results of a qualitative study carried out in 2023, which compares the governance models of different PA categories in the Marche region and their contribution to territorial justice. As general results, it is mentioned that (a) regional parks and reserves show greater regulatory flexibility, which favors more open and relevant management to the territory than the national ones, the latter linked to biologist-oriented discourses and multiple conflicts; (b) regional reserves, in particular, hold a high degree of participation and a sense of environmental-territorial justice, especially linked to the recovery of environments and management agreements (e.g., Esino River Contract); (c) the smaller the number of participating communes, the greater the local government commitment to the conservation of a protected area; (d) environmental education is one of the main reasons and impacts of PAs in the territory; (e) the role of women in the leadership of conservation in the Marche is alarmingly inequitable, while there is a lack of gender awareness of this problem in management. As main conclusions, it is mentioned that the territorial perspective is of fundamental importance to understand and address just and socially relevant conservation; and that local and small protected areas, usually marginal in policies and studies, are a valuable opportunity in this direction.

Keywords

Conservation · Ecofeminism · Governance · Regional reserves · Territorial justice

1 Introduction

The Italian territorial-environmental debate currently fluctuates between the interests of environmental universalism and the guidelines of European policies, on the one hand, and the need for development, repopulation, and a strong local identity of internal lands, on the other (Calandra 2015). In this sense, the oscillation of powers and priorities between the national, regional, and local governments creates various conflicts and tensions.

Internationally and particularly at the level of European policies (e.g., CEPE Agreement), governance and citizen participation are considered useful strategies to promote dialog between territorial agents and tend toward just Protected Areas (PAs) and development projects (Farinós Dasí 2008; Borrini-Feyerabend et al. 2014). This is particularly relevant in countries like Italy, where space consists of

P. E. Degele (✉)
Santa Cruz Research and Transfer Center (CONICET-UNPA-UTN), Rio Gallegos, Argentina
e-mail: pamelaesther.degele@unimc.it

University of Macerata, Macerata, Italy

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an anthropized landscape and there are no places of "wild nature," as conceived in Americanist conservation models (Calafati 2002). In this sense, Italy has innovative legislation (Law 394/91) that stands out from others both for incorporating the perspective of territory in conservation and for proposing a governance system that involves participants and decision-makers in local authorities (Marotta 2010). However, these processes involve numerous criticisms, as will be seen later.

In the Marche region, particularly, the debate on models of governance and conservation of the environment and landscape is highly relevant, since natural areas have been proposed in the last decade (e.g., Development Rural Plan), as a valuable alternative to boost the economy of internal areas, which are affected by a trend toward depopulation, recently increased by the 2016 earthquake (Nicosia and Porto 2018). Currently, in addition, the Regional Landscape Plan is being renewed in a search that aims not only to preserve the landscape, but also to invigorate and integrate it (Zenobi 2015). In this sense, parks appear as a model of integration and coordination in a highly fragmented landscape, with strong local and conservative identities, based on the commitment to sustainable tourism and citizen participation.

However, tensions are observed between conservation and development, as well as between governments at different scales and between local stakeholders, proving that it is necessary to critically analyze governance systems, recognizing their opportunities, but also their shortcomings when promoting just processes for the people.

This paper presents a summary of the results of a qualitative study carried out in 2023, which compares the governance models of different PA categories in the Marche region and their contribution to territorial justice. Based on the scientific literature and previous research, the hypothesis is supported that small PAs dependent on local governments have a greater capacity than those of a larger scale to promote a positive perception of justice in people.

2 Sources and Methods

For this work, a triangulation methodological strategy was applied, which implies the strategic combination of different qualitative and quantitative techniques and methods to address complex problems and objects of study. Specifically, we carried out: (a) 15 interviews with local citizens, experts, and political officials linked to PAs of the Marche's region (Monte Sibillini National Park, Gola de la Rosa e Frassasi Regional Park, Monte Conero Regional Park, Sentina Regional Reserve, Ripa Bianca Regional Reserve, Monte San Vicino Regional Reserve, Gola di Furlo National Reserve), (b) 26 questionnaires with structured questions to master's students from the University of Macerata, (c) 9 visits to those parks and regional reserves and field observations, and (d) review of bibliography and public documentation.

3 Results

3.1 Regulatory Overview

National Law No. 394/1991 differentiates national PAs from regional ones according to the value given to the protected elements. At the same time, it differentiates the parks from the reserves; the first is raised from a landscape perspective (cultural and natural values), while the second is oriented to the conservation of ecosystems or specific flora or fauna species.

The Law proposes a governance model for national parks, which includes a President, Governing Board, Executive Council, Board of Auditors, and what is called the Park Community, a body made up of the presidents of the regions and the provinces, the mayors of the municipalities, and the presidents of mountain communities. The latter is one of the innovations of the Law, aimed at satisfying local participation. It is a consultative and proactive body whose opinion is mandatory on (a) the regulation of the park, (b) the park project, (c) other matters, at the request of one-third of the members of the Governing Council, and (d) the balance sheet and final account. The park community is also responsible for drafting and developing an economic and social plan, subject to the binding opinion of the Governing Council.

Regarding regional PAs, unlike national ones, they have greater flexibility of government insofar as, according to the regional Law No. 15/1994, the management can be entrusted to various local institutions such as consortiums, provinces, universities, communes, or public or private organizations.

3.2 Opinions and Observations: Governance and Participation in Different Categories of PAs in the Marche region

In general, there is agreement among the informants in positively assessing the impact of PAs for the region. One of the main reasons is the environmental education activity organized by all categories of PAs, sometimes in coordination with private companies. This has had a favorable influence on awareness of the value of the territory, with greater or lesser intensity on the local and regional scale. Another reason is the promotion of tourism ventures, especially in internal areas where parks and reserves are one of the few possibilities for economic revitalization. It was clear, for example, in the cases of Parco Gola de la Rosa e Frassasi, Reserve Monte San Vicino, and Reserve Gola di Furlo.

Nature conservation, in the face of industrial or private advancement, is another of the benefits of PAs, although in the long-term perspective of some informants, a decline is observed precisely linked to an intensive flow of visitors, as has been reported in the case of regional PAs Parco Gola de Frassasi and Monte San Vicino (internal area) or Sentina Reserve (coastal area) in summer.

The informants agree that, at the beginning, regional parks didn't have public acceptance, mainly due to fear of the existence of restrictions on current productive and/or traditional activities, and also due to the protection of feared species such as the wolf. However, they mention that over time they have gained public support, especially since the preservation of heritage and landscape, or its restoration, entails the recreational enjoyment of people, sustainable tourism and, ultimately, an increase in quality of life.

However, in the case of the Monte Sibylline National Park, which due to its national categorization is subject to more restrictive and bureaucratic management, the tensions related to traditional activities such as agriculture or hunting are still valid and cast doubt on the benefits of the park for local populations.

Regarding the governance system, the informants agree in attributing certain advantages and disadvantages to both the national and regional PAs. It is mentioned that in the case of national parks, they present numerous conflicts of interest between the nation, region, and communes, as well as with actors in the territory that are outside the governance model established by the Law, like the peasants. In addition, it is criticized that national parks hold a speech based on biological aspects (known as environmental universalism) that is not sensitive to the traditional uses and needs of the territory. On the contrary, regional parks have the advantage of being created and managed with a perspective of greater affinity to local problems and interests, while being favored by greater regulatory flexibility and less bureaucratic difficulty, which encourages more citizen participation with educational and cultural programs and events, for example, volunteering, festivals, research, etc. A good example of this is Monte Conero Regional Park, such as is visible on its official web page and newsletter.

Between parks and reserves, the main differences in governance according to the informants are that the former benefit from having a specific management entity, while the latter are often managed by local organizations that do not have qualified human resources or that have multiple other occupations, such as municipalities. However, the small size of the reserves, sometimes dependent on a single commune (e.g., Sentina reserve, dependent on San Benedetto di Tronto), favors more effective management without facing the complex challenge of coordination with other governments. In addition, as in the cases of the Ripa Bianca de Jesi and Sentina regional reserves, the initiative gestated by and entrusted to local organizations has promoted a voluntary and constant work over time that favored a sense of identity and belonging in the local community, as well as a greater citizen commitment for conservation. In addition, these small but well-defined spaces act as special places for recreation and learning in the city environment, which tends to favor greater support for their care. This is especially evident in the case of recovered environments such as the above-mentioned reserves, where the contrast with the previous use (dumps) caused an evident positive landscape impact.

Regarding the composition of the PA's steering committees from a gender equity perspective, records on official data sources show that the presence of women is alarmingly low. The 12 PAs in the region are headed by men, as are 80% of the composition of their steering committees and park communities. Besides, it is interesting to observe that the informants did not manifest an awareness of this situation, which is perceived as equitable and non-problematic. The same happens with the perception of social representativeness in the committees, which was mainly seen as sufficient when it was proved that diverse local stakeholders were out of the decisions. These facts show a non-critical perspective of the current system of governance of PAs in the Marche.

Regarding the opinion of young people, according to the results of the surveys, 81% of the students consider that citizen participation has a positive impact on the activity of the PAs, although only 62% agree willing to collaborate with them. In the case of the Sentina Reserve, for example, there is a youth group that actively participates in the Reserve (FAI youth group of San Benedetto del Tronto), but according to an interviewed informant, the main difficulty is the lack of perseverance in the projects.

The surveys also show that, concerning the valuation of the PAs, students have a majority concept of nature that is not articulated with identity and culture, considering PAs to be important just for the conservation of flora and fauna, alluding to ideas like "uncontaminated nature" or "non-intervenuta." Only a low percentage has recognized the rapport between nature and human beings, thinking of PAs as tourist resources.

4 Discussion and Conclusion

Based on the results obtained, two issues are central to the discussion. On the one hand, the variable of the territory, with all its cultural, historical, social, and economic components, is determinant to understanding the emergence and development of PAs, especially as regards the existence of problems and/or conflicts, participation in citizenship and public support, all issues that are directly related to

a sense of territorial justice (Porto-Gonçalves 2002; Degele 2023). In this sense, the analysis in the Marche indicates the need to plan and adapt conservation projects and objectives according to territorial variables, such as the coast or internal land, whose dynamics are very different. This evidence is especially relevant when generating development strategies based on PAs, as proposed by the latest Rural Development Plan, of which their creation cannot be standardized.

It is important to mention that territorial awareness when designing PAs is not necessarily evident in international conservation policies (West et al. 2006; Swyngedouw 2011; Degele and Pedregal 2022), which show a biologist, apolitical, and a-historical orientation. The effectiveness of this discourse was evident, for example, in the answers of the students, who still perceive the PAs as spaces oriented solely to the conservation of flora and fauna, and in the orientation of national parks, aligned with international policies. Territorial awareness when creating PAs thus appears as a prior step for the promotion of territorial justice for its inhabitants in various aspects such as identity, economy, and gender. Italian legal innovation, despite the practical difficulties mentioned, has the potential to guide this development.

Another important aspect to consider in relation to the promotion of a sense of justice is the category of PA and the dynamics of participation that are related to it. In this sense, although the existence of a governance structure with the participation of local entities is relevant and innovative, it still generates a lot of friction and an inflexible structure that leaves out many social actors, on the contrary, the management flexibility of the reserves, as well as their clear delimitation and accessibility, denote an openness that facilitates the commitment, support, and participation of citizens, who defend their PAs precisely as natural spaces for recreation and education that are fair to maintain for current and future generations. In this sense, we verify the initially proposed hypothesis regarding the relevant role of small and local PAs for territorial justice.

To keep analyzing these often undervalued local conservation figures, it will allow us to contribute to the international debate regarding the OMEC or "Other Effective Area-Based Conservation Measures" (Jonas et al. 2021; Quintana Anastasia et al. 2021), an approach that was derived from goal No. 11 of the Strategic Plan for Biological Diversity 2011–2020 and includes local government measures, such as municipal parks, urban reserves, zoning in land use plans, as well as other private and community initiatives (e.g., indigenous territories, private reserves). Thus, the idea of OMEC opens the door to the possibility of recognizing the value of alternative conservation and management mechanisms, encouraging the study of local conservation and/or restoration initiatives that, as we have seen on regional reserves, have the potential to contribute to a more just, community and equitable sense of management (Jonas et al. 2021; Quintana Anastasia et al. 2021; Sofrony 2020).

The scarcity of research on the subject in Marche region indicates the need to continue developing studies, while discussing them with other regions of Italy and Europe to tend toward an integrated environmental conservation with greater territorial justice in the post-2020 era.

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Distribution and Isotopic Composition of Micro-Mollusks in Fossil Core Sediments of Gulf of Mannar Marine Biosphere Reserve, Tamilnadu, India

Prince Samuel Godson, Soumya Lalithamma, Rincy Babu, Krishnakumar Subbiah, Chandrasekar Nainarpandian, Magesh Nochyil Sivan, Arya Dennison Bindulekha, and Salom Gnana Thanga Vincent

Abstract

A total of 66 sub-sample core sediments have been collected during December 2020. A total of 37 families of micro-mollusks, representing 49 species, were identified in the study. Micro-gastropods were dominated by *Mellanella* sp., *Cerithiopsis* sp., and *Clithon oualaniense*, whereas *Timoclea* sp. and *Anadara* sp. were the most abundant among micro-bivalves. The diversity of micro-mollusk is higher in sandy and clayey (muddy) sediments compared to very fine grain size sandy sediments. The grain size analysis shows that the sediment in Krusadai Core 1 counts 92.1% sand, 7.09% silt and 0.01% clay. In Krusadai Core 2, sediment counts 97.42% sand, 2.34% silt and 0.24% clay. In Krusadai Core 3, it is 94.16% sand, 5.81% silt and 0.03% clay. In Krusadai Core 4, 75.32% sand, 23.43% silt and 1.25% clay have been recorded. In Shingle Core 5, 98.12% sand, 1.70% silt and 0.18% clay have been noticed respectively. TOM ranges from 0.25% to 1.77%, and TOC is recorded from 0.15% to 1.02% in Krusadai islands. A high value of proteins is seen where the percentage of clay particle is high, and the protein-to-carbohydrate ratio ranges from 0.0939 to 12.4685. The high value of the protein-to-carbohydrate ratio indicates the presence of large amounts of living and/or newly produced organic matter in the study area. Carbon ^{13}C (‰) isotope ranges from −1.43 to −2.58 and the Oxygen ^{18}O (‰) isotope ranges from −0.79 to −1.42. Therefore, all the samples come under modern climatic condition, denoting no remarkable change in this study.

Keywords

Micro-mollusks · Core sediments · Organic nutrients · Diversity indices · δ ^{13}C and δ ^{18}O isotopes

P. S. Godson (✉)
Centre for Marine Science and Technology, Manonmaniam Sundaranar University, Tirunelveli, India
e-mail: princegodsons@gmail.com

S. Lalithamma · R. Babu · A. D. Bindulekha · S. G. T. Vincent
Department of Environmental Sciences, University of Kerala, Thiruvananthapuram, India
e-mail: soumyajyothi9645@gmail.com

R. Babu
e-mail: rincybabukkd@gmail.com

A. D. Bindulekha
e-mail: aryadb94@gmail.com

S. G. T. Vincent
e-mail: salom@keralauniversity.ac.in

K. Subbiah
Department of Geology, Malankara Catholic College, Kaliyakkavilai, India
e-mail: coralkrishna@gmail.com

C. Nainarpandian
Centre for Geotechnology, Manonmaniam Sundaranar University, Abishekapatti, India
e-mail: profncsekar@gmail.com

M. N. Sivan
Centre for Water Resources Development and Management, Kozhikode, India
e-mail: magesh@cwrdm.org

1 Introduction

The pressure on coastal and marine ecosystems introduced by land-use change, climate change, the invasion of non-native species and other impacts of anthropogenic activities that affect biodiversity and threat to the resources in the ecosystem (Snelgrove 1998). Marine organisms contribute to many critical processes that directly and indirectly affect the health of the oceans and living beings that depend on marine resources. Micro-mollusks occupy every trophic level, and the structure and distribution of the micro-mollusks are strongly influenced by environmental, physical and biotic factors (Nurhasballah and Suwarno 2019). The

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composition of the micro-mollusks species shell (Mg^{2+} and Ca^{2+}) is accreted from seawater (Lecuyer et al. 2012). Carbon and oxygen isotope compositions of these two shell carbonate polymorphs (aragonite or calcite) constitute suitable proxies of water mass properties such as temperature, salinity and productivity. Generally, the isotopic composition of land micro-mollusks' shells ($\delta^{13}C$) reflects dietary habits and life cycles (McConnaughey and Gillikin 2008).

The preserved calcareous part of the micro-mollusks provides valuable information on palaeoenvironments and ecology (Lyman 1994; Martin 1999). However, the carbonates are suitable multiproxy archives for the evaluation of palaeoecological perspectives and reconstruction of depositional palaeoenvironments (Flugel 2004; Zoeram et al. 2015). The need for more specific studies on fossil micro-mollusks is a common problem in several countries worldwide, particularly in India. Earlier researchers have focused on this microfauna (micro-mollusks) as an important source of information on paleo-oceanographic registers, terrestrial vegetation from isotope compositions and ecology. Under these circumstances, the present work aims to document the paleo-oceanic environment, ecology, diversity and taphonomic signatures of the micro-mollusks from the fossil core sediments of the Gulf of Mannar, Southeast coast of India.

2 Materials and Methods

In this study, five different core sediment samples were collected up to the depth of 0–90 cm from the two coastal islands (Krusadai and Shingle) of Gulf of Mannar, Marine Biosphere Reserve (GOMMBR), Southeast coast of Tamil Nadu, India (Krishnakumar et al. 2017) i.e. four core samples from Krusadai Island (Krusadai Core 1 to Krusadai Core 4) and one from Shingle Island (Core 5) Table 1.

The univariate and multivariate statistical parameters were analyzed by using PRIMER 6.1.10 software. Physicochemical properties of core sediment samples were analyzed by using standard procedures (APHA, AWWA 1995). Carbon ($\delta^{13}C$) and Oxygen ($\delta^{18}O$) isotope analysis were carried out using Plasma multi collector-ICPMS & Isotope-Ratio Mass Spectrometry (IRMS) and Delta Plus Advantage Mass Spectrometer coupled with an automatic carbonate (Kiel IV) device. Evaluation of sand, silt and clay percentage was done using the pipette out method (Krumbein 1938).

The environmental factors influencing the distribution of micro-mollusks. The preserved calcareous part of the micro-mollusks provides valuable information on palaeoenvironments and ecology (Lyman 1994; Martin 1999). However, the carbonates are suitable multiproxy archives for the evaluation of palaeoecological perspectives and reconstruction of depositional palaeoenvironments (Flugel 2004; Zoeram et al. 2015). The need for more specific studies on fossil micro-mollusks is a common problem in several countries worldwide, particularly in India. Earlier researchers have focused on this micro-mollusks as an important source of information on paleo-oceanographic registers, terrestrial vegetation from isotope compositions and ecology. Under these circumstances, the present work aims to document the paleo-oceanic environment, ecology, diversity and taphonomic signatures of the micro-mollusks from the fossil core sediments of the study area.

3 Results

In the present study, a total of 1740 micro-mollusk species were isolated and identified from 5 sediment cores (66 samples), out of which 1468 species were identified as micro-gastropods belonging to 31 families and 49 genera with relative abundance of 84%, 272 species were identified as micro-bivalves belonging to 6 families and 10 genera with relative abundance of 16%. The results of the depth-wise diversity and numerical abundance of micro-mollusks were found to be relatively high in Krusadai Core 1. In this core, a total of 504 species were identified belonging to 30 families and 41 genera comprising of both micro-gastropods and bivalves, out of which 444 species were micro-gastropods and only 60 species were identified as micro-bivalves. The maximum number of organisms was isolated from K2Co1**,** followed by K1Co1, K3Co1 and K4Co1**.** Most of the species were gastropods. Micro-gastropods were the dominant group in this core, comprising 88% of the identified organisms. As evident from the diversity data, increasing depth decreases

Table 1 Cores, core depth and number of samples in the study area

Cores	Core depth (Cm)	Sampling points (No. of Samples)	Latitude (^{0}N)	Longitude (°E)
Krusadai Island				
Krusadai Core 1	0–72	K1Co1-K12Co1 (12)	$9^0 14' 35.08"$	$79^0 12' 11.33"$
Krusadai Core 2	0–90	K1Co2-K15Co2 (15)	$9^0 14' 47.17"$	$79^0 12' 28.09"$
Krusadai Core 3	0–72	K1Co3-K12Co3 (12)	$9^0 14' 53.80"$	$79^0 12' 44.42"$
Krusadai Core 4	0–72	K1Co4-K12Co4 (12)	$9^0 14' 56.41"$	$79^0 13' 4.61"$
Shingle Island				
Shingle Core 5	0–90	S1Co5-S15Co5 (15)	$9^0 14' 32.72"$	$79^0 14' 6.90"$

the diversity and abundance of micro-gastropods in this first core Krusadai Core 1.

A total of 60 species were identified as bivalves in the study area, belonging to 7 families and 5 genera. Bivalve species were the infrequent group comprising 12% of the total organisms isolated from this core. In depth-wise diversity, bivalves is found to be maximum in the core depth of 12 cm (Krusadai Core 2) with the numerical abundance of 20 species with a relative abundance of 3.97% followed by a total of 12 species from K5Co2 and a total of 8 species were accounted from Krusadai Core 1 with relative abundance of 2.38% and 1.59%, respectively. As revealed from the collected data, bivalves showed significantly less composition with increasing depth, decreasing the species diversity and numerical abundance. Regarding the diversity indices of micro-gastropods in the 5 cores, Shannon Weiner diversity index varied from 0.500 to 0.983. The maximum index was observed in the K6Co4 (6 cm depth) sample in the fourth core of Krusadai island and the minimum was observed in K2Co2 of Krusadai island and the Shingle Core.

In the case of Pielou's evenness index, it ranged from 0.334 to 0.983, the maximum index was shown in K6Co1 Core (36 cm of core depth) and the minimum was recorded in K8Co3 (48 cm depth) of Krusadai Core 3. The Margalef index ranged from 0.334 to 0.900. The maximum range was observed in K3Co4 (core depth of 18 cm) of Krusadai Core 44 and the minimum were recorded in Krusadai Core 2 of Krusadai and Shingle Islands. The Simpson index ranged from 0.337 to 0.929; maximum range was shown in K1Co4 of Krusadai Core 4 of Krusadai island, and the minimum range was showed from Krusadai Core2 of Krusadai island and also in the Shingle core. The oxygen isotope $\delta^{18}O$ (‰) ranged from −1.42 (K12Co3) to −0.79 (K6Co1). Carbon isotope ($\delta^{13}C$) (‰) ranged from −2.58 (K9Co4) to −1.43 (K3Co1). This result reveals that the modern environmental conditions prevailing all over the study area is due to the less impact of anthropogenic activity all along the coast.

4 Discussion

The families contributed a large number of organisms identified from the class Gastropoda, including Cerithiopsidae, Cerithidiiae, Eulimidae, Trochidae, Neritidae and Liotidae. The families that comprised a maximum number of organisms were identified from the class Bivalvia, including Arcidae and Veneridae. Among the identified 49 genera of micro-gastropods, *Rissoina pachystoma* was the dominant group followed by *Melanella* sp., *Cerithiopsis* sp., *Nassarius* sp., *Phasianella solid*, *Bothropoma* sp., *Cyclostrema* sp., *Turbonilla* sp., *Columbella* sp., *Rissoina* sp., *Clithon oualaniense, Cerithium* sp., *Alcyna* sp., *Umbonium velarium* and so on. Among the 10 genera, *Timoclea* sp. contributes many species in the case of micro-bivalves, followed by *Anadara* sp., *Arca* sp. and *Lepirodes lanyards.* The minimum number of organisms identified from micro-gastropods includes *Euclipta scripta, Cerithium zonate, Nassarius jacksonian, Liotimpoma* sp., *Pseudominolia* sp., *Cantharidus* sp., *Pseudonoba,* sp., *Littorina* sp., *Cellana* sp., *Gerorissa* sp., *Marginella* sp., *Zocalantica galathea, Cheilea* sp. *and Vomanus.* In the case of micro-bivalves, less number of species were identified, including *Mytilopsis* sp., *Ctena divergence, Pillucina Vietnam, Gafrarium* sp. and *Sunetta* sp. The pH value of these sediments ranged from 9.1 to 10.2, indicating the basic nature of deposits. Most of the sediment is sandy, so the deposition of organic matter on these sediments is relatively low. The total organic matter content varied from 0.01% to 1.77%, and total organic carbon varied from 0.15% to 1.02%. Organic matter and organic carbon are comparatively high in the sediments from Krusadai Island. In the biochemical composition of organic matter, in the sediments from Krusadai Island, protein (0.0004 mg/g to 0.0057 mg/g) dominated carbohydrate (0.0002 mg/g to 0.0042 mg/g), indicating it as freshly deposited organic matter. In Shingle Island, carbohydrate (0.0026 mg/g to 0.0042 mg/g) dominated the concentration of protein (0.0010 mg/g to 0.0039 mg/g), indicating the refractory nature of organic matter. The protein-to-carbohydrate ratio (0.0939 to 12.4685) is greater than 1 in Krusadai Island, an indication of a eutrophication environment.

5 Conclusions

The textural charactersof the sampling area were predominantly sand. In the sediment from the 4th site, the textural characters are slightly varied, such as sand, loamy sand and sandy loam. In Shingle, it ranged from 0.3150 to 0.9730. The values are less than 1 indicating the oligotrophic nature of the environment. The quantity and quality of organic matter had a significant role in coastal marine eutrophication. Protein and carbohydrates are two critical tools to describe the trophic state of the coastal environment. The present study concludes that the coastal environment of Krusadai Island is in the early stage of eutrophication, and Shingle Island environments are in the oligotrophic condition. The carbon ($\delta^{13}C$) (‰) isotope ranged from −1.43 to −2.58, and the Oxygen $\delta^{18}O$ (‰) isotope ranged from −0.79 to −1.42. Therefore, all the samples come under modern climatic changes, denoting no remarkable changes in this study. This indicates that the environment is still in pristine condition. The present work suggests the micro-mollusks isotope signatures are useful proxy for the paleo-ecological and paleoenvironmental reconstructions. A survey of fossil mollusks is a suitable proxy for understanding the depositional model, paleo-oceanic environ-

ment, ecology and taphonomic signatures of the Gulf of Mannar coral islands. The outcome of this research will shed light on the management of micro-mollusks and their ecosystem in the near future. The study helps to understand the importance of marine conservation.

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Floral Surveys of Mountain Peaks in NW Saudi Arabia: A Refuge for Mediterranean and Irano-Turanian Species

Shahina Ghazanfar, Eric Hopkins, Gary Brown, Othman Llewllyn, Bahaa Ismael, David Olson, and Ricardo Ramalho

Abstract

We carried out floral surveys of 10 mountain peaks in NW Saudi Arabia above 1500 m during May 2023. We found scattered and isolated stands of *Juniperus turbinata* and *Pistacia khinjuk*, and several other taxa on the peaks that are not uncommon in the Mediterranean and Irano-Turanian floristic regions. Their presence on the mountain peaks indicate a former wider Mediterranean influence, with the high peaks offering a refuge to these taxa. We recorded 18 taxa that are near endemics elsewhere found only in the Sinai Peninsula, Jordan, Palestine, and Syria. The relatively warm summers and cold winters with regular frost (and occasional snow) and rainfall reaching 150 mm–200 mm per year make these mountains a bioclimatic refuge for the relict Mediterranean and Irano-Turanian species. Many of the relict plants of Mediterranean, Eurasian, or African origin survive in small populations in restricted localities as we have seen on the summits of the NW mountains. This makes them especially vulnerable to climatic fluctuations which has profound effects on isolated and relict populations. Such populations play an important role in the conservation and dissemination of genetic material, as well as the evolution of new forms. The rock outcrops and gullies on the NW mountains provide a special water regime for plants, thereby acting as moist islands in a surrounding desert environment. We highly recommend preserving the genetic diversity of these taxa that have been isolated for several thousands of years to understand their adaptation to the changing environment and climate.

Keywords

Biogeography · Conservation · Genetic diversity · NW Saudi Arabia · Refugia

1 Introduction

The mountains of NW Saudi Arabia are species rich and preserve several species that are relicts of the Mediterranean and Irano-Turanian floristic regions. Quick floral surveys were carried out on 10 mountain peaks of the NW mountains in NW Saudi Arabia to document the species found there (in the summit area), to establish species richness and diversity, endemism and biogeography, and to assess the habitat and human disturbance of these mountain peaks. The aim behind the surveys was to prioritize biodiversity conservation areas relating to the National Centre for Wildlife (NCW) proposal for a serial World Heritage Site comprising the bioclimatic refugia of western Arabia. In addition, surveys were conducted to further identify national priorities for biodiversity conservation within the newly established NEOM area in SW Saudi Arabia (Llewellyn 2013).

The Northwest region of Saudi Arabia is located within 27° 30′–29° 30′ N and 34° 29′–36° 45′ E. The NW range of mountains is present in the Madyan (Midian, Midyan) region, bounded by the Hisma plateau in the east and by the

S. Ghazanfar (✉)
Science-Royal Botanic Gardens, Kew, Richmond, UK
e-mail: s.ghazanfar@kew.org

E. Hopkins
Beacon Development, King Abdullah University of Science and Technology, Thuwal, Saudi Arabia

G. Brown
Centre for Biodiversity Monitoring and Conservation Science, Leibniz Institute for the Analysis of Biodiversity Change, Bonn, Germany

O. Llewllyn · B. Ismael
Saudi Wildlife Authority, Riyadh, Saudi Arabia

D. Olson
Nature Reserve, Neom, Saudi Arabia

R. Ramalho
King Abdullah University of Science & Technology, Beacon Development, Thuwal, Saudi Arabia

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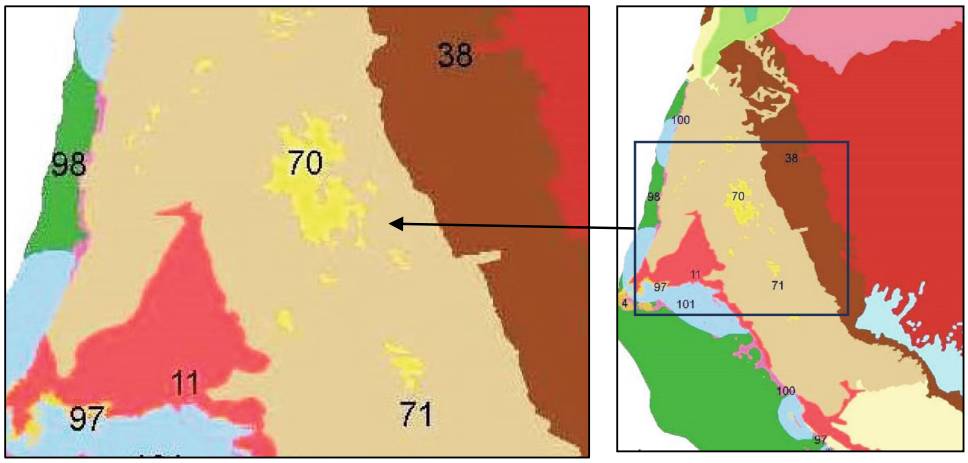


Fig. 1 The NW Region of Saudi Arabia. Legend: 38 Hisma plateau; 70 Madyan mountains above 1000 m; 71 Madyan mountains below 1000 m; 11 Red Sea coastal plain and sabkha; 97 Coral reef; 98 Red Sea deeper than 15 m. Map after AEGDI Units 2016

Gulf of Aqaba and the Red Sea in the west. Geologically, the western part of the Madyan region is composed of igneous and metamorphic basement rocks of the Arabian Shield, steep and rocky soils, predominantly with coarse, silty soils. The granite formations, in some places are overlain by sedimentary rocks; the eastern part is composed of sandstones of the Hisma plateau which is intensively dissected and weathered forming canyons which overlie the igneous and metamorphic coastal hills of Madyan (Trent and Johnson 1968). The mountain range consists of the highest peaks in the NW region of Saudi Arabia, ranging in elevation from 2380 m (Jabal al Qalom) to 1400 m (Jabal Harb) (Fig. 1).

2 Methodology

Floral surveys were carried out on 10 mountain summits (or at the highest points) where a helicopter could land. Substrate, elevation, slope, aspect was recorded for each mountain summit. All plants that could be accessed in the area were georeferenced and recorded together with their habitat and abundance. No plants were collected for herbarium preparation (Fig. 2).

3 Results

Table 1 provides the new records and range restricted taxa recorded in the NW mountains. Several taxa belong to the W Irano-Turanian floristic region (mainly C and E Turkey, Iran, Iraq, Syria, Jordan, and Palestine), with some belonging to the Sahara Arabian and the E Mediterranean floristic regions. All identifications were made using the Flora of the Kingdom of Saudi Arabia (Chaudhary 2001) and Wildflowers of Saudi Arabia (Collenette 1999).

4 Discussion

The Madyan Mountain Summits in NW Saudi Arabia, ranging in elevation from 1400 to 2400 m above sea-level, with relatively warm summers and cold winters, regular frost (and occasional snow), and rainfall reaching 150–200 mm per year make these mountains a bioclimatic refuge for relict Mediterranean and Irano-Turanian species. The cool and relatively humid conditions support plant communities with open evergreen woodlands of scattered *Juniperus turbinata*, with *Pistacia khinjuk*, *Retama raetam*, *Moringa peregrina, Olea europaea* subsp. *cuspidata*, *Dodonaea angustifolia*, *Globularia arabica*, and a dense ground layer of Irano-Turanian taxa such as *Artemisia sieberi* and *Astracantha echinus* subsp. *arabica.* Relict Mediterranean and Irano-Turanian taxa include *Thymus decussatus*, *Phlomis brachyodon*, *Atraphaxis spinosa*, *Verbascum decaisneanum*, *Dianthus sinaicus*, *Daphne linearifolia*, *Ephedra pachyclada* var. *sinaica*, *Ajuga chamaepitys* subsp. *tridactylites*, *Colutea istria*, *Echinops glaberrimus*, and *Scorzonera intricata* (Leonard 1989; Llewellyn et al. 2010).

Many of the relict plants of Mediterranean, Eurasian, or African origin, survive in small populations in restricted localities on the summits of the NW mountains. Such populations play an important role in the conservation and dissemination of genetic material, as well as in the evolution of new forms. These refugia habitats support plants that have remained in the area from various penetrations of floras in the remote past. The rock outcrops and gullies provide a special water regime for plants, thereby acting as moist islands in a desert surrounding.

Scattered and isolated stands of *Juniperus turbinata* with an understorey of *Artemisia sieberi*, *Astragalus echinus* subsp. *echinus*, form the southernmost outposts of the

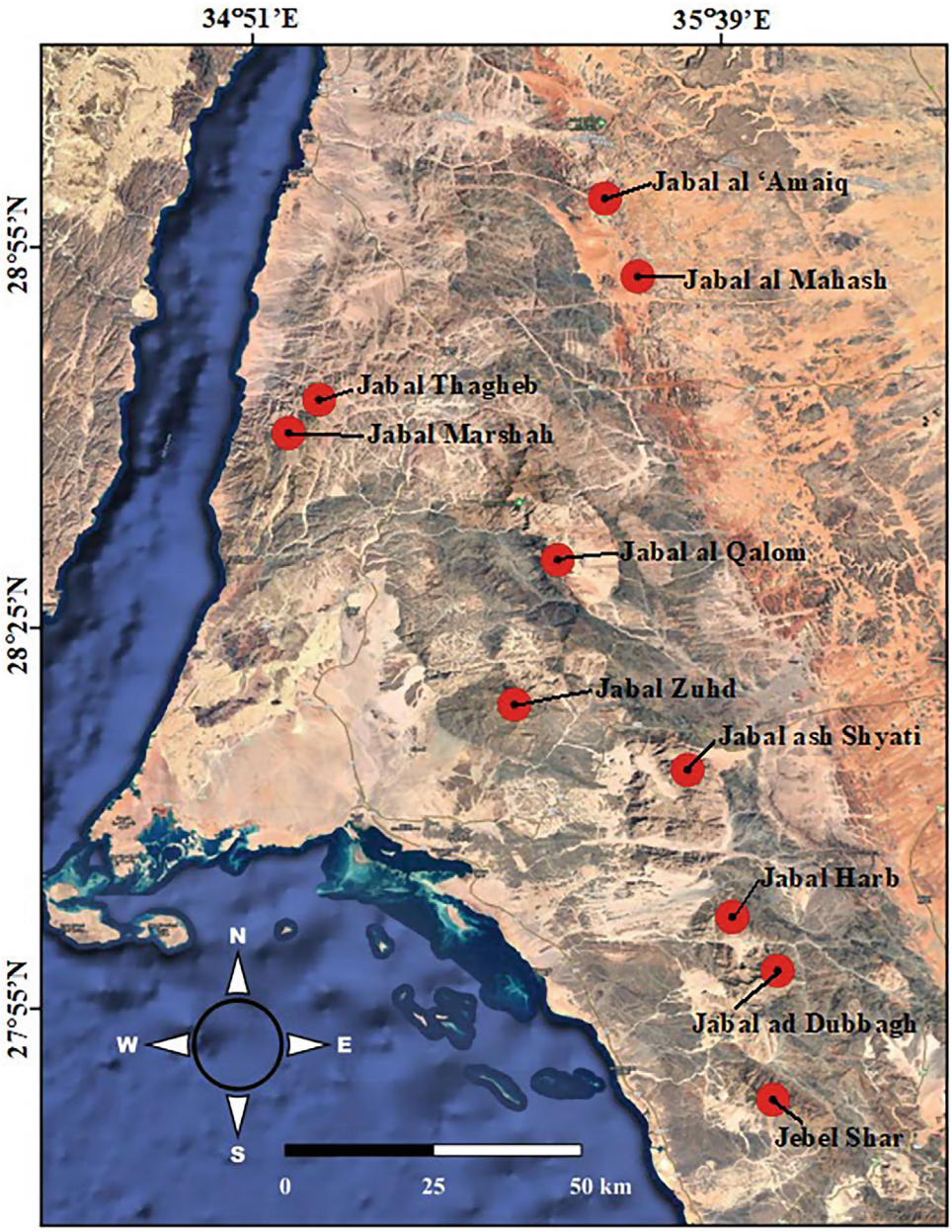


Fig. 2 The ten mountain peaks surveyed of the NW mountains in Saudi Arabia along the Coastal areas of the Red Sea and Gulf of Aqaba

arborescent Mediterranean element. Relict stands are also present on the Sinai Peninsula and in the Edom highlands of Jordan (Ghazanfar and Fisher 1998).

Pistacia khinjuk, an Irano-Turanian species that probably migrated pre-Pleistocene, together with other species such as *Prunus korshinskyi*, *Pistacia atlantica*, *Astragalus echinus,* and *Retama raetam*, into the mountains of NW Saudi Arabia from the Kurdo-Zagrosian mountains. *Pistacia khinjuk* is confined exclusively to the high elevations of the mountains of NW Saudi Arabia. It is rare in Saudi Arabia, its southernmost limit in distribution is Egypt (Sinai) and Sudan (Ghazanfar and Fisher 1998).

The presence of Amaranthaceous genera such as *Anabasis setifera*, *Anabasis articulata, Atriplex leucoclada, Noaea mucronata, Caroxylon villosum* on mountain summits are examples of the Sahara-Arabian desert flora from the Mesogean stock (of the region that developed into the Mediterranean Sea) (Ghazanfar and Fisher 1998).

A single Afro-montane species, *Euryops jaberiana* is endemic to the NW mountains. A second species, *Euryops arabicus* is found in the Arabian Peninsula (N Oman, Yemen) and NE Africa (Djibuti, Somalia). *E. jaberiana*, *E. arabicus,* and *E. socotranus* (the latter two also found in Ethiopia & Socotra respectively) are the only three taxa found outside Africa (Chaudhary 2001; Leonard 1989).

Table 1 New records, endemic, and near endemic taxa recorded for the NW mountain summits in Saudi Arabia

Taxon	Endemic, near endemic, and new records and where elsewhere found
Ajuga chamaepitys subsp. *tridactylites*	Sinai to W Iran; not common
Bituminaria bituminosa	New record, rare, recorded from two summits; European and African Mediterranean region to the Caucasus;
Centaurea scoparia	Near endemic, rare, found on 1 summit; Sinai, Jordan, and Palestine
Daphne mucronata subsp. *linearifolia*	Relict species of the E Mediterranean floristic zone; rare, found on 1 summit; Jordan, Palestine, and Syria
Echinops glaberrimus	Near endemic, common; Sinai, Palestine, Jordan
Euphorbia terracina	New record; rare, recorded from two locations; Macaronesia, Hungary to the Mediterranean region;
Euryops jaberiana	Endemic; NW mountains on 2 mountain summits
Ferula sinaica	Near endemic, found on 1 summit; Jordan, Sinai
Kickxia pseudoscoparia	Near endemic, found on 1 summit; Palestine, Sinai, and Sudan
Galium sinaicum	Near endemic; not uncommon; Sinai, Jordan, Palestine
Nepeta glomerata	New record; Turkey, Syria
Odontarrhena subspinosa	New record; near endemic found on 1 summit; Palestine
Paronychia sinaica	Near endemic, not uncommon; Egypt, Sinai, Jordan
Phagnalon sinaicum	Near endemic, found on 3 summits; Yemen, Sinai, Palestine, Jordan
Phlomis brachydon	Near endemic, restricted to 2 summits; Palestine, Jordan, Syria
Plantago siniaca	Near endemic, restricted to 2 summits; Sinai, Jordan
Podonosma orientalis	Near endemic, rare found on 1 summit; S Turkey, Iran, Iraq, Syria, Palestine, Jordan
Polygala sinaica var. glabrescens	Near endemic, not uncommon; Sinai, Palestine, Jordan
Pseudodictamnus hispanicus	C. Italy, Albania, Yugoslavia, Bulgaria, S. & E. Turkey, Syria, Palestine, Saudi Arabia, Sinai
Pycnocycla saxatilis	New record, near endemic, found only on 1 summit; Palestine, Jordan (Wadi Rum)
Rhamnus disperma	New record; near endemic, found only on 1 summit; Egypt, Palestine, Jordan, Syria
Scorzonera schweinfurthii	Near endemic; Egypt, Palestine, Jordan, and S Iraq
Silene corylina	Endemic to NW Saudi Arabia; recorded on 3 summits
Silene grisea	New record; Palestine, Syria
Stachys aegyptiaca	Near endemic, not uncommon; Egypt, Palestine, Jordan
Tanacetum sinaicum	Near endemic, common; Sinai, Jordan
Teucrium leucocladum	Near endemic, not uncommon; Sinai, SW Jordan
Thymus deccusatus	New record, near endemic, found on 2 summits; Sinai
Verbascum decaisneanum	Near endemic, rare, found on 1 summit; Syria, Jordan, Palestine, Sinai
Verbascum schimperiana	New record, near endemic, not common, found on 1 summit; Syria, Jordan, Palestine, Sinai

5 Conclusions

Each one of the NW Saudi Arabian mountain summits are unique in that they have a few near endemic or relict species present on them, indicating that these species once formed more continuous populations, now severely fragmented due to the change in climate and increased aridity of the Arabian Peninsula over several thousand years. Such taxa present in crevices and shaded gullies are likely to be severely affected by the increasing aridity in the Arabian Peninsula. Climatic data from 1978 to 2009 shows that rainfall over Saudi Arabia has decreased and that the decrease rate is faster and more significant in the recent past (1994–2009), compared to the entire analysis period (1978–2009) (Ghazanfar and Fisher 1998). Data also shows that the drier zone over Egypt extends into northern Sudan and into northwestern Saudi Arabia (Almazroui et al. 2012).

With recent climate change trends towards an increase in temperature and decrease in rainfall, the relict taxa need conservation priority. To preserve the genetic diversity and uniqueness of the endemic and near endemic (relict) taxa, it is highly recommended that measures are taken sooner than later to preserve the genetic material of these taxa.

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Estimation of the Advance of the Agricultural Frontier and the Anthropogenic Pressure in the Aguarongo Forest-Ecuador Through a Multitemporal Analysis

Estefanía C. Avilés-Sacoto, Jhonny P. Rodriguez-Ponce, Wazhingthon Wilfrido Delgado Siguencia, and Bryam Marcelo Vásquez Vázquez

Abstract

The Aguarongo Forest (Ecuador) was declared a protected area under the denomination of Forest and Protective Vegetation Area in 1985 with a total of 1758 ha. For the year 2008, the Environment Ministry of Ecuador designated that it has1935 ha, of which 1480 were native forest and 423 agricultural mosaic; therefore, it is evident that it is an area in which the agricultural frontier and the anthropic pressure continue to advance. The objective of this work was to determine the change in vegetation cover and land use within the forest through a multitemporal analysis of satellite images from Landsat 7 sensor for the years 2000, 2005, and 2010 and from Landsat 8 sensor for the years 2015 and 2020 and to establish whether or not there is anthropogenic pressure that endangers the conservation of the Aguarongo Forest. Software such as Catalyst and ArcMap were used for the pre-processing and processing of satellite images. Radiometric, atmospheric, and geometric corrections were made. An object-based classification was performed and a transition matrix was estimated in order to determine changes. The generation of cartography and the data were verified in the field. It is shown that, during the 20 years of the study period, 188.95 ha of forest and 102.07 ha of uncovered land areas have been replaced by grasslands, increasing it to 287.79 ha. More specifically, 9.5% of forest area during the period 2000–2005, 7.38% during the period 2005–2010, 8.74% during the period 2010–2015, and 5.44% during period 2015–2020 was lost. This shows that the agricultural frontier is advancing and exerting pressure in the forest. It is proposed to establish more rigorous measures for the preservation of the place, update the effective area of the forest, and apply recovery and conservation strategies.

Keywords

Forest · Vegetation cover · Land use · Multitemporal analysis · Remote sensing

1 Introduction

Ecuador is a country with great biodiversity (Espinoza and Manzero 2015); however, it is being threatened by various anthropic causes, highlighting among them: the change in vegetation coverage that deforests thousands of hectares per year (Ministerio del Ambiente del Ecuador Homepage 2023a).

According to the National Action Program to fight desertification, it is estimated that approximately 90,000 ha of the total area of Ecuador are threatened, and they are in deterioration due to vegetation coverage changes by human actions (Astudillo Guzmán 2023).

One of the implemented measures to prevent the loss of the biodiversity housed in various areas of Ecuador is the designation of various conservation zones known as protected areas. Ecuador has 70 designated zones, which correspond to 20% of the national territory (Ministerio del Ambiente del Ecuador Homepage 2023b).

The Aguarongo Forest was declared in 1985 as a protected area with an area of 1758 ha. Until 2002, it had 2879 ha; however, in 2008, the Ministry of the Environment recorded that its total area was 1935.56 ha, of which 1480.75 ha corresponded to forest while 423.34 ha to agricultural land (Criollo 2023).

To know if the declaration of the Aguarongo Forest as a protected area has been efficient for its conservation, and to know how it has changed in 20 years (Gallardo and Martinez

E. C. Avilés-Sacoto (✉) · W. W. D. Siguencia · B. M. V. Vázquez
Universidad Politécnica Salesiana, Cuenca, Ecuador
e-mail: eaviles@ups.edu.ec

J. P. Rodriguez-Ponce
AGP Geospatial Company, Quito, Ecuador

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2012), a multitemporal analysis (Cede et al. 2011) using Landsat 7 and Landsat 8 satellite images was performed. The observed changes were later represented through thematic maps. Finally, measures that allow the preservation of the area were proposed, based on the loss of forest cover associated with deforestation processes through spatial remote sensing (Carnevale and Alzugarray 2007).

2 Materials and Methods

This study began with the approach to the problem that is the loss of protected area due to agricultural activities on it, the effective delimitation of the study area with the use of secondary information (cartography) that corresponds to the Aguarongo Protected Forest located in the province of Azuay in the south of Ecuador (Fig. 1).

The multispectral satellite images of the Landsat 7 and Landsat 8 sensors were selected because of their availability, they both have a pixel size of 30 m. The satellite image for years 2000, 2005, and 2010 were from Landsat 7, while for the years 2015 and 2020 were used images from Landsat 8 sensor. The dates from the images are in Table 1.

The images were pre-treated for radiometric and atmospheric corrections using Catalyst and ArcMap 10.8 software. A band combination was carried out to get a false color to interpret the land uses in the images. The bands used in the Landsat 7 image were 5-4-3, while the bands used in the Landsat 8 images were 65-4. These combinations use the wavelength: near infrared, red, and green and help to clearly differentiate forest from grassland and to discriminate ground from water. Later, an Object-Based Image Analysis (OBIA) classification and data validation were carried out through the kappa coefficient and the confusion matrix as well as field visits. A multitemporal analysis of land cover and use changes using the transition matrix from the obtained thematic maps (Chuvieco 2008) was performed in order to assist in the formulation of proposals for the conservation of this site. The methodology does not have major obstacles to be developed tackling the main problem for this type of studies which is the access to multispectral images and the number of available bands. Image classification is a methodology that has been in use for many years in numerous studies. We use

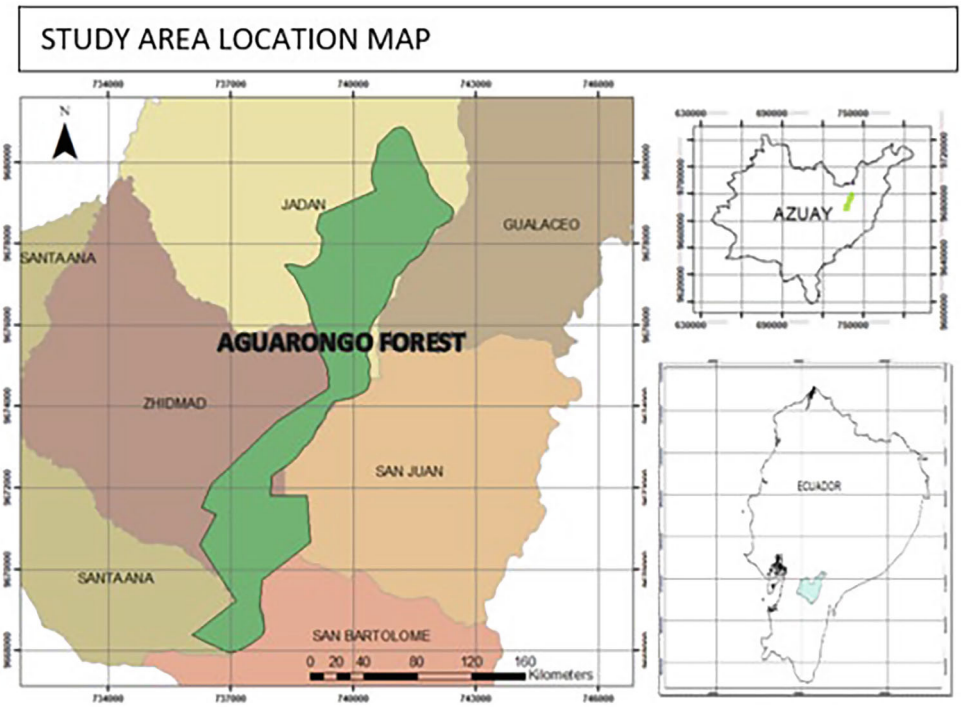


Fig. 1 Aguarongo protected forest located in the province of Azuay (South of Ecuador)

Table 1 Satellite images used in the study

Year	Sensor	Date
2000	Landsat 7 ETM+	03/11/2001
2005	Landsat 7 ETM+	09/07/2005
2010	Landsat 7 ETM+	14/10/2011
2015	Landsat 8 OLI TIRS	20/11/2016
2020	Landsat 8 OLI TIRS	27/08/2020

Table 2 Study results

Year	% Coverage		
	Forest %	Grasslands %	Uncovered Areas %
2000	78	14	8
2005	76	21	3
2010	76	22	2
2015	72	26	2
2020	69	28	3

the OBIA method for this classification which is a new and developing technique, yet perfectly applicable to any type of satellite sensor using medium, high, and very high-resolution images. No vegetation indexes estimated because the goal of the study was to determinate the land use changes and not the vegetation status.

3 Results

The results are presented in Table 2. Considering a total study area of 2079.60 ha and calculating the coverages area of each coverage obtained after the classification images process and a kappa index of 1 for all the images.

In the Fig. 2, the maps of the coverages obtained are present.

According to the results, it is possible to observe how the land uses have changed, how the forest coverage decreases, as well as how the grassland coverage increases.

The obtained transition matrix for the period 2000–2020 indicates that the forests were maintained at 63.65% and the grasslands at 11.30%, while the change from forest to grassland was 13.23%. In these 20 years of study, 108 ha of forest and 102 ha of uncovered areas were replaced by pastures; the study area remained 77% and changed 23%. Figure 3 shows the changes during the study period (2000–2020) in summary form:

As seen in sequence in Fig. 2 for different time periods, Fig. 3 shows a considerable percentage of the area has changed (23%) during the entire period under consideration. Table 3 shows the results of the transition matrix for the 20 study years.

As seen in Table 3, forest is being replaced mainly by grasslands and a loss of 23% means that, approximately, a

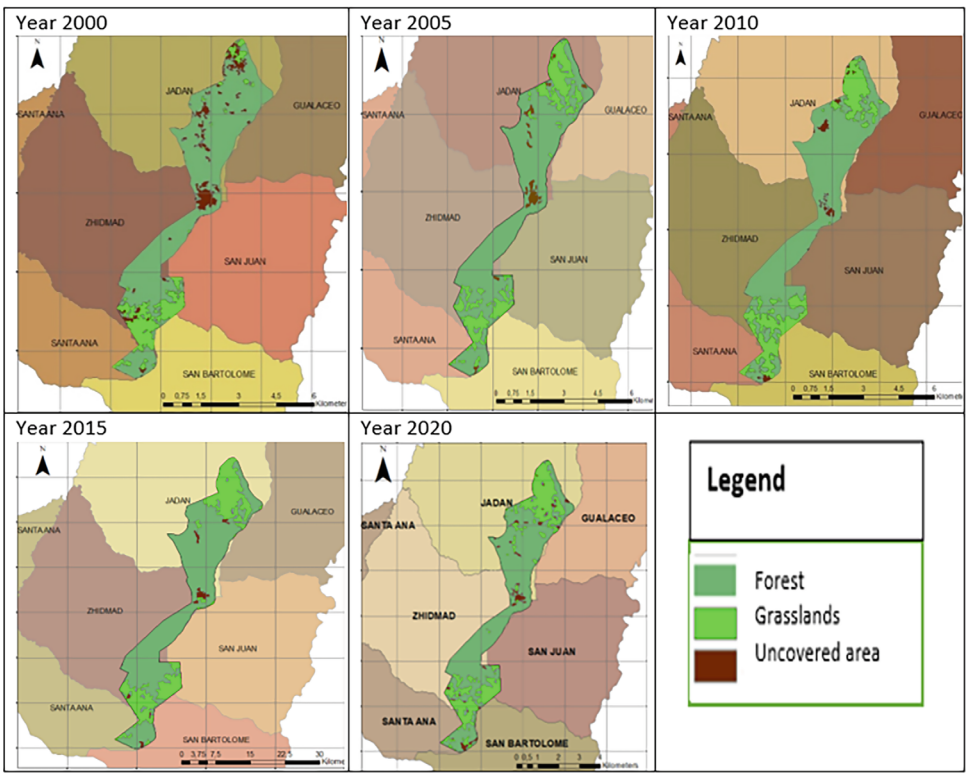


Fig. 2 Maps of the land use coverage during years 2000, 2005, 2010, 2015, 2020

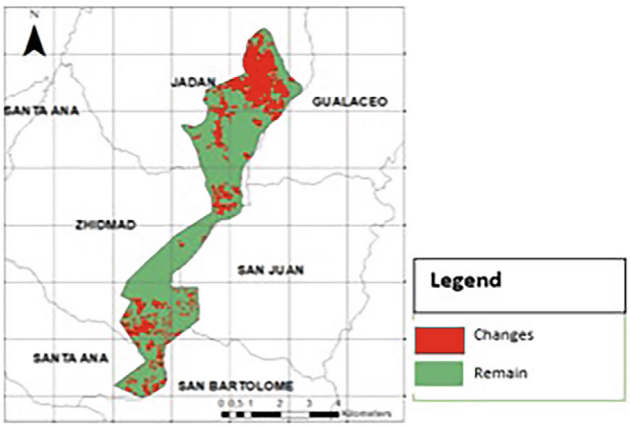


Fig. 3 Maps of the total changes during the study years 2000–2020

Table 3 Transition matrix summary

Description	Change	Area ha	%
Forest	Forest remains	1316.66	63.65
Grasslands	Forest to grasslands	273.66	13.23
Uncovered areas	Forest to uncovered area	25.13	1.21
Forest	Grasslands to forest	51.89	2.51
Grasslands	Grasslands remain	233.78	11.30
Uncovered area	Grasslands to uncovered area	4.04	0.20
Forest	Uncovered area to forest	60.71	2.93
Grasslands	Uncovered area to grasslands	69.89	3.38
Uncovered areas	Uncovered area remains	32.93	1.59

quarter of the protected area has been lost due to agricultural frontier advance.

4 Discussion

This study shows the usefulness of satellite imagery as a tool for studying historical changes in land use as well as to evaluate deforestation processes, as has been suggested in other investigations (Chuvieco 2008). The advance of the agricultural frontier continues to be one of the main threats to the loss of forest cover despite being in a protected area, as was made visible in the study of (Espinoza and Manzero 2015), who highlight the impacts of changes in land use coverage within protected areas. The advance of grasslands in the Aguarongo Forest and the loss of forest cover can be evidenced. The territorial planning documents of the cantons in which the Aguarongo Forest is located have maps that show a variation with respect to this study in the area occupied by the forest so they should be uploaded.

5 Conclusions

The Aguarongo Forest has suffered deforestation and the agricultural frontier has advanced, displacing the forest. Throughout the study period, there is a decrease of 188.95 ha of forest and 100.07 ha of uncovered areas, which have been replaced by 287.79 ha of grasslands. There is a considerable advance of the agricultural frontier. Despite the declaration of the Aguarongo Forest as Protected Vegetation Forest in 1985, 23% of the forest has been lost from the year 2000 to the year 2020. It is evident that these declarations do not show to be efficient in the conservation of this ecosystem, and the advance of the agricultural frontier continues to be its greatest threat. It is suggested to implement more restrictive measures in the use of land and vegetation cover that allow to protect the forest starting with an update of the territorial planning documents and the forest limits. Reforestation programs as well as the implementation of agroforestry systems should be efficient to protect the study area.

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Tunisian Forests in a Changing Climate: Resilience and Adaptation to Climate Change

Issam Touhami, Touhami Rzigui, Ali Khorchani, Hamdi Aouinti, Mohamed Tahar Elaieb, and Mohamed Larbi Khouja

Abstract

In its Fifth Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) concluded with heightened certainty that global climate change is unequivocal. The average global temperature in 2020 is projected to be approximately 1.2 °C above the pre-industrial (1850–1900) level. Climate change has impacted natural ecosystems, leading to increased temperatures and altered precipitation patterns. Many forest regions worldwide, particularly Tunisian forests are susceptible to the long-term effects of drought, resulting in reduced tree growth and health and increased vulnerability to insect pests and pathogens. This paper presents a review of the current state of knowledge regarding the impacts of climate change on sclerophyllous and semi-deciduous forest ecosystems in Tunisia. The research focuses on reviewing natural disturbances in recent years and exploring how certain forest species contribute to adaptation and resilience in the face of climate change in Tunisian forests.

Keywords

Mediterranean ecosystems · Climate change · Drought effects · Disturbances · Tree mortality · Forest resilience

I. Touhami (✉) · A. Khorchani · H. Aouinti · M. T. Elaieb · M. L. Khouja
Laboratory of Management and Valorization of Forest Resources, The National Research Institute of Rural Engineering, Water, and Forestry, INRGREF, University of Carthage, Ariana, Tunisia
e-mail: issam_touhami@yahoo.fr

T. Rzigui
Institut Sylvo-Pastoral de Tabarka, Université de Jendouba, Tabarka, Tunisia

Forest ecosystems play a crucial role in climate stabilization, providing essential resources such as food, water, wood products, and medicines, and supporting a significant portion of the world's biodiversity. Despite reduced deforestation rates in certain regions, forests face substantial threats. According to research from the World Resources Institute (WRI), 30 percent of global forest cover has been cleared, and an additional 20 percent has been degraded, leaving only about 15 percent intact, with the rest fragmented. Analyzing the complexity of forest damage is a challenging research issue that various authors have addressed (IPCC 2014; Touhami et al. 2023). In the Mediterranean area, particularly in North Africa, studies have indicated an increase in air temperatures, coupled with general trends of declining rainfall (IPCC 2014). Anticipated changes are even more significant as the fifth report (AR5) identifies this area as one that will be particularly affected by climate change (IPCC 2014). This study reviews existing knowledge about potential climate change impacts on Tunisian forests and seeks to understand the adaptive capacity of certain forest species to cope with changing conditions.

1 Methodology

The methodology employed in this research involves a systematic search for published surveys on climate-induced forest decline and mortality in Tunisia during recent years. This search is conducted using the SCOPUS, ISI Web of Science, and Google Scholar databases. The review focuses on examining the impact of climate changes on Tunisian forests and providing a comprehensive overview of the current understanding of how certain forest species enhance resilience to climate change. For each identified paper, metadata on the study location and methodological approach (empirical, experimental, or simulation-based) are recorded. Additionally, consultation with regional forestry experts is

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undertaken to identify examples documented in governmental reports and other sources (such as data and photos) beyond the scientific literature.

2 Results

2.1 Observed Changes in the Climate System

The average temperature in 2020 increased by 1.2 °C compared to the pre-industrial level of 1850–1900 (Fig. 1). Africa's annual temperature has shown a notable rise of 0.12 °C per decade since 1910, doubling to 0.31 °C since 1981 (NOAA 2020). In Tunisia, the mean annual temperature has witnessed an average increase of 1.4 °C throughout the twentieth century, with the most significant warming occurring since the 1970s. Annual rainfall in the northern part of the country has experienced a decline of 5% per decade since the 1950s, accompanied by an increase in the frequency of heavy rainfall events. Climate changes, characterized by elevated temperatures and modified precipitation patterns, have impacted natural ecosystems (IPCC 2014). Drought is often cited as the primary stressor leading to tree dieback; however, injuries caused by frost, wind, and insects can also contribute to decline.

2.2 Tree Cover Loss

Between 2001 and 2019, Tunisia experienced a loss of 26,900 hectares of tree cover, representing a 12% decrease in tree cover since 2000 (Fig. 2a). In this period, 5.0% of tree cover loss in Tunisia occurred in areas where the primary drivers were associated with deforestation. The region's most significantly impacted were Bizerte and Jendouba, accounting for 55% of all tree cover loss between 2001 and 2019. Bizerte witnessed the highest tree cover loss, with 9910 hectares lost, compared to an average of 1058 hectares (Watch (GFW) 2021).

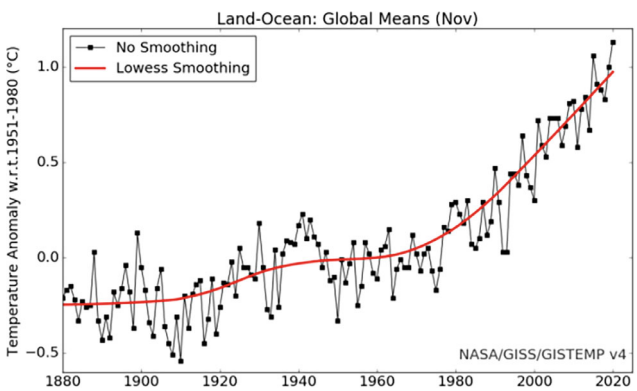


Fig. 1 Average annual global temperatures since 1880 compared to the long-term average (1901–2020) (NOAA 2023)

2.3 Fire

Tunisia's forested area spans one million 300 thousand hectares, primarily located in the North-West, Central-West, and Northern regions. The fire season typically extends from May to October each year. In 2020, the number of fires in Tunisia exceeded the recorded figures for the previous 8 years (2011–2019). According to the General Directorate of Forests (DGF), 438 fires were reported by August 28, 2020 (Fig. 2b), affecting 1958 hectares of forests. The hotter-than-usual weather in 2020 increased the frequency and risk of wildfires. Between July 22 and the beginning of August, an accelerated rate of wildfires occurred, with fifty-five fires reported in the governorates of Béja, Jendouba, Kef, Siliana, Bizerte, and Nabeul.

3 Discussion

Climate change poses substantial risks and challenges for forests, presenting a significant threat to forest managers (Touhami et al. 2021). The inherent lack of adaptive responses of trees to environmental changes renders forests sensitive and vulnerable to the impacts of climate change. In Tunisia, forests play a vital role in providing various socioeconomic benefits, including energy, construction materials, food, and essential environmental services such as carbon storage, biodiversity support, and climate regulation. Climate change is expected to have complex effects on cork oak forest ecosystems, particularly during extreme drought events, as suggested by Touhami et al. (Touhami et al. 2021). Numerous studies in Tunisia have focused on understanding the adaptation and resilience mechanisms of trees to extreme heat events and prolonged drought (Rzigui et al. 2018). For cork oak trees, (Rzigui et al. 2018) demonstrated that populations with lower stomatal and hydraulic conductance exhibited better tolerance to water scarcity. These physiological changes are likely the result of population-level divergence in phenotypic plasticity. Additionally, research on the impact of summer drought on photosynthetic capacity in cork oak populations native to different ecological conditions revealed significant population-level differentiation, with cork oak from dry sites exhibiting higher tolerance (Jazzar et al. 2019).

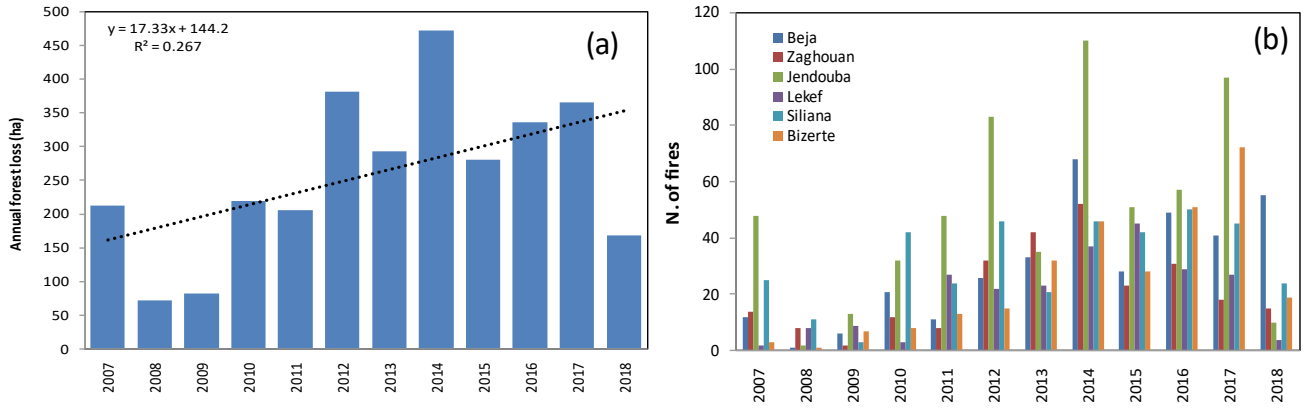


Fig. 2 The graphs show **a** The annual forest loss in hectares between 2007 and 2018 and **b** The number of forest fires from the 2007—2018 period in Tunisia

4 Conclusions

Climate change is causing more frequent and extreme events in the Mediterranean region, such as heatwaves and droughts, disrupting forest species and impacting their productivity and product quality. Trees and forest ecosystems exhibit diverse adaptive capacities in response to climate changes. Understanding the adaptive capacity of certain species is crucial for identifying which ones are most vulnerable to the effects of climate change.

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The Temporal Variability in the Relationships Among Discharge and Suspended Sediment Concentration Within Two Small Contrasted Mediterranean Catchments (Middle Atlas of Morocco)

Hassan Ouakhir, Hanane Reddad, Josep Fortesa, Julián García-Comendador, Yahia El Khalki, Mohamed El Ghachi, and Joan Estrany

Abstract

In the Maghreb region, land uses and lithology influence runoff generation soil detachment. This research aims to evaluate the hydro-sedimentary dynamics within two Mediterranean catchment areas characterized by contrasted land cover practices (agricultural and agroforestry) and lithology types. The two studied catchments (i.e., < 2 km^2), located at the headwaters of the Srou River basin (1443 km^2), in the Moroccan Middle Atlas, were instrumented in October 2017 to continuously monitor water and suspended sediment fluxes. Annual and seasonal data of precipitation, runoff, and sediment load were computed to evaluate the intra- and inter-annual variability. Six representative flood events were also selected and assessed, occurring from October 2017 to December 2019. These events were analyzed to discover the primary factors influencing sediment generation using bivariate statistics and examining the hysteresis patterns between flow and suspended sediment concentrations. At the annual scale, variations in lithology and land uses attributes led to differences in sediment yields between agricultural (ranging from 895 to 674 t km^2 $yr.^{-1}$) and agroforestry (varying from 411 to 346 t km^2 $yr.^{-1}$) catchments. An examination of the seasonal runoff revealed that 43% and 38% of the total runoff were produced during the spring in the agricultural and agroforestry catchments, respectively. During the spring season, the agricultural catchment witnessed the greatest sediment load, accounting for 66% of the annual load, while the agroforestry catchment achieved 72%. The specific flood events evidenced that land use was the primary factor influencing sediment load behavior. Within the agricultural catchment, the prevalence of bare soils without protective vegetation promoted the increase of erosion processes and the generation of badlands. Conversely, in the forested catchment, the distribution of forest cover at the headwater parts contributed to reduce runoff and sediment generation. The most frequent occurrence of hysteresis patterns observed in both catchments was the figure-eight, indicative of the interplay of diverse runoff generation mechanisms.

Keywords

Suspended sediment transport · Runoff generation · Hysteretic loops · Agricultural and agroforestry catchments · Middle Atlas · Morocco

1 Introduction

To address the global change concerns affecting earth system dynamics such as erosion processes in hotspot areas like Morocco, it is essential to comprehend the factors and mechanisms governing water and sediment fluxes, useful variables for assessing land degradation processes. This understanding is pivotal for grasping the sediment budget within a catchment, comprehending biogeochemical cycles, assessing human influences on sediment movement, and executing strategies for soil conservation (Walling and Webb 1987; Fortesa et al. 2020; Milliman and Syvitski 1992). This communication primarily uses continuous monitoring of water and sediment fluxes to assess suspended sediment

H. Ouakhir · H. Reddad · Y. El Khalki · M. El Ghachi
Laboratory «DPRP», Faculty of literatures and Humanities, Sultan Moulay Slimane University, Beni Mellal, Morocco

J. Fortesa · J. García-Comendador · J. Estrany (✉)
Mediterranean Eco-geomorphological and Hydrological Connectivity Research Team, Geography Department, Palma, Spain
e-mail: joan.estrany@uib.cat
URL: http://medhycon.uib.cat

J. Fortesa · J. García-Comendador
The Agro-Environmental and Water Economy Research institute of–INAGEA, Balearic Islands University, Palma, Spain

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dynamics at two small headwater contrasted catchments in Morocco's Middle Atlas to decode sediment transport mechanisms by interpreting how sediment sources are distributed spatially and how rainfall, runoff, and discharge dynamics interact (Hessel et al. 2014). Furthermore, the hysteresis patterns or loops used for understanding sediment transport processes by interpreting the spatial distribution of sediment sources, the dynamics of rainfall, runoff, and discharge.

2 Study Area

The focus of this research is developed within two small contrasted catchments; the agricultural Talhiant Creek (Agr-cat; 1.14 km^2) and the agroforestry Mougeryberdan Creek (AFo-cat; 1.15 km^2). These catchments are located at the headwaters of the Srou River basin (1443 km^2), located in Morocco's Middle Atlas region (Barakat et al. 2019) (see Fig. 1). Geological data extracted from Rabat map with 1:500000 scale (1976) revealed that lithology features for both catchments are composed of red clay, shale, siltstones, and basalt. These lithological components are a blend of sedimentary, metamorphic, and volcanic rocks (refer to Fig. 1c, d).

2.1 Monitoring and Data Calibration

In April 2017, the installation of two measurement stations was completed at the outlet of the studied headwaters. This facilitated the continuous monitoring of water stage and turbidity measurements. The gauging station of the Agr-cat is situated within the central-western area of the Srou River basin at an altitude of 819 m. Similarly, the gauging station for the Afor-cat is positioned in the northeastern part of the Srou River basin, at an elevation of 998 m. Both monitoring sites were established within rectangular cement structures

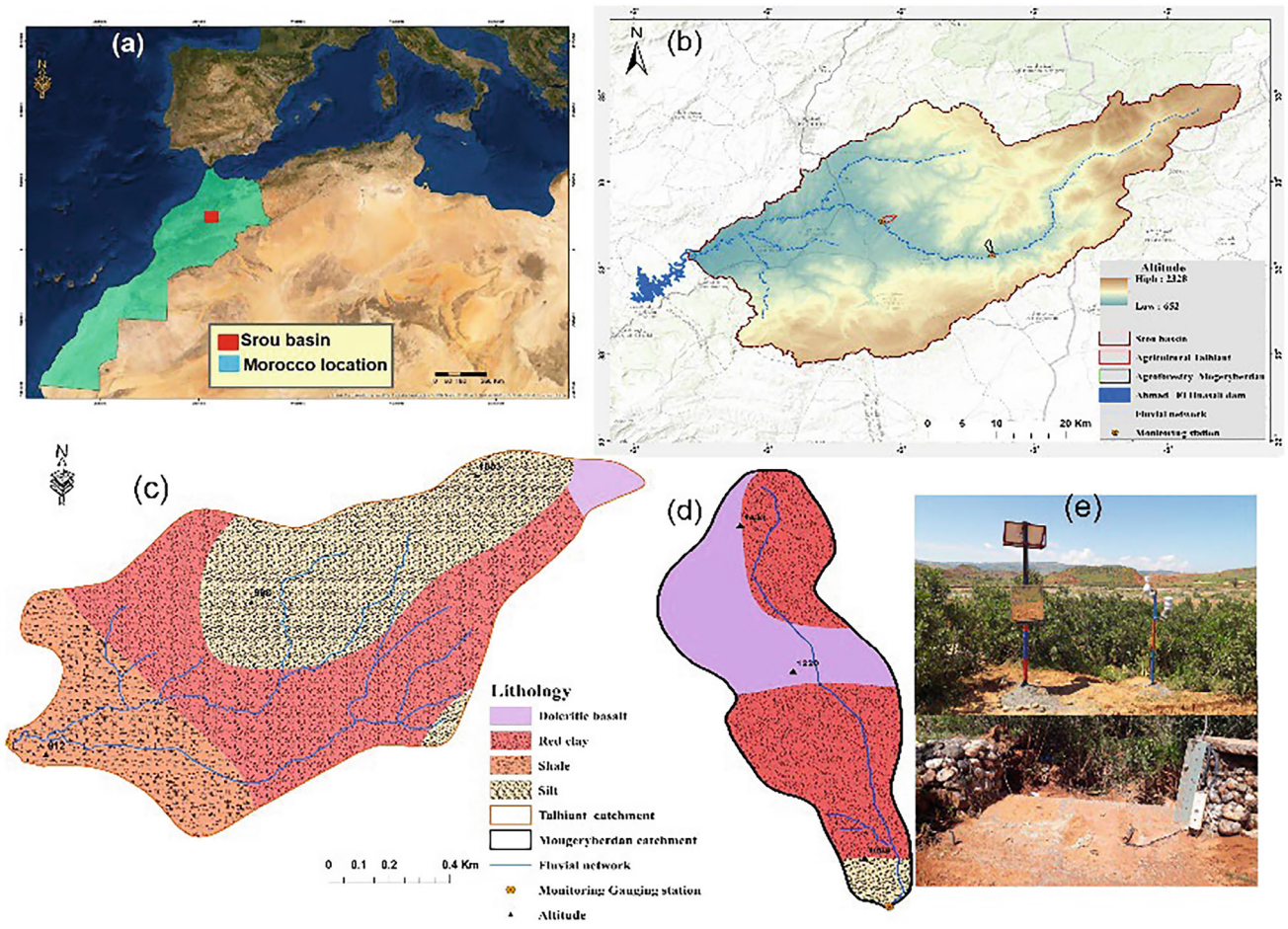


Fig. 1 **(a)** Location of Morocco in North Africa and within the southern Mediterranean region; **(b)** location of the Srou Basin within Morocco; **(c)** lithology of the agricultural Talhiant catchment; **(d)** lithology of the agroforestry Mougerybrdan catchment; and **(e)** location of the two monitoring stations

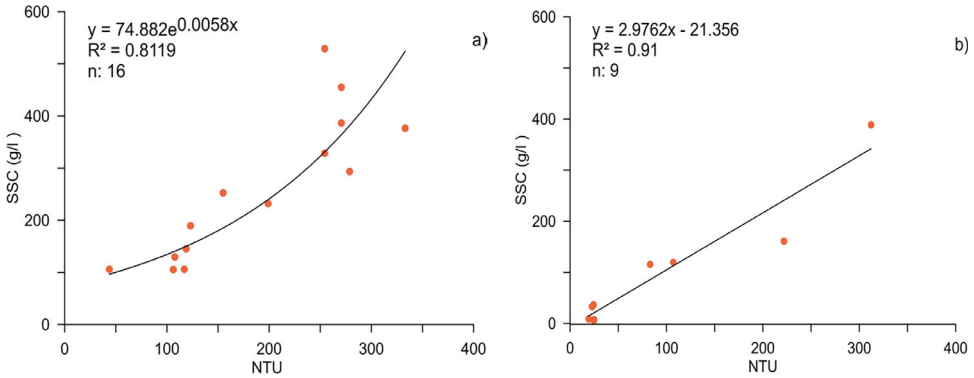


Fig. 2 Calibration relating suspended sediment concentration to measured turbidity, manual samples collected during 2018 and 2019 at **a** agricultural and **b** agroforestry catchments

with wide crests, where the channel banks are constructed using dry-stone walls to act as control sections for discharges (refer to Fig. 1e). For the continuous monitoring and recording of water levels, rain gauge data, and turbidity, a pressure sensor, the Campbell Scientific CS451, was installed and connected to a *Campbell Scientific PC200W* data logger. Turbidity measurement was carried out using self-cleaning nephelometric turbidity sensors (*NTU*), featuring a measurement range starting from 1.000 to 3.000 *NTU*; with minimum detection limits of 0.05 or 0.5 *NTU* (Schick 1967) (Fig. 2).

2.2 Rainfall, Runoff, and Suspended Sediment Relationships

Rainfall (R), runoff (R), and suspended sediment concentration (SSC) and load (SL) were computed at the annual, seasonal, and the event scales using continuous monitoring data over two normal years (2018 and 2019). This analysis aimed to evaluate their temporal patterns. The SL was measured based on the catchment area to derive the sediment yield (SY). An extensive database containing data for 87 flood events was extracted and organized, including information for P, R, Q, and SS.

2.3 Hysteresis Loops

The qualitative examination of the interactions between R, Q, and SSC involves comparing the SSC/Q ratios during both the ascending and descending limbs. The relationships were analyzed using the hysteresis patterns investigated by Williams (1989). Five common classes of these relationships were analyzed at the studied catchments: single line, clockwise loop, counter-clockwise loop, figure-eight, and complex loop.

3 Results

3.1 Hydro-Sedimentary Response at Different Scales

3.1.1 From Annual to Seasonal Scales

Rainfall at the annual scale ranged from 807 to 328 mm yr.$^{-1}$ at Agr-cat, and from 925 to 604 mm yr.$^{-1}$ at AFor-cat during the 2018 and 2019 years, respectively. Computing the flood events by seasons, spring recorded the most significant hydro-sedimentary response when 43.36% of R also generated the 65.62% of SL at Agr-cat; being 38.25% of R and the 71.95% of SL at AFor-cat. Autumn was the second season, recording 28.96% of R and 22.97% of SL at Agr-cat; and 22.28% of R and SL 15.54% at AFor-cat. During winter, R shown an important percentage of 27.68% and 22.28%; while SL recorded a lower value 11.41% and 15.51%, respectively, at the two catchments (Table 1).

Table 1 Relative contribution of runoff and suspended sediment load at event time scale during the study period 2018/2019 at both catchments

	Relative seasonal contribution (%)		
Agr-cat 2018/2019	Season of the event	Runoff (%)	Suspended sediment load (%)
	Winter	27.68	11.41
	Spring	43.36	65.62
	Autumn	28.96	22.97
AFor-cat 2018/2019	Winter	39.15	12.51
	Spring	38.25	71.95
	Autumn	22.28	15.54

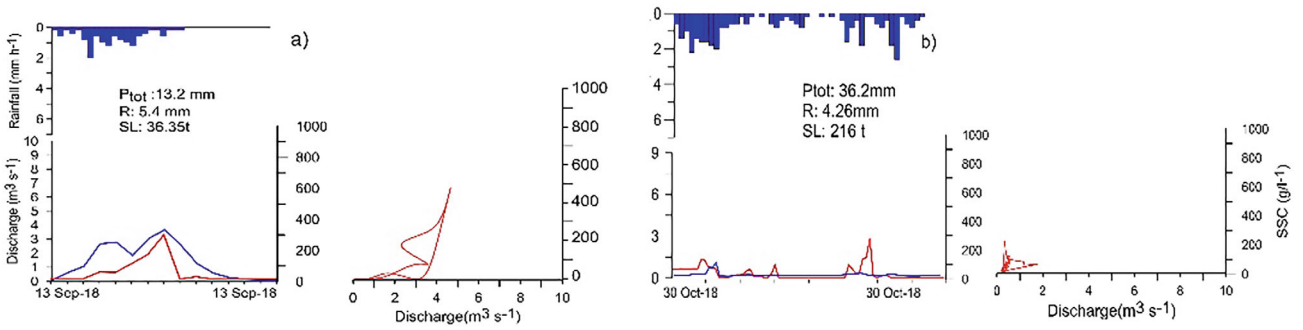


Fig. 3 R, Q, and SSC for the representative events and the hysteresis patterns for each event at both contrasted catchments

3.2 Hysteretic Loops for Discharge-Suspended Sediment Concentration at Event Scale

At Agr-cat, 4 of the 32 flood events (13%) showed clockwise hysteretic loops, and 13 events (41%) displayed figure-eight being the most dominant class in this catchment. In addition, seven events (22%) showed complex hysteretic loops. Whereas, at AFr-cat, the most dominant hysteretic class was complex, being 15 of the 34 flood events (44%) and 13 events (38%) showed figure-eight. Figure 3 illustrates these hydro-sedimentary dynamics for the most representative flood events at both catchments.

4 Discussion

By comparing the hydro-sedimentary responses of the two distinct catchments, we can uncover the significance of catchment attributes and delve into the analysis of the implicated processes. As noted by Probst and Suchet (1992), specific suspended sediment yields in the Maghreb region can be notably high. Several drainage basins exhibit sediment yields surpassing 700 t km^2 yr^{-1}, with five basins exceeding 4500 t km^2 yr^{-1}, and a peak of 7200 t km^2 yr^{-1} observed for the Agrioun River in Algeria. The obtained results are also compared with the findings of (Fortesa et al. 2020; Estrany et al. 2009). The correlation between hotspot erosion rates and downstream sediment yields provides insights into the mechanisms of sediment delivery within a drainage basin. The hysteresis assessment allowed a first approach to sediment provenance in both catchments, elucidating that the dominance at Agr-cat of figure-eight could be related to heterogeneous sizes of sediment or different runoff generation processes, especially during the spring when drying-up could alter the hydrological pathways activation. Precisely, the dominance of complex figures at AFr-cat could also be related to this alteration due to higher evapotranspiration demand by forests. Furthermore, hysteretic loops hold crucial insights into sediment provenance within diverse catchments. The prevalence of figure-eight loops in Agr-cat reflects intensified erosion due to exposed soil surfaces and the dynamic of land use/land cover, resulting in rapid sediment generation and accumulation during flush flood events. Conversely, the intricate and complex loops observed and dominated in Afor-cat signify a more complex interplay between soil characteristics, vegetation density, and land management practices, yielding diverse sediment sources and pathways (Walling and Webb 1987).

5 Conclusions

This communication has investigated the temporal variability in the relationships among discharge and suspended sediment concentrations within the two small contrasted Mediterranean catchments in the Middle Atlas of Morocco. The hydrological dynamics of both studied catchments are underscored by their contrasting annual rainfall ranges and distinctive seasonal hydro-sedimentary responses. Furthermore, the dissimilarities between the studied headwaters are also evident in their hysteresis behaviors. While agricultural catchment is characterized by a notable prevalence of figure-eight loops among its flood events, whereas the agroforestry catchment exhibits a different pattern with complex loops dominating its flood events. This clear distinction in hysteresis behavior revealed the contrast hydro-sedimentary dynamics between the two catchments.

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An Assessment Framework for the Sustainable Energy and Climate Action Plans and their Contribution to Urban Biodiversity in Northern Italy

Luca Lazzarini and Israa Mahmoud

Abstract

This paper aims at assessing the contribution of the sustainable energy and climate action plans (SECAP) to conserving natural habitats and improving biodiversity from a sample of 24 provincial capital cities in Northern Italy. The plans are systematically analyzed through a quantitative assessment binary framework that took into consideration five criteria: (1) strategies and actions linked to biodiversity, (2) monitoring indicators and (3) expected costs and resources needed to implement the actions, (4) tools and mechanisms of public participation and community engagement, and (5) account of vulnerable groups and context-specific vulnerabilities in the plan. Findings highlight the multiple actions related to urban biodiversity, where the attention is not just on new urban greening interventions but also on experimenting with new forms of management of green areas and monitoring the plant and animal species. Moreover, the relevant role that context-specific vulnerabilities and path-dependent factors play in each city toward defining the components of the SECAP emerges. One limitation concerns the significant trade-offs between the urgency of climate change threats and the weak actions put in place, constricted by limited financial resources and scarce expertise in the local governments.

Keywords

Urban biodiversity · Climate change · Climate plans · Public participation · Community engagement

L. Lazzarini (✉) · I. Mahmoud
Laboratorio di Simulazione Urbana Fausto Curti, Department of Architecture and Urban Studies (DAStU), Politecnico di Milano, Milan, Italy
e-mail: luca.lazzarini@polimi.it

I. Mahmoud
e-mail: israa.mahmoud@polimi.it

1 Introduction

Environmental pressures in urban and peri-urban areas have become a major challenge for cities and metropolitan regions to ensure the protection of natural resources while also enhancing territorial resilience. Among, a key concept approach is urban biodiversity (UB) which came to the vanguard of the debate to guide the ecological transition in the European context lately after the EU Strategy for Biodiversity 2030. Nonetheless, recent studies on the integration of aspects such as green infrastructure (GI), nature-based solutions (NBS), and biodiversity in policy-making processes reveal a limited acknowledgment of such concepts in urban planning, especially in the Italian context where conditions of inertia, scarce innovation, feeble institutional commitment are often encountered.

Within this context, this paper aims at assessing the contribution of the sustainable energy and climate action plans (SECAP) to restore and improve UB from a sample of 24 provincial capital cities in Northern Italy. The objective is to investigate what strategies and actions the SECAPs put in place to increase biodiversity in urban contexts and what levels of commitment to implementation characterize these plans. This contribution is organized into three sections. Section 2 introduces the research framework and methodology which is based on a quantitative assessment framework taking into consideration five criteria. Section 3 highlights the results based on each of the criteria examined. The contribution ends with a discussion and conclusion section which underlines a few critical issues emerging from the analysis.

2 Methodology

The sample is formed by the SECAPs adopted by the provincial capital cities in seven Northern Italian regions (Valle d'Aosta, Piemonte, Lombardia, Trentino Alto Adige,

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Friuli Venezia Giulia, Veneto, and Emilia-Romagna). Twentysix SECAP were mapped on a total of 47 provincial capital cities. Despite being approved, 2 SECAP (Vicenza and Lecco) were excluded from the sample because the plan documents could not be retrieved from the municipal websites. The decision to focus on the Northern Italian provincial capital cities is framed within the undergoing research activities conducted by the research unit of POLIMI/DAStU for the National Biodiversity Future Center (NBFC), one of the five national research centers created and funded by the National Recovery and Resilience Plan (PNNR) and dedicated to the topic of biodiversity conservation, monitoring, and enhancement in the Mediterranean context. Specifically, the analysis is part of the activities performed by the Spoke 5 of the NBFC, oriented to examine biodiversity patterns and dynamics in urban contexts and, specifically, Task 3.1 having the objective to build a screening of plans and projects tackling UB.

The 24 plans have been systematically analyzed through a documentary analysis of the official planning documents retrieved from the municipal websites. These documents were examined through a comparative lens and a quantitative assessment binary framework, that took into consideration five criteria, each related to the presence of: (1) strategies and actions linked to biodiversity, (2) monitoring indicators and (3) expected costs and resources needed to implement them, (4) tools and mechanisms of public participation and community engagement in the plan, and (5) account of vulnerable groups and context-specific vulnerabilities in the plan. While the first three criteria are directly linked to biodiversity actions, the public participation attribute aims to understand if the SECAPs mention participatory mechanisms in relation to the identification of biodiversity-related actions and their implementation. Moreover, the reference to vulnerable groups and context-specific vulnerabilities recalls the need to see if the actions are spatialized in the local context and if the plan has a concern on the equity-justice objectives, e.g., by taking into consideration the impacts that climate risks generate on specific age groups or section of the populations living in a particular vulnerable area of the municipality (Reckien et al. 2023).

These criteria were identified by taking as reference the guidance document developed by the EU Joint Research Centre to support the Covenant of Mayors signatories in developing effective SECAPs (Andreanidou et al. 2018). Moreover, the criteria of the analysis stem from the framework of some recent contributions (Mahmoud and Morello 2021; Nilon et al. 2017; Reckien et al. 2023) and it was developed by the authors through relevant literature reviews, in addition to the consultation process with the scientific group members.

3 Results

As far as the strategies and actions related to biodiversity are considered, the analysis underlined that all SECAPs include at least one or more actions related to UB conservation, restoration, and increase, meaning that this criterion is widely tackled by the plans. Six clusters of actions can be identified [see Fig. 1]. The most recurring actions refer to three clusters: (i) the creation of new urban green areas (trees, orchards, urban parks, rain gardens, sustainable urban drainage systems, and other NBS) (42 actions in 19 plans), (ii) the management and monitoring of green spaces, including plant and animal species (19 actions in 14 plans), and iii) the protection and enhancement of specific habitats, including prevention from wildfires and other hazards (11 actions in 7 plans). It is important to mention that the first cluster also comprises a relevant number of actions referring to the creation of urban forests. This denotes an embodied attention toward the multiple benefits of urban forestry as a specific typology of urban greening interventions to improve climate change adaptation in the city (Matsler et al. 2021; Scheuer et al. 2022). Nevertheless, in some plans, it was noted that interventions related to agriculture and forestation were totally disconnected from the biodiversity ambits with mere connections to the green plan frameworks to be developed by each local authority, yet, not with concrete measures to correlate among each other.

The use of indicators for monitoring and evaluating the implementation of the actions as mentioned above is expressed in the majority of plans investigated (18 plans). This shows the relevance that the dimension of commitment to implementation has in the SECAPs, which is stronger than the one usually found in statutory or sectoral planning, especially in the Italian context.

Being also related to the commitment to implementation dimension, the expected costs and resources criterion is present in a smaller number of plans (9 plans), with a majority of them (15) having no specific or detailed account of the financial resources needed to bring those actions into reality. Moreover, the reference to the typology of funding to be retrieved is present (e.g., EU, national, regional, or municipal resources) but no detailed account of the dedicated budget is specified.

The mention of the public participatory processes and mechanisms to sustain and inform the plan elaboration is denoted in 14 plans up to 24, although with a variety of forms and different scales of involvement in the planning process. In some plans, participation is developed in a preliminary phase and is oriented to share the SECAP objectives and focus with an array of stakeholders from the locality. In some cases, participation permeates distinct phases of SECAP going beyond the mere communication of its key challenges

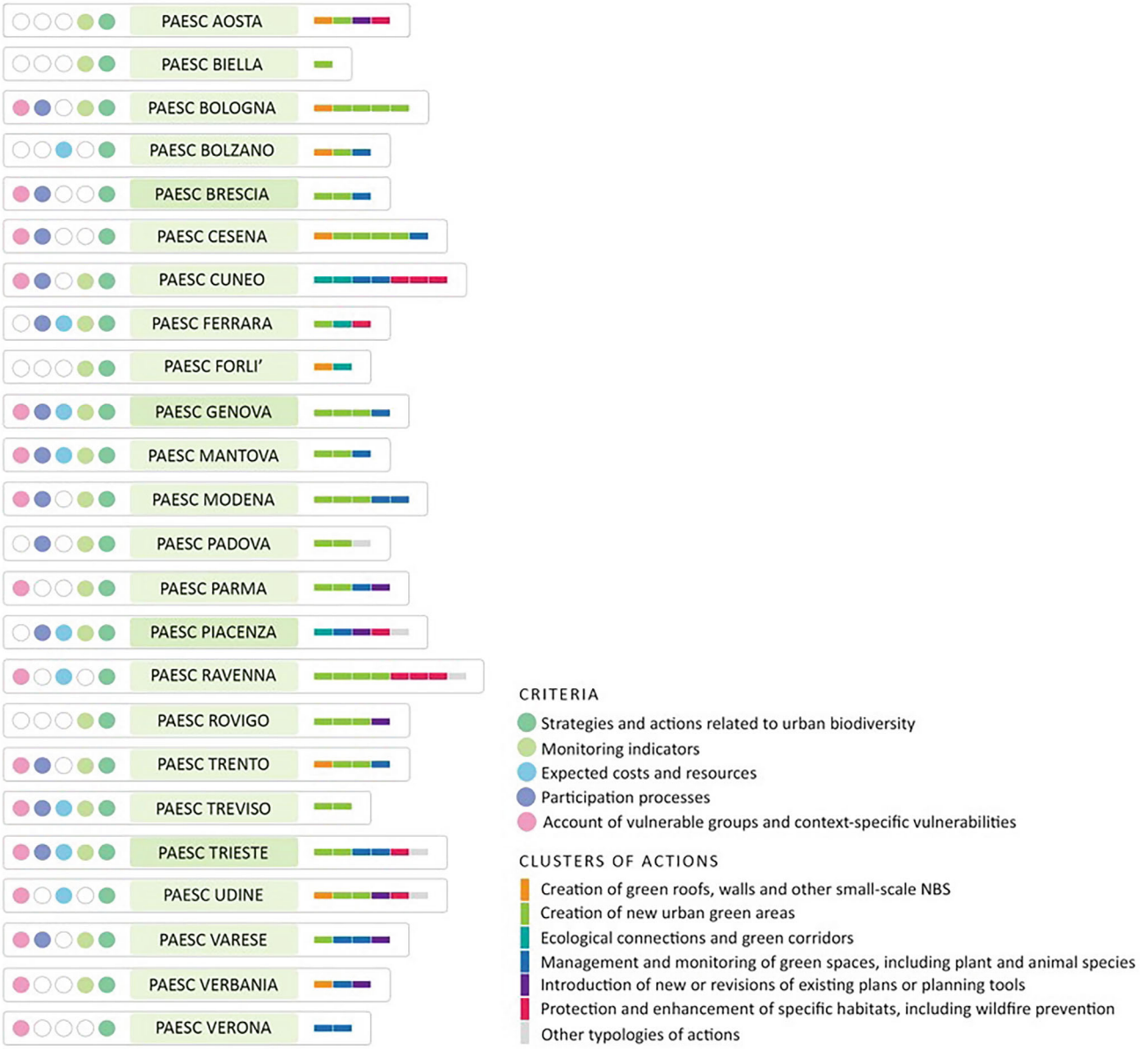


Fig. 1 Diagram showing the criteria and number of actions according to the six clusters identified related to biodiversity for each plan. *Source* elaboration by the authors

to the local community, from the co-design of some of the actions of the plan, to their co-implementation and the co-monitoring of its results, which eventually increases the plan effectiveness (Mahmoud and Morello 2021).

The account of vulnerable groups and context-specific vulnerabilities is mentioned in 16 plans. This demonstrates that the strategies and actions by SECAP are frequently developed with an attention to consider the impact they have on the municipal territory, although the forms of vulnerability mostly tackled by the plans are the physical and environmental rather than prioritizing the socio-economic ones (Reckien et al. 2023).

4 Discussion and Conclusion

Summarizing, the SECAP plans under investigation have defined multiple strategies and actions related to UB, with an attention on the creation of new urban green areas such as orchards, rain gardens, urban forests, but also small-scale NBS interventions such as green roofs and walls on the existing built environment, as in the case of the Bologna PAESC. Those actions are mainly clustered as physical interventions when relating to biodiversity, which comes as a priority in all plans. From the 24 plans analysis, it is evident that some cities do refer to the biodiversity increase and

conservation actions within a general framework toward enhancing resilience to environmental hazards and risks rather than a specific action that merely acts on biodiversity per se. Also, it is notable that the actions on natural environments and forestation areas have connections with the territorial vulnerability to climate change hazards and risks, and their impacts on the local population are only considered throughout maintenance and monitoring phases, as in the case of the Parma PAESC for instance.

A noteworthy aspect concerns the significant trade-offs between the urgency of climate change threats and the scarce attention that plans devote to the issue of financial resources needed to implement the actions. The analysis has shown that a relevant number of plans are constricted by a way too broad specification of the amount and typologies of resources needed for their implementation. At the same time, when a budget is specified, this clashes with the limited financial resources and scarce expertise that often characterize local governments in Italy. One way to tackle these issues would be to activate specific measures and forms of support at the national level dedicated to the implementation of climate plans and the monitoring of their impacts.

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Mediterranean Ecosystems: Conserving Water While Enhancing Transplanting Success Under the Challenges of Climate Change

Valasia Iakovoglou and Aikaterini Syropli

Abstract

Mediterranean ecosystems retain high levels of biodiversity. Hence, their ecological footprint is of great importance. Abiotic factors such as water-deficit conditions are frequent phenomena for those semi-arid areas, particularly during summertime. The increased intensity and frequency of those phenomena due to climate change pose additional obstacles to their sustainable management and conservation. This study investigated the impact of irrigation treatments on seedling performance of forest species and their potential for successful transplanting while conserving water. It was hypothesized that seedlings pretreated to reduced irrigation frequencies help trigger physiological cues that enable them to overcome water-deficit-stressed environments. The studied species were selected according to altitudinal differentiation based on the species' distribution. Pine seedlings of low-altitude (*Pinus halepensis* Mill.) and high-altitude species (*Pinus sylvestris)* were subjected for a month to three irrigation frequencies: two irrigations per week, one irrigation per week, and one irrigation per two weeks. The Root Growth Potential (RGP) was used as an indexed variable to address the physiological species' potential to successful transplant based on the ability to grow new roots for nutrient and water exploitation. Based on the research outcome, it has been indicated that both species maintained their welfare, even under the intense stressed conditions of one irrigation per two weeks, with *Pinus halepensis* showing greater RGP. This implies that for both species, seedlings preconditioned to reduced watering conditions had characteristics (RGP) that enable seedlings to better cope with transplanting stressed conditions while also conserving water.

Keywords

Biodiversity · Restoration · Reforestation · Seedling physiology · Transplanting success

1 Introduction

The semiarid Mediterranean ecosystems are of high ecological value that associate with the increased biodiversity levels. Under the challenges of climate change, transplanting success for the Mediterranean region becomes even harder due to the enhanced aridity phenomena (Lionello et al. 2006). Forest nurseries are called upon to face those challenges and successfully restore and reforest disturbed sites.

Transplanting success could be enhanced through drought preconditioning particularly for semi-arid areas (Iakovoglou and Halivopoulos 2016). This method initiates physiological cues enabling seedlings to overcome the transplanting stress (Iakovoglou and Halivopoulos 2016). "Root Growth Potential, RGP" is a variable that addresses the ability of the seedlings to develop new roots and successfully grow under harsh field conditions (Mattsson 1986).

Pinus halepensis Mill. (Aleppo pine) and *Pinus sylvestris* L. (Scots pine) are both considered drought-tolerant, light-demanding, pioneer species (Tapias et al. 2004). They both co-exist at northern Greek ecosystems, with *P. halepensis* occurring at low altitudes (0–600 m) and *P. sylvestris* at high altitudes (1200–1600 m) (Dimitrakopoulos et al. 2011). It was hypothesized that the RGP would be greater for seedlings that received reduced watering. By studying the performance of seedlings under watering frequencies, the benefit is dual; saving water while also increasing the percent of transplanting success.

V. Iakovoglou (✉) · A. Syropli
International Hellenic University, Drama, Greece

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2 Materials and Methods

For the experimental purposes, three-year-old seedlings were placed under controlled growth condition: 14-hour photoperiod, 21 ± 2°C room temperature, and 40 ± 10% humidity. The seedlings were subjected to three irrigation frequencies: two waterings and one watering each week and one watering every two weeks. Prior to the initiation of the experiment, the seedlings were evaluated (control). Continuously, five seedlings were harvested for each irrigation treatment (total of 20 seedlings per species).

The evaluated variables were the HT (Height), RCW (Root Collar Width), and LA (Leaf Area). In order to estimate the dry weights, the seedlings were placed for 72 h in an oven at 80 °C. The evaluated dry weights were LDW (Leaf Dry Weight), SDW (Shoot Dry Weight), TRDW (Total Root Dry Weight), TDW up (Total Dry Weight above ground), and TSDW (Total Seedling Dry Weight)). The RGP (Root Growth Potential) was determined by the NRDW (New Root Dry Weight)) and the MaxNR (Maximum New Root Length) (Mattsson 1986). Also, the ratios of SLA (Specific Leaf Area) and RATIO (TRDW/TDWup) were estimated.

One-way ANOVA was used to compare irrigation treatments with the Tukey's multiple range tests at a significance level of $p < 0.05$. The data were tested for homogeneity and normality (SPSS Rel 15.0 2006).

3 Results

The results indicated differences in the physiological response of the studied species. Specifically, for *P. halepensis,* the LDW was greatest for the seedlings that were irrigated twice every week and decreased as irrigation frequency reduced (Fig. 1). On the contrary, the greatest SLA was observed for the seedlings that received the least irrigation (1 H2O/2 WK). *P. sylvestris* indicated no differences among treatments for both LDW and SLA. Similar results were revealed for the RGP-related variables, with *P. halepensis* indicating significant differences among irrigation treatments, while *P. sylvestris* responded similarly to all irrigation frequencies (Fig. 2). Specifically, both the MaxNRL and the NRDW had greater growth for the seedlings that received one watering every two weeks.

4 Discussion

Despite the physiological similarities between the species of *P. halepensis* and *P. sylvestris* (Tapias et al. 2004), they responded differently to the irrigation frequency treatments, with more profound effect for *P. halepensis.* Specifically, for the low-altitude pine species, the LDW decreased while the SLA increased as irrigation frequency reduced. This might be the result of leaf abscission that occurred during the exper-

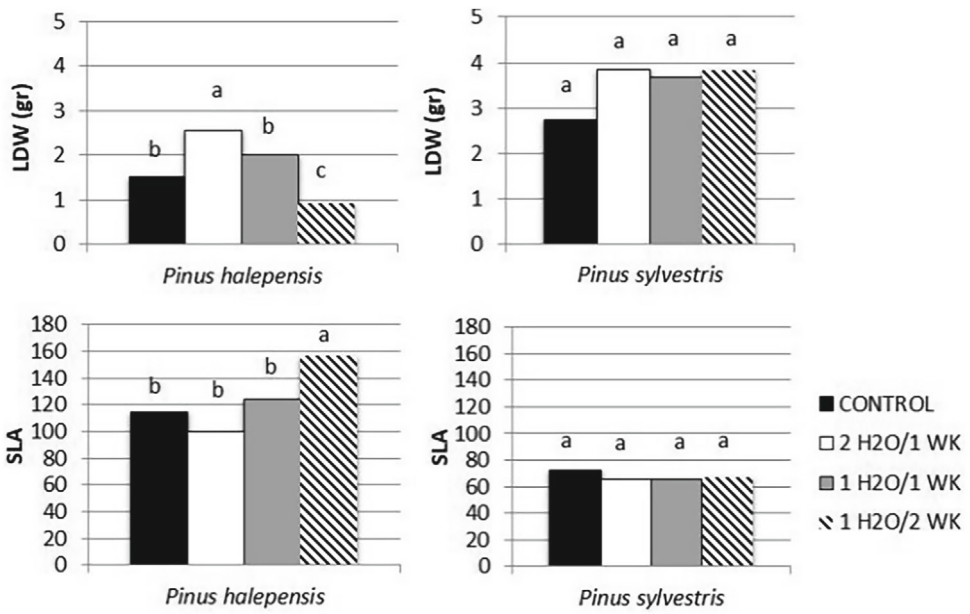


Fig. 1 Growth of *P. halepensis* and *P. sylvestris* seedlings based on irrigation treatments for SLA and LDW

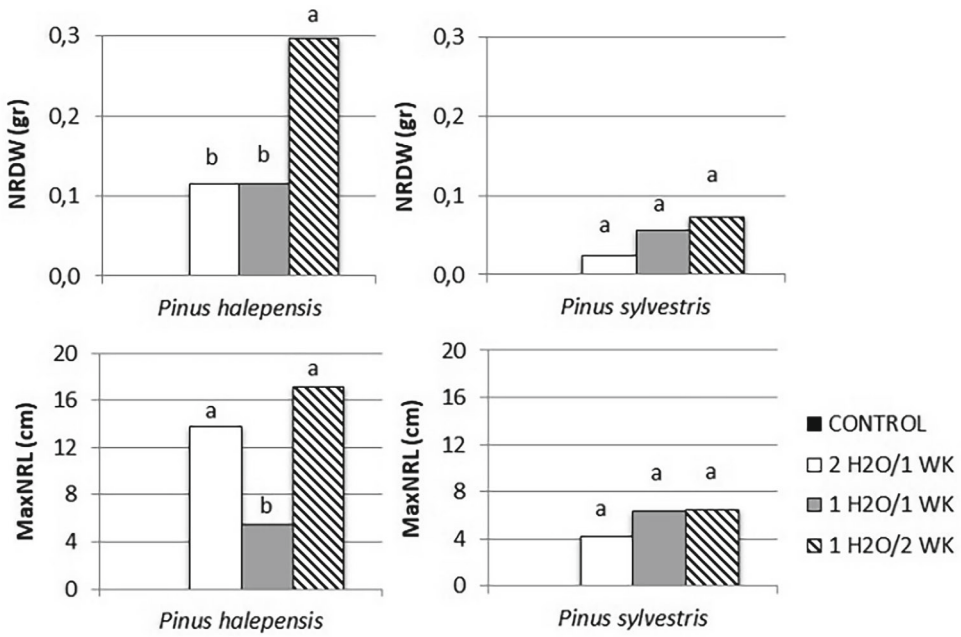


Fig. 2 Growth of *P. halepensis* and *P. sylvestris* seedlings based on irrigation treatments for MaxNRL and NRDW

imental month (experimental observation) for the least irrigated seedlings of *P. halepensis*, a defense mechanism to overcome water-deficit-stressed conditions. For the high-altitude pine species, there were no differences among irrigation treatments.

Further, the lest watered seedlings were able to respond better based on the RGP response in terms of their ability to produce new roots. That was evident by both the new root biomass accumulation (NRDW) and root elongation for increased ability for water and nutrient exploitation (MaxNRL). So, the period of one-month preconditioning was adequate to trigger physiological cues to shift the metabolic growth toward new root development for the species of *P. halepensis*. For *P. sylvestris*, although no significant differences among treatments were noted, there was an increased trend for the growth of new roots as irrigation frequency decreased. This implies that the drought preconditioning for the higher altitude species might require longer periods of drought preconditioning or another type of preconditioning such as cold treatments, associated with the physiology of high-altitude species.

Overall, the hypothesis was that seedlings pretreated to reduced irrigation frequencies helped trigger physiological cues that stimulated new root growth. That was statistically evident only for the low-altitude species of *P. halepensis*. Nonetheless, both species tolerated and maintained growth under the extremely reduced watering of only once every two weeks. So, drought preconditioning particularly for the low-altitude species of *P. halepensis* had a dual benefit: saving water while enhancing transplanting success.

5 Conclusions

It has been indicated that both species maintained their welfare, even under the intense stressed conditions of one irrigation every two weeks, with *P. halepensis* having greater RGP. In addition, altitudinal distribution should always be taken under consideration when preconditioning, even for similar physiological species like *P. halepensis* and *P. sylvestris*. Further, drought preconditioning is a useful tool for nursery practices with a dual benefit: saving water while enhancing seedling characteristics (such as RGP) that increase transplanting success.

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The Ecosystem Services Offered by Traditional Pastoralism can Guarantee the Conservation of the Environments of the Mediterranean Biogeographical Region, Natural Biodiversity, and the Calabrian Sciara/Moscia Sheep

Vincenzo Sauro, Santo Carpino, Emanuele D'Anza, Francesca Ciani, Luigi Esposito, and Nadia Piscopo

Abstract

The general concept of biodiversity loss is closely linked to the loss of wealth. If ecosystems and the organisms that inhabit them disappear, local landscapes, products, and cultures will be destroyed. The different components of agroecosystems play an active or passive role in providing Ecosystem Services or Disservices. The description of the complexity of the services offered by the ecosystem and of the benefits from an economic point of view is the future challenge to win. The impressive affirmation of globalization has push toward intensive livestock, which has contributed to the decline of genetic variability (genetic erosion). The Calabrian Sciara/Moscia sheep (SMC) is one of the breeds affected by this phenomenon. Since 2017, the authors, assisted by AssoNaPa, have identified 50–60 animals with the morphological characteristics typical of the SMC breed. The results show that the SMC sheep has productive, reproductive, and frugality potentialities which allow it to be capable of providing useful ecosystem services for the Calabrian habitats in the entire Mediterranean Biogeographical Region.

Keywords

Calabrian Sciara/Moscia sheep · ancient Orbace wool · Mediterranean Biogeographical Region · Environment conservation · Ecosystem services

V. Sauro
Associazione Nazionale della Pastorizia (ASSONaPa), Roma, Italy

S. Carpino
Associazione Regionale Allevatori Calabria (ARA Calabria), Lamezia Terme, CZ, Italy

E. D'Anza · F. Ciani · L. Esposito (✉) · N. Piscopo
Dipartimento di Medicina Veterinaria e Produzioni Animali—UNINA, Napoli, Italy
e-mail: luigi.esposito4@unina.it

1 Introduction

The acceleration of production processes has changed and reduced ecosystems and habitats as well as genetic heritage (Adla et al. 2022). The third millennium require sustainability policies to be applied aiming in the protection of biodiversity (UN 2021; Esposito et al. 2022). It is urgent to reverse the paradigm of the currently dominant model of "unsustainable growth" toward the "model of sustainable growth" (UN 1992). The political response was to provide funds in favor of breeds and species at risk of genetic erosion by making the mistake of recognizing to these living beings only the dignity of survival and not their dignity as an "ecosystem service" (Millennium Ecosystem Assessment 2005). Our study identifies animals which survive in poor habitats but can produce food and services for humans. The Calabrian Sciara/Moscia sheep (SMC) deriving from the Karakul sheep (Venturi 1946) was arrived in southern Italy with the Saracen (Scipioni 1924) and is one of the oldest breeds in the Italian peninsula (Scipioni 1924). Currently, a small group of SMC sheep is present in Calabria and National Shepherding Association (AssoNaPA) and Calabria Regional Breeders Association (ARA Calabria) will attempt to recover it.

2 Materials and Methods

The study evaluated the survival potential of the SMC sheep (critically Endangered) comparing the breed characteristics with two white breeds of sheep (Sarda, Bagnolese) and two black breeds of sheep (Massese, Arbus black sheep). We recorded: (1) the numerical consistency (herd books); (2) the morphological characteristics (withers' height, adult weight); (3) reproductive characteristics (prolificacy, fecundity, age at first calving, number of calving per year, number of lambs per calving); (4) milk

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production and products (primiparous and pluriparous milk Kg, cheeses); (5) composition of the milk (fat, protein, cheese yield); (6) wool production; (7) food characteristics (food needs, diet type, ration's cost); (8) Ecosystem Services and Disservices (Provisioning, Habitat & Biodiversity, Regulating, Cultural). To evaluate the species' differences, a scale of values from 0 to 5 were used (0 = absence; 1 = insufficient; 2 = sufficient; 3 = good; 4 = very good; 5 = excellent). The maximum score is recognized to the highest value of the different characteristics considered. The percentage of total score was statistically tested by Chi-Square test.

3 Results

The more reduced morphological traits are of the Arbus black (Table 1). Number of heads (LG n.) is very different among breeds. Ecosystem Service evaluation (0–5) is assigned. Sheep breeds are compared for reproductive (Table 1); milk production and quality (Table 2), cheese production (Table 3); wool production (Table 4); animal feeding (Table 4). Finally, the Ecosystem Services and Disservices connected to each breed are evaluated (Tables 5 and 6).

4 Discussion

To understand the extent to which it is possible to evaluate an Ecosystem Service, it would be enough quote a sentence reported by Vincenzo Dorsa in his book of the 1884 (Dorsa 1884): "*the hen must also be black and not white, as the dark color of the underworld re-quired it: in fact, the dogs were black and the sheep were black, which the ancients offered victims to Proserpina and the other infernal gods.*" We highlight that to the sheep's selected for quantitative productions can be flanked by less productive breeds

Table 1 Number of heads (LG), morphology (height and weight) of males (M) and females (F), reproductive and Ecosystem Service evaluation (ES) among five breeds examined

Sheep	LG	Height		Weight		Prolificacy		Fecundity		Birth/Year		Lambs/Birth		Lambs 30 days	
Breed	n.	M cm	F cm	M kg	F kg	%	ES	%	ES	n.	ES	n.	ES	kg	ES
White															
Sarda	4,500,000	71	63	60	42	110	3	97	3	1	3	1.1	3	8.5–10	3
Bagnolese	12,000	74	70	95	58	150	5	90	1	1	3	1.5	3	10–13	4
Black															
Massese	80,216	85	77	90	65	150	5	120	5	2	5	1.75	5	12–13	5
Arbus black	5000	55	50	30–40	24–28	120	4	110	4	2	5	1.2	4	9.5–9.8	3
Sciara	55	70–75	55–60	60–65	45–50	100	2	95	2	1.5	4	1	2	8–9	3

Table 2 Productive and quality characteristics of Primiparous (Pr) and Pluriparous (Pl) milk evaluation and Ecosystem Service evaluation (ES) among five breeds examined

	Delivery				Lactation								Milk quality					
Sheep	Age I		Age II		Age Pr		Milk Pr		Age Pl		Milk Pl		Fat		Protein		Yeld	
Breed	mths	ES	mths	ES	days	ES	Lt	ES	days	ES	Lt	ES	%	ES	%	ES	%	ES
White																		
Sarda	15	5	22	5	100	5	100–130	5	180	5	200–250	5	6.5–7.0	3	5.0–5.3	2	17–19	2
Bagnolese	15–18	3	24	4	100	5	70–90	3	180	5	90–120	3	6.5–7.5	5	5.0–5.6	3	20–22	4
Black																		
Massese	15–18	3	24	4	100	5	90–120	4	180	5	130–180	4	6.9–7.0	4	5.6–6.0	5	19–20	3
Arbus black	15	5	22	5	100	5	45–50	2	100	4	88–98	2	6.5–6.9	2	5.0–5.6	3	19–20	3
Sciara	16–18	2	24	4	100	5	35–40	1	100	4	50–55	1	6.5–7.5	5	5.6–6.0	5	22–24	5

Table 3 Cheese evaluation among the five breeds examined

Sheep	Cheese		Maturation		Maturation		Maturation		Wheels		Wheels	
Breed	Fresh		Short dd		Long dd		Very long mths		Small kg		Large kg	
White												
Sarda	Ricotta	5	20–60	5	>60	2	No	0	1.0–2.3	2	1.7–4.0	4
Bagnolese	Ricotta	5	60–90	3	150	4	72	5	1.5	3	5.5	5
Black												
Massese	Ricotta	5	30–60	4	180	5	No	0	0.7	4	2.0	2
Arbus black	Ricotta	5	60–90	3	120	3	12	4	0.5	5	3.0	3
Sciara	Ricotta	5	60–90	3	120	3	12	4	0.5	5	1.0	1

Table 4 Wool production evaluation among the five breeds examined

Sheep	Ram		Sheep		Product		Food needs		Diet cost		Grazing	
Race	Wool kg		Wool kg		Wool		UFL/year		€/year		Use %	
White												
Sarda	2.5	1	1.2	1	Nessuno	0	437	5	1.19	5	30	5
Bagnolese	2.2	1	1.2	1	Nessuno	0	400	3	0.60	3	50	4
Black												
Massese	2.2	1	1.5	1	Nessuno	0	420	4	0.68	4	50	4
Arbus black	2.2	4	1.2	4	Orbace	5	350	1	0.50	2	90	2
Sciara/Moscia	3.0	5	2.2	5	Orbace	5	350	1	0.45	1	90	2

Table 5 Wool and diet evaluation among the five breeds examined

Sheep	Ram		Sheep		Product		Food needs		Diet cost		Grazing	
Breed	Wool kg		Wool kg		Wool		UFL/year		€/year		Use %	
White												
Sarda	2.5	1	1.2	1	None	0	437	5	1.19	5	30	5
Bagnolese	2.2	1	1.2	1	None	0	400	3	0.60	3	50	4
Black												
Massese	2.2	1	1.5	1	None	0	420	4	0.68	4	50	4
Arbus black	2.2	4	1.2	4	Orbace	5	350	1	0.50	2	90	2
Sciara	3.0	5	2.2	5	Orbace	5	350	1	0.45	1	90	2

Table 6 Ecosystem Services evaluation connected to the five breeds examined

Sheep	Provisioning		Habitat/Biodiversity		Regulating		Cultural		Total		Delta
Breed	Service	Disservice	Service	Disservice	Service	Disservice	Service	Disservice	Service	Disservice	S/D
White											
Sarda	70	17	1	4	2	3	2	0	75	24	51
Bagnolese	78	12	3	2	3	2	3	0	87	16	71
Black											
Massese	82	14	3	2	2	3	3	0	90	19	71
Arbus black	87	5	4	1	4	1	5	0	100	7	93
Sciara	81	4	4	1	4	1	4	0	93	6	87

that are able to integrate with environments and Mediterranean traditions. Using Ecosystem Services tool helps to demonstrate that the value of highly selected animals decreases when if the supply services (milk, meat, wool) are contrasted with the disservices (farm management, energy, industrial feeds). An ecosystem service/disservice must be quantified based on the benefits/disadvantages into context in which it is located, including cultural component (aesthetic, spiritual, educational, recreation-al value). The approach used showed that the evaluation of the five breeds studied using the Ecosystem Services as a yardstick would make the Arbus black sheep and the SMC sheep preferable ($P < 0.01$) in the Mediterranean coast environment respect to Sarda and Massese sheep. Last, the Bagnolese sheep would be the best both in terms of production and in terms of ecosystem compatibility in its ecological niche.

5 Conclusions

The Domestic Animal Diversity Information System describes 2,371 sheep breeds in the world of which 1,138 in Europe and 84 in Italy. The Sciara and Urbascia breeds, which would correspond to our SMC, appear to be extinct (Bittante 2011). Present study describes an albeit minimal population of sheep which, even today, retain the characteristics of the SMC. In ecological terms, sheep that use the natural resources would turn out to be more sustainable than those intensively used for large production/distributions. If efforts to save biodiversity will concentrate only in terms of gene selection, the poor breeds are destined to disappear. In addition to providing subsidies to livestock farmers (FAO 2009), it will be necessary to enhance Ecosystem Services and its monetary. The political tools (Agenda 2030, from farm to fork) have not yet succeeded in subverting the culture of productivity and product standardization which, obviously, is preferred by globalization stakeholders. Finding the right balance between human beings and nature is a heavy task, which requires knowledge and coordination but which, with current technological innovations, but which will be completed. Biodiversity is life and can do without man while the reverse is not possible.

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Identification of Cultural Ecosystem Services in Urban Wetlands in Bogotá Colombia

Victor Fabian Forero Ausique, Diana Cristina Diaz Guevara, and Favio Cala Vitery

Abstract

This research proposes a socio-environmental analysis of urban wetlands in the city of Bogota in Colombia, which is based on the supply of Cultural Ecosystem Services (CES); three wetlands were studied: Santa Maria del Lago, Juan Amarillo and Cordoba, these were included in the Ramsar Convention in 2018, a condition that makes them the object of care and protection. Currently, studies on wetlands are limited to biophysical and environmental impact assessments, but do not transcend to the knowledge of people's experiences and perception of the importance of these ecosystems. The CES were identified and evaluated by means of a questionnaire with semi-structured questions; the sociodemographic characteristics and preferences for the CES were known and analyzed using correlation coefficient. Positive and negative significances were found between the sociodemographic variables and the CES, and a hierarchical cluster analysis (HCA) was performed to group the sample according to their interests. Positive significance was found between the variables: economic income, age, and level of education, and it was identified that the ESS with the highest value were related to well-being and nature. It was concluded that the sociodemographic characteristics differ in each wetland due to its geographic location and socioeconomic stratification, that the perception studies in relation to the ESS allow understanding, from the subjectivity of each one, patterns of knowledge and common realities for the realization of plans, programs, and strategies for effective environmental management, for the benefit of the urban wetlands of Bogota in order to comply with the Ramsar Convention.

Keywords

Ecosystem services · Wetlands · Disservices · Urban · Sociodemographic

1 Introduction

The wetlands of Bogota are subject to protection due to their environmental importance and were declared Ramsar wetlands as of August 3, 2018. The wetlands studied are Santa María del Lago, Juan Amarillo, and Córdoba (Secretaría Distrital de Ambiente 2020) were selected because they are part of the Salitre basin in Bogotá. These have environmental management plans elaborated only with information of their biophysical conditions such as: water quality, air, soil, fauna, and flora, but the importance that these places had for their visitors has never been inquired. Therefore, this research aims to propose a new method that integrates biophysical conditions and visitor perceptions to improve the environmental management of these ecosystems, taking as a theoretical basis the Cultural Ecosystem Services (CES) since CES are a combination of biophysical and social factors that contribute directly or indirectly to human welfare (Daily 1997).

2 Methodology

A questionnaire was designed with closed questions to determine the sociodemographic conditions of the visitors: sex, age group, income, educational level, and place of origin. Questions were also used to inquire about SECs and were evaluated using the scale with values from 0 to 5, 5 being the most important value and zero the least important. The

V. F. F. Ausique · D. C. D. Guevara · F. C. Vitery
Universidad Jorge Tadeo Lozano, Bogotá, Colombia

V. F. F. Ausique (✉)
Universidad Nacional Abierta y a Distancia, Bogotá, Colombia
e-mail: victorf.foreroa@utadeo.edu.co

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sample design and calculation were based on a simple random probability model, with a confidence level of 95%. The Rho was calculated to determine the existence of significance among the variables, and a hierarchical cluster analysis was performed to categorize the visitors according to their tastes and preferences in relation to the CES.

3 Results

3.1 Characteristics Sociodemographic

Regarding the gender of visitors, the highest percentage of men was found in the Córdoba and Juan Amarillo wetlands, while the highest percentage of women was found in the Santa María del Lago wetland (Fig. 1). In terms of age groups, Córdoba wetland presented the highest percentage of people over 50 years old; Juan Amarillo <24 years old and Santa María del Lago between >31 years old (see Fig. 2). Regarding the economic income of the visitors, it was found that in the Córdoba wetland the highest income was >4 Minimum Legal Minimum Wages in Force (MLMWF).

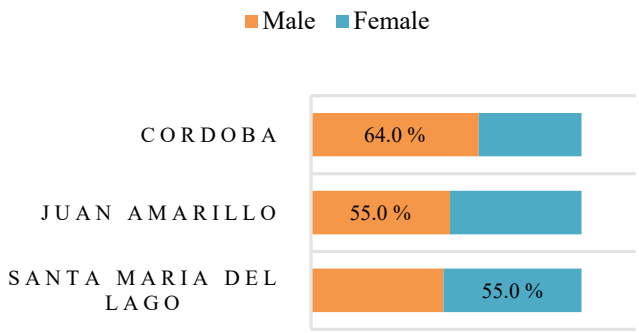


Fig. 1 Gender of visitors to each wetland

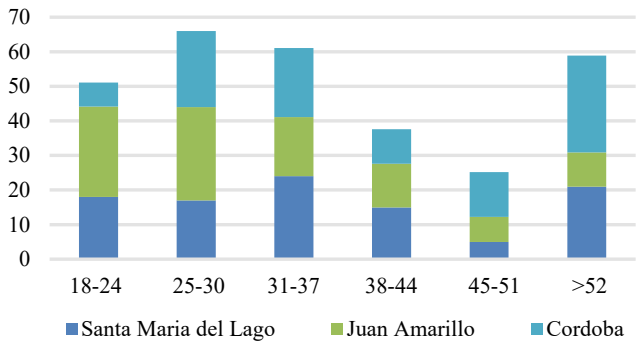


Fig. 2 Age group of visitors

3.2 Cultural Ecosystem Services

The CES were identified in the three wetlands, the most important being enjoyment of the landscape; however, the lowest CES in Santa María del Lago was recreation, and in Juan Amarillo and Córdoba spiritual experience (see Fig. 3).

3.3 Statistical Test

The correlation coefficient (Rho), positive significances were found between the variables: economic income, age, and educational level in the three wetlands, with Rho values in a range between 0.50 and 0.60 with a moderate to strong relationship. With the principal components analysis and hierarchical cluster analysis using the Euclidean and Ward distance method, visitors were grouped into two (2) groups according to their interests, between activities (recreation, tourism, and sports) and other activities (nature and appreciation of the enjoy landscape).

4 Discussion

The sociodemographic study of the three wetlands showed that the highest percentage of visitors is male; this could be due to the perception that exists about the lack of surveillance and control in wetland ecosystems, as was also concluded in Páramo Paja Blanca where a higher influx of men was found (Estacio Hernandez 2022). However, women attributed higher CES values than men (Zoderer et al. 2016). Consistent with Rho, it was shown that as the age of visitors increases, their academic level and economic income increases, and they identify more strongly the CES of enjoyment of the landscape and knowledge of nature, as was also identified in the Entrenubes High Mountain Park (Montes-Pulido and Forero 2021) and in the Colombian Amazon (Báez 2016).

5 Conclusions

The sociodemographic characteristics were different in each wetland but are related to the geographic location within Bogota and the socioeconomic strata; wetlands located in the higher strata have visitors with higher levels of education and income, as well as better public management of the ecosystem. The CES has made it possible to know the perception that visitors have of the wetlands, identifying their level of comfort and discomfort and grouping them through statis-

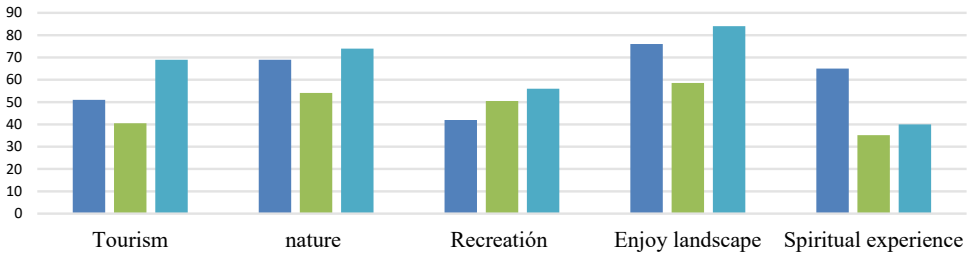


Fig. 3 Identification of CES in wetlands

tical analysis (hierarchical cluster analysis) to establish environmental management strategies; in addition, this method based on the CES strengthens the biophysical environmental impact studies for the protection of wetlands.

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Use of Smart Technology for the Protection and Management of Sacred Groves in India: *A Study of Kozhikode Metropolitan Region*

Suchitra Karthik and Anilkumar P.P.

Abstract

In India, sacred forests or groves have been protected and revered as undisturbed pieces of evergreen vegetation, pivotal to religious beliefs of the regions for centuries. Rich in biodiversity, they are known to manage the hydrological balance and contribute to reducing pollution. Their interactions between the rare and endemic species and the external environment is known to influence the microclimate of the region significantly. Sacred forests in many parts of the country are fast vanishing due to rapid urbanisation, pollution and the constant threat illegal activities.

The state of Kerala is estimated to have about 1500 sacred groves. The Institution of Foresters Kerala (IFK) documented the district-wise details of the groves between 2013–2021. The area taken for the current study is the Kozhikode Metropolitan Area (KMA), this encompasses the limits of urban agglomerations that are contained within the Kozhikode district boundary as well as urban areas as defined by the census. The study utilises GIS for mapping the groves within KMA (based on the data provided by the IFK report).

A detailed analysis of existing data led to the identification of major issues faced in the existing monitoring and management systems. The concept of community participation is identified as an effective e-governance strategy to assist in the sustained preservation of the pristine ecosystems. The study focuses on the preservation of endemic species, reducing the effects of human activity on the environment and the general upkeep of the rich ecosystem.

As a result, an ICT-based system is conceptualised and designed wherein all the information about the groves pertaining to ownership, land details, monitoring and management can be documented. A spatial decision support system (SDSS) is conceptualised that clearly defines a system for collection, compilation and dissemination of information and responsibilities from administrative to community and individual levels within KMA. The final result is an implementable ecological dataset making the overall management of the groves centralised and organised, ensuring the conservation of land and biodiversity.

The study propounds that the decentralisation of responsibility would create a more engaged and involved community actively involved in the protection and preservation of the sacred ecosystems.

Keywords

Smart technology · E-governance · ICT-IoT systems · Biodiversity conservation · Sacred groves

1 Introduction

A traditional kaavu/sacred grove, is a mostly unaltered area of evergreen flora that is dedicated to female deities, usually serpent goddesses, who have been revered for centuries by the local populace. These groves are home to a wide variety of animals, including birds, butterflies, reptiles and medicinal plants. They also frequently have water features like ponds, streams or wells (Notermans et al. 2016).

Under the Kerala Forestry Project (1998–2003), the Institution of Foresters Kerala (IFK) undertook the task of documenting the distribution of sacred groves in all 14 districts in the state (2013–2021). IFK (2016) Smart Healthy Living for Smart Kozhikode Metropolitan Area, detailed in the book Smart Living for Smart Cities published in 2020, explores

S. Karthik (✉) · Anilkumar P.P.
National Institute of Technology Calicut, NIT Campus P.O, Kozhikode, India

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the preservation of sacred groves under ecological health management for Kozhikode Metropolitan Area which encompasses the limits of urban agglomerations that are contained within the Kozhikode district boundary as well as urban areas as defined by the census (Vinod Kumar 2020). The proposed strategies involve using ICT and IoT but in the economical use of available resources, primarily by developing the Resident's Welfare Association (RWA) into a Smart Community Unit. The current study builds on this premise and details the responsibilities of various stakeholders in a conceptual framework for the management of sacred groves.

2 Analysis of Data and Generation of Maps

The existing potentials of smart technologies were analysed, and based on the analysis, a framework is created which best utilises the existing resources and enhances the overall management of sacred groves in the study region—Kozhikode Metropolitan Area (KMA). For the purpose of this study, the entire spatial entity of KMA—which is the boundary of census area definition of Kozhikode urban agglomeration and covers a major part of Kozhikode district, has been considered to assess the existing identified scared groves within the area and understand there management. Finally interventions are proposed which utilise the concepts of smart governance and community participation for enhanced management of the groves (Figs. 1 and 2).

The Travancore Literary, Science and Charitable Societies Act of 1955 allowed the Institution of Foresters Kerala (IFK) to be incorporated in 1987. Its central headquarters is located in Thiruvananthapuram. Researching subjects relevant to forest management was one of IFK's goals ((IFK) 2016). Accordingly, a project—'A comprehensive study on the socio-economic and cultural aspects of sacred groves in Kerala' was prepared and submitted to Kerala Forest Department in June 2012. On completing the field work in 2015 the number of sacred groves was found to be 1231 against the earlier expected number as around 100. (Institution of Foresters Kerala ((IFK) 2016).

In the current study, maps were generated using data from the report by Institution of Foresters Kerala—sacred groves in Kozhikode district. Based on their size, the groves were divided into six categories namely—under 5 cents, 5.5–10 cents, 11–20 cents, 21–54 cents, 55–100 cents and above 125 cents (Figs. 3, 4, 5, 6, 7, and 8).

Individual maps for the same were generated to understand the spread and number of the groves. The study of the sacred groves (SGs) based on extent allowed the development of proposals for both larger and smaller groves.

3 Results and Discussions

3.1 Results

The issues identified based on the various literature studies on sacred groves as well as the studies conducted with regard to KMA reiterated the importance of community participation in the management of the groves.

The importance of an e-governance framework that integrates and designates the upkeep and protection of the sacred biomes to the community around it using the Residents Welfare Association as a tool for the same. (Fig. 9) This resulted in the definition of numerous responsibilities related to sacred groves and the areas where varying degrees of community involvement would be necessary. (Fig. 10).

3.2 Discussions and Future Scope

The study propounds that the decentralisation of responsibility, especially in the context of rich diverse ecosystems like sacred groves, creates a more engaged and involved community that not only actively assists in maintaining their environment but also enhances the belief systems and cultural identity of the region. The framework is conceptual and developed to organise the existing mechanisms into a structured, implementable set of delegated responsibilities that utilise the existing resource pool of the community. This conceptual framework when integrated into a community structure for practical application will help in the identification of its possible limitations and challenges.

4 Conclusions

This study focused on creating possible engineering applications that can be used to empower a community to protect their environment using smart technology. The core concepts developed in this study focus on environmental management using community participation and cultural affinity for the holistic upkeep of rich bio-reserves like sacred groves that are protected and revered as sacrosanct.

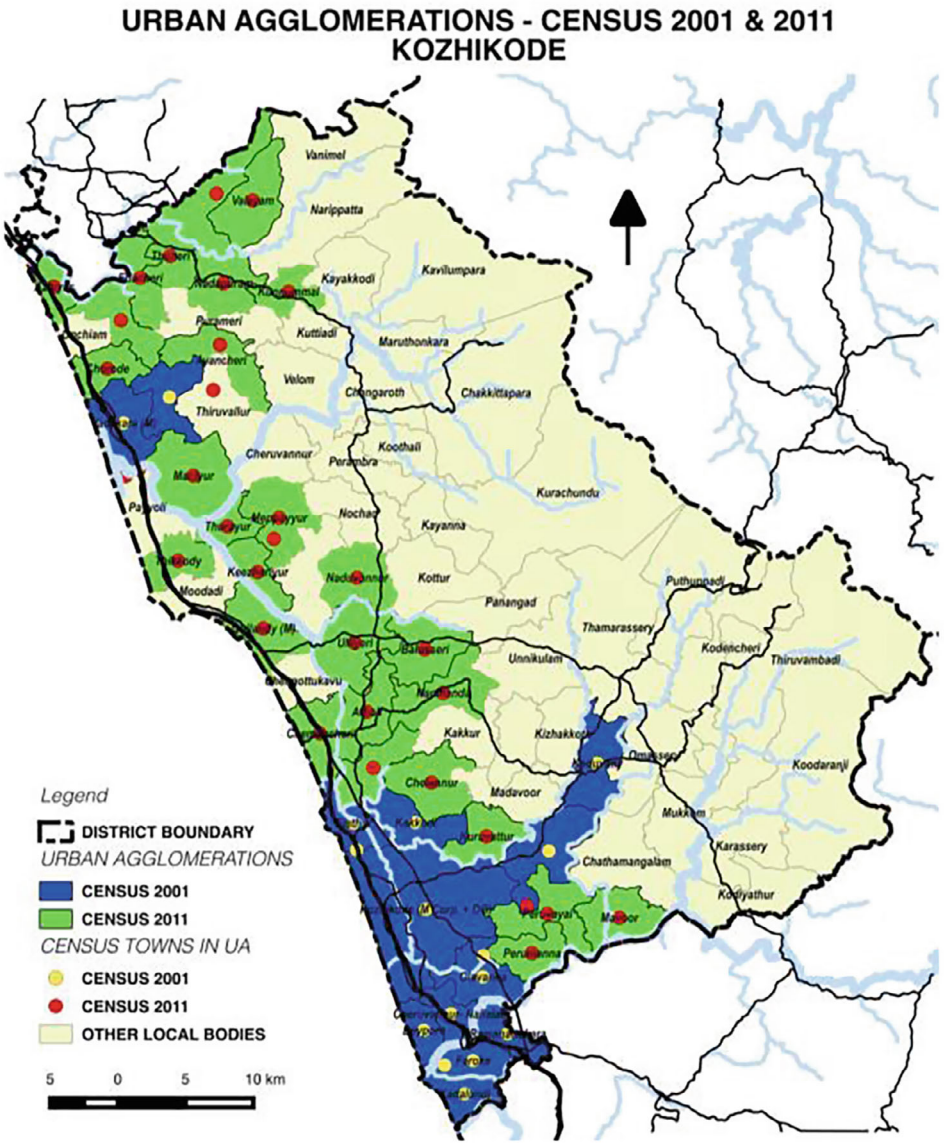


Fig. 1 Map showing urban agglomerations in Kozhikode, based on Census 2001 and 2011 data. The map highlights district boundaries and urban areas, with blue indicating Census 2001 and green for Census 2011

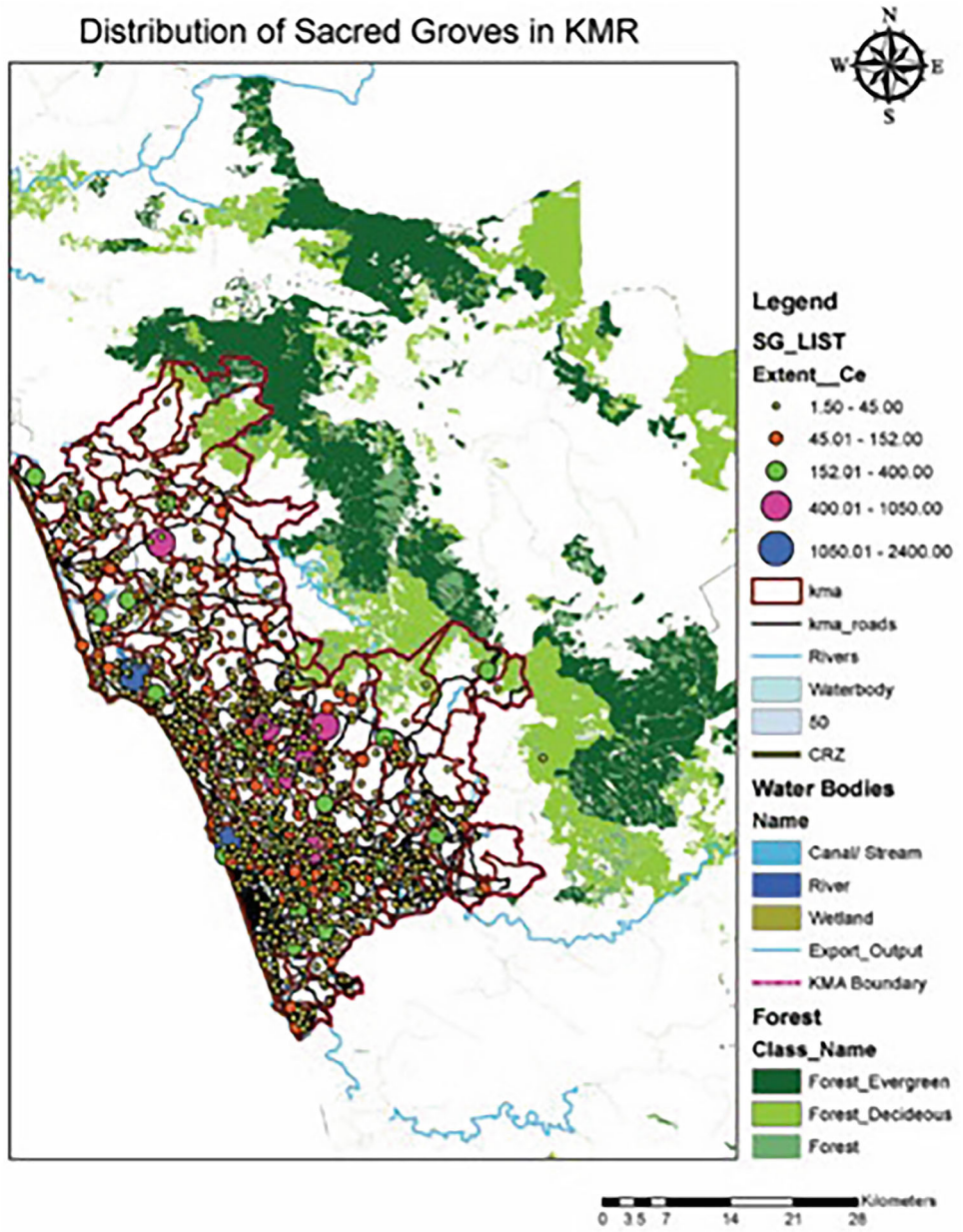


Fig. 2 Distribution of sacred groves in KMR-study area

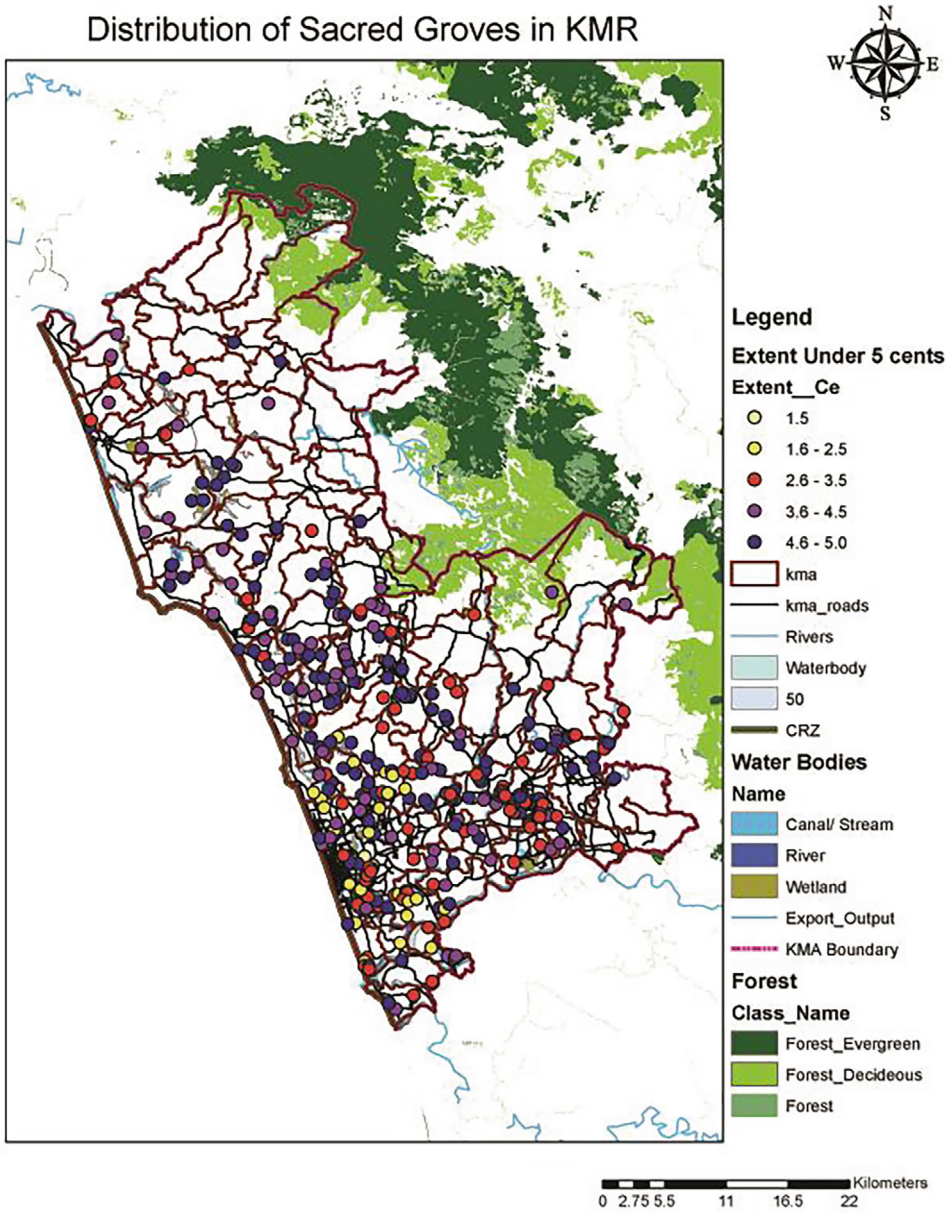


Fig. 3 Distribution of SGs below 5 cents extent

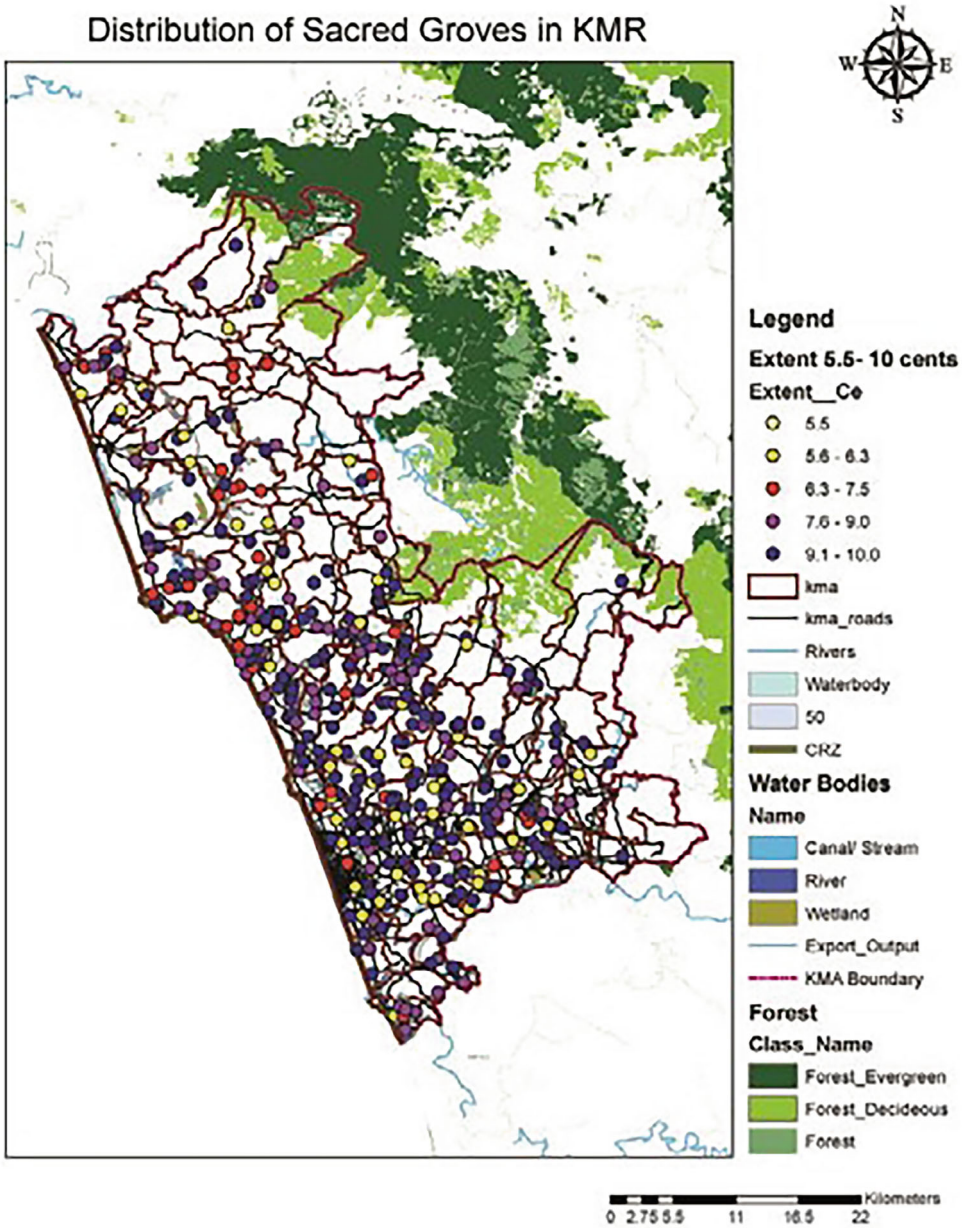


Fig. 4 Distribution of SGs 5.5–10 cents extent

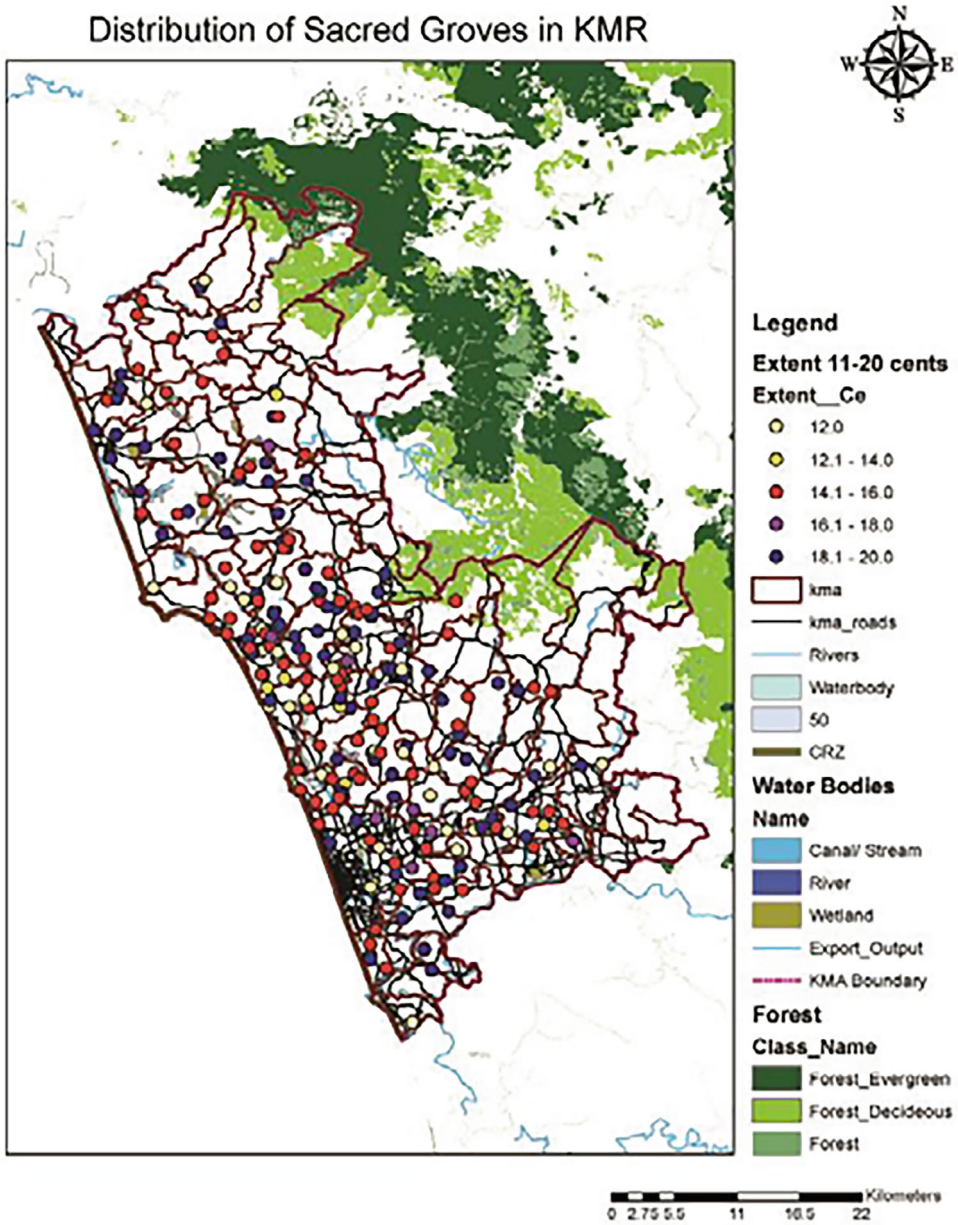


Fig. 5 Distribution of SGs 11–20 cents extent

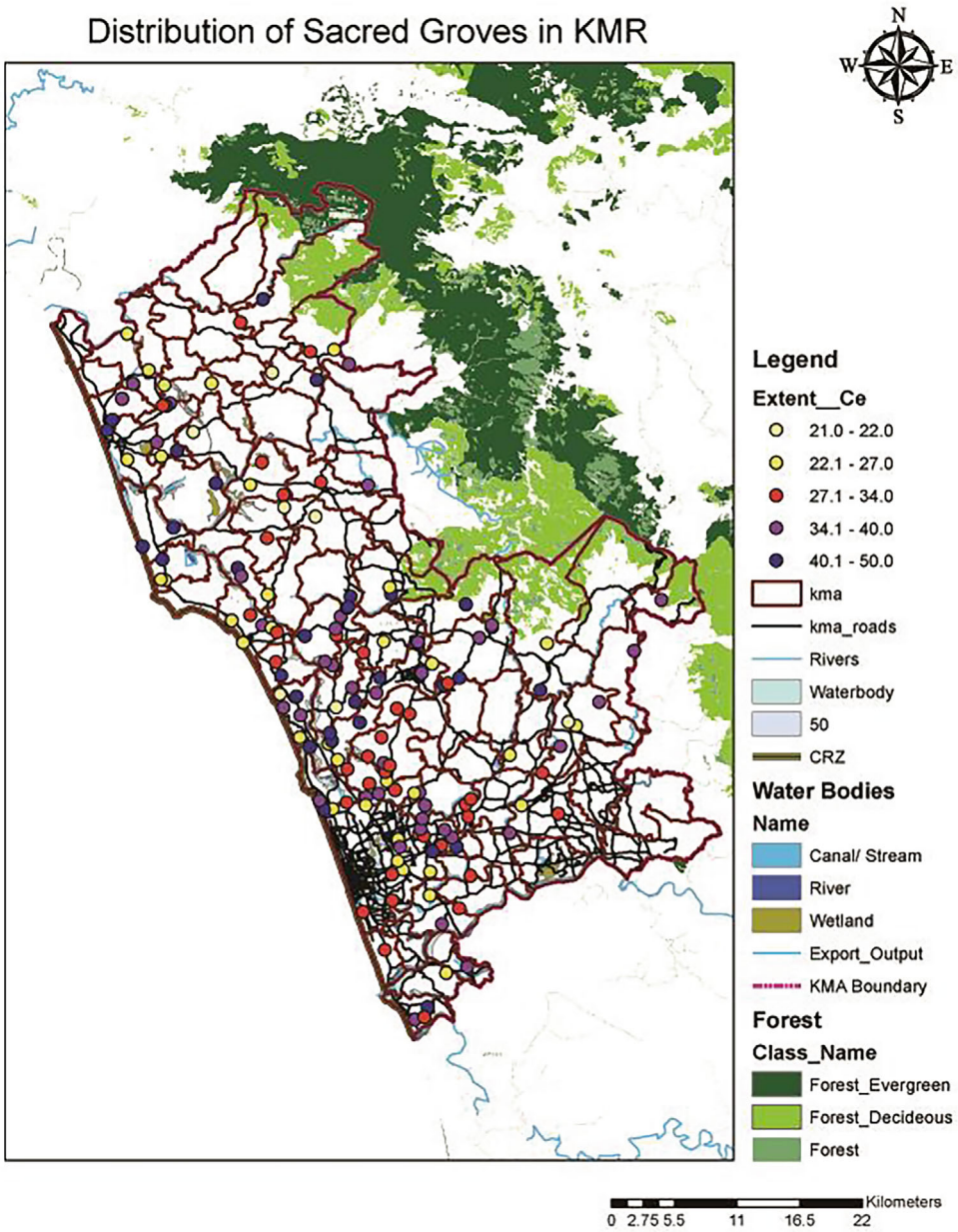


Fig. 6 Distribution of SCs 21-54 cents extent

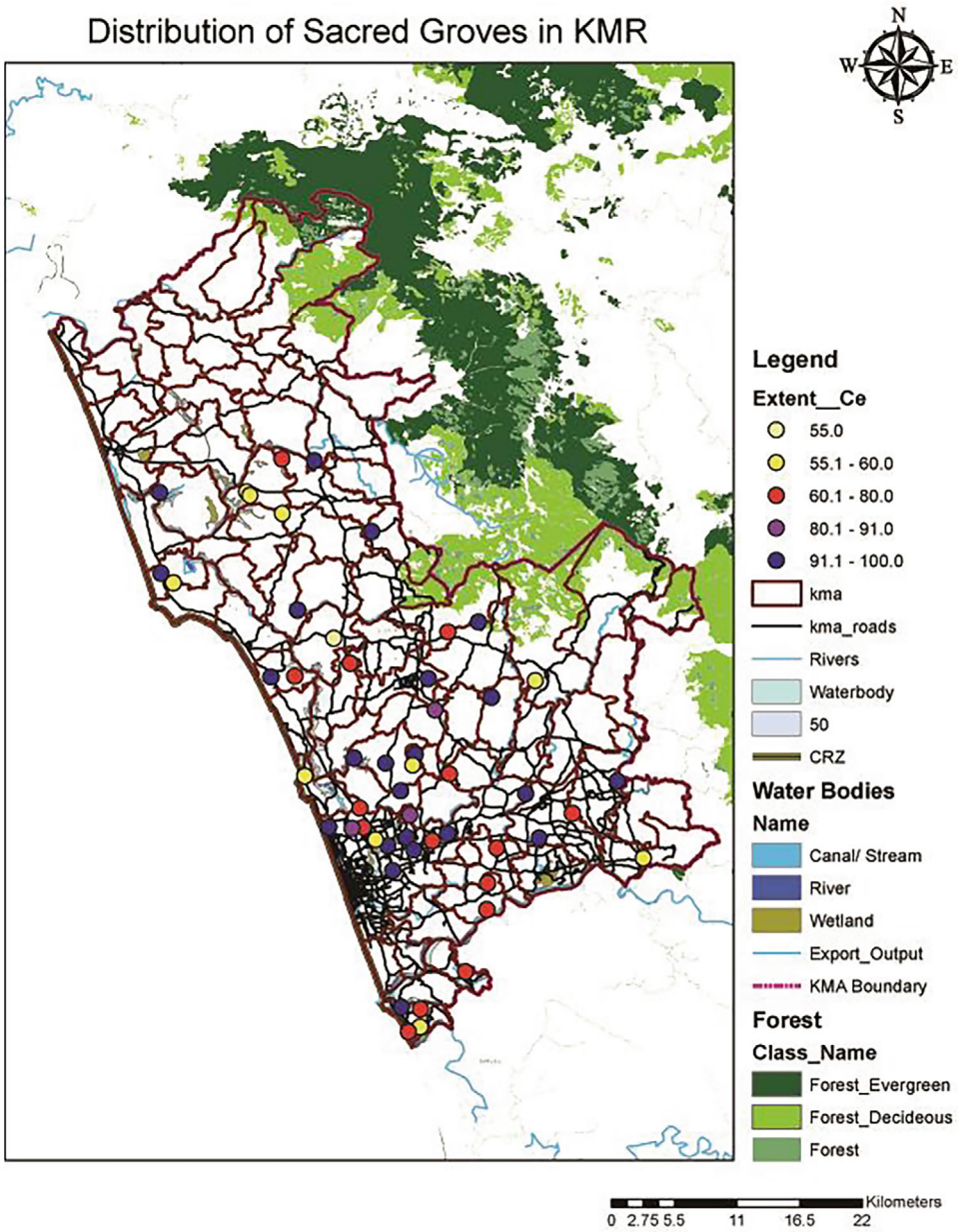


Fig. 7 Distribution of SGs 55–100 cents extent

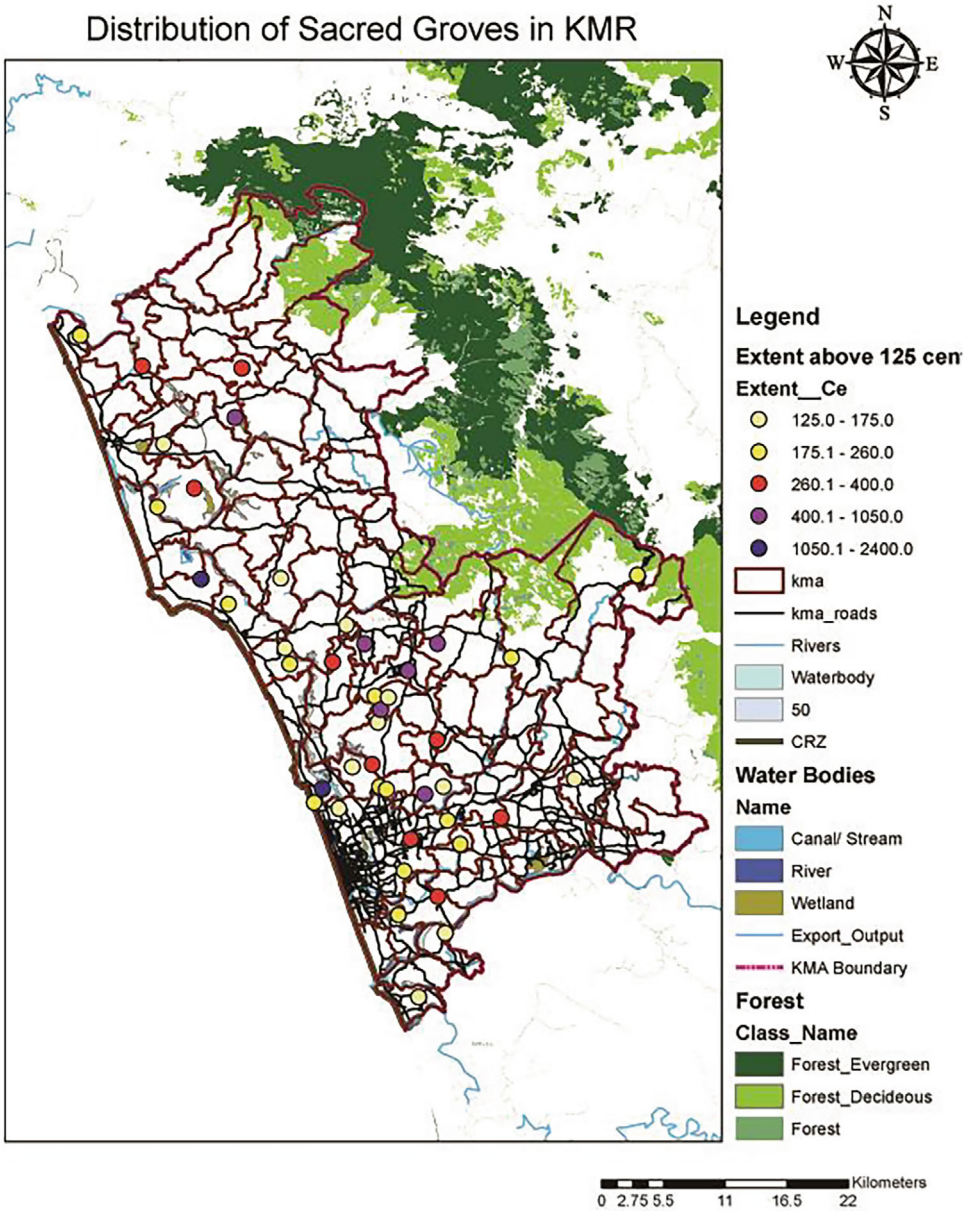


Fig. 8 Distribution of SGs above 125 cents extent

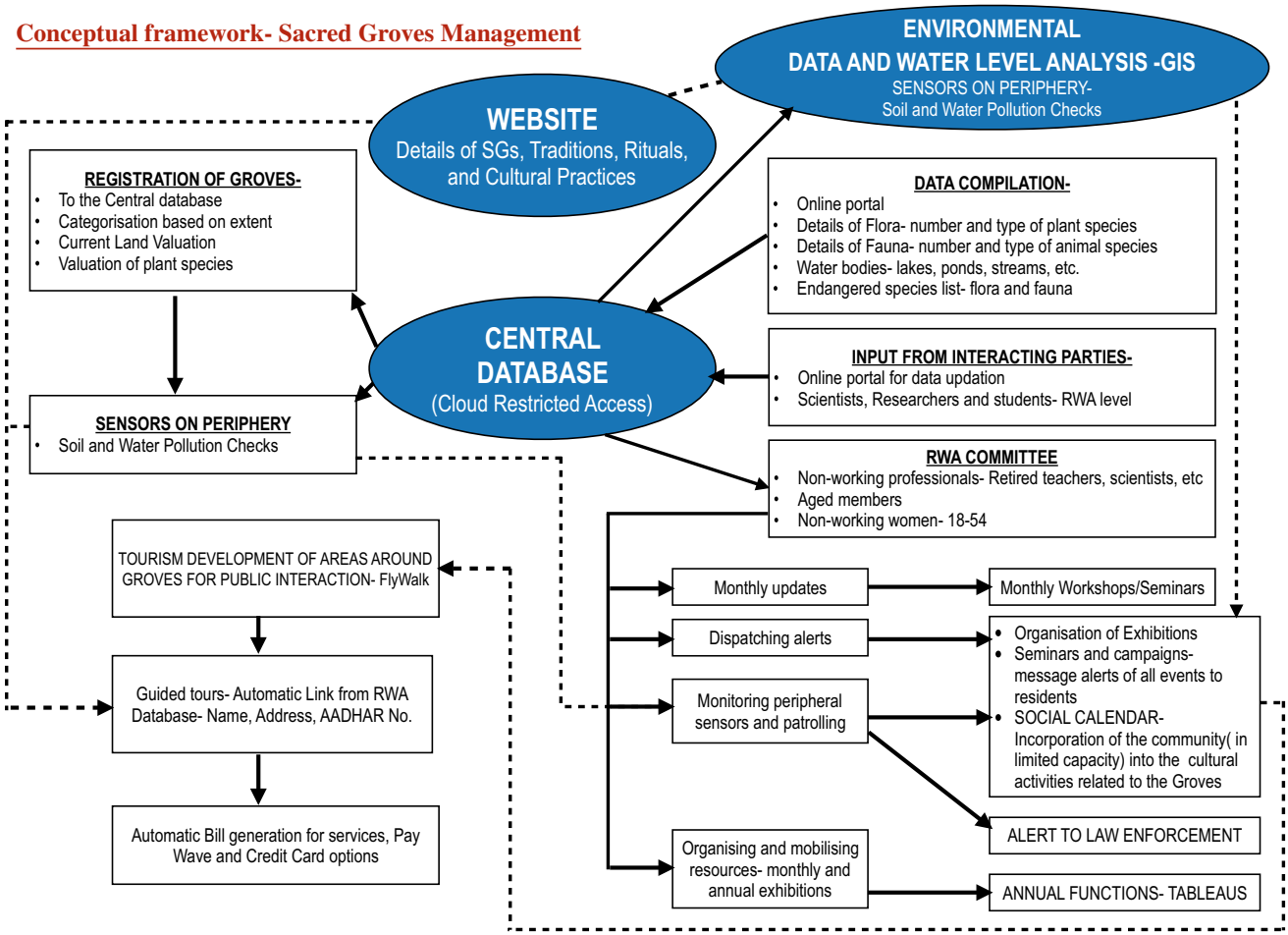


Fig. 9 Conceptual framework—Sacred groves management

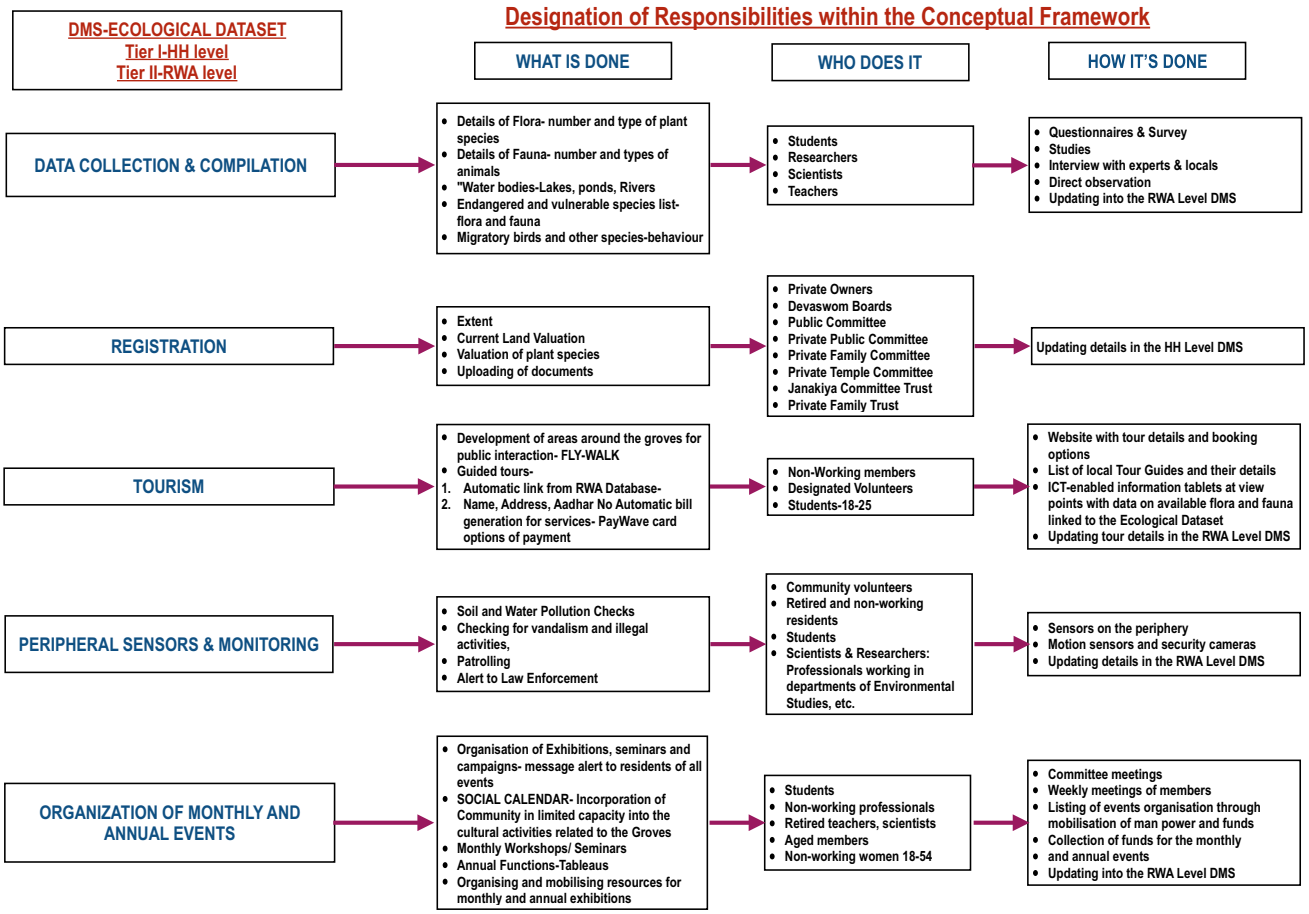


Fig. 10 Sacred groves management—designation of responsibilities

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Posidonia oceanica as Bioindicator in Marine Coastal Monitoring: What Is Wrong in the Current Indices to Evaluate the Good Environmental Status (GES)

Scarcelli Faustino, Piro Amalia, Osso Vincenzo, Oliva Daniela, Giovanelli Pietro, Nisticó Dante Matteo, Greco Silvestro, and Mazzuca Silvia

Abstract

Purpose: In the Mediterranean region, the endemic marine plant *Posidonia oceanica* has been selected as bioindicator for coastal marine waters by the Water Framework Directive (2000). Italy, together with France, has adopted the *Posidonia oceanica* rapid easy index (PREI) which is currently used in coastal marine monitoring programs as indicated in the marine strategy directive. *Methods*: The research group carried out the continuous annual monitoring of the *Posidonia oceanica* meadows in the Calabrian SAC/SCI (special conservation area/site of community importance) object of the project. Highly qualified researchers and divers have been engaged in all campaigns of monitoring, sampling, and data analysis. *Results*: Our assessment of *Posidonia oceanica* meadows at various scales—macroscale, mesoscale, and individual level—utilized the *Posidonia* rapid easy index (PREI) for measurement. However, we identified a notable discrepancy between the PREI values and the actual ecological conditions as observed by field experts over different seasons. This mismatch is attributed to the way the index categorizes ecological quality, with its qualitative reference thresholds leading to uniform classification as "Good," regardless of plant density being "very sparse" or "normal." Supporting Oprandi et al. (Ecol Indic 131:108118, 2021), our research also highlighted that the PREI's multimetric method tends to minimize the variance observed in individual parameters, often resulting in an optimistic overestimation of the meadows' ecological status (Mancini et al. in Vie Milieu 70: 55-61, 2020). This overestimation poses a significant risk, potentially skewing the development and update of management strategies and rendering them ineffective in reflecting the true state of the meadows. *Interpretation*: Macroscale, mesoscale, and individual-level descriptors made it possible to evaluate the PREI values which appeared discordant with the real environmental status evaluated by the researchers during seasonal monitoring. The PREI index, in fact, positively overestimated the quality of the meadows. *Conclusion*: This highlights that several constrains, more al local scale, determine the resilience or sensitivity of *P. oceanica* to environmental constrains and future research has to be oriented to update and integrate the parameters widely used by national and regional agencies responsible of the monitoring the Mediterranean coastal environments.

Keywords

Posidonia oceanica · Monitoring · Index PREI

1 Introduction

The Water Framework Directive, adopted by the European Union in 2000, obliges EU Member States to assess and monitor the ecological status of water bodies across Europe through the use of biological quality elements (BQE). In the Mediterranean region, the endemic *Posidonia oceanica* has been selected as EQB for coastal marine waters, thanks to its wide diffusion and sensitivity to environmental disturbances (Pergent et al. 1995). To achieve this, EU Member States had to undertake a benchmark intercalibration exercise. In this work, the importance of seagrass monitoring activities has emerged both associated with a clear understanding

S. Faustino · P. Amalia (✉) · O. Vincenzo · O. Daniela · G. Pietro · N. D. Matteo · M. Silvia
Laboratorio di Biologia e Proteomica Vegetale, Dipartimento di Chimica e Tecnologie Chimiche, Università della Calabria, Rende, Italy
e-mail: amalia.piro@unical.it

G. Silvestro
Stazione Zoologica A. Dohrn, Sede di Amendolara, CS, Italy

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of both the characteristics of the species indicators and its responses to disturbances at the eco-regional level. Italy, together with France, has adopted the *P. oceanica* Rapid Easy Index (PREI) (Gobert et al. 2009) which is currently used in coastal marine monitoring programs as indicated in Module 10 of the Marine Strategy Directive. In the Calabria region, a fundamental biogeographic barrier between the western and eastern Mediterranean basins, *P. oceanica* forms highly productive ecosystems both along the Tyrrhenian and Ionian coasts; monitoring programs and research activities have been undertaken to evaluate the real ecological status of these ecosystems to preserve the associated services and promote the blue economy to improve the quality of life of the populations living along the coasts and relaunch the tourist interest for Calabria. Important aspects of monitoring strategies include site selection and subdivision of the total monitoring area (Lopez y Royo et al. 2010). In the monitoring program under study, six SAC (special areas of conservation) with the presence of *P. oceanica* meadows were selected, three along the Tyrrhenian coast and three other sites along the Ionian coasts of Calabria. Macroscale, mesoscale, and individual-level parameters were measured and used to compare the indices usually used to evaluate the GES of *P. oceanica* habitat. The results are discussed in terms of local and field scales to demonstrate the relationship between the measured descriptors and the reference qualitative classes of the indices themselves. Finally, to link GES to the degree of resilience of *P. oceanica*, we reported a pilot experiment in which acute heat stress was imposed on plants from two sites whose evaluated PREI index had a "good" ecological status for both.

2 Materials and Methods

2.1 Selected Sites and Sampling Method

We carried out the continuous annual monitoring of the *P. oceanica* meadows in the Calabrian SAC/SCI object of the project. Highly qualified researchers and scientific diver operators (AIOSS) were engaged in all the monitoring, sampling, and data analysis campaigns.

Transects were carried out in all the selected sites, all the data relating to the evaluation of the ecological status were collected and finally the necessary samplings for the laboratory analyzes were carried out (Fig. 1).

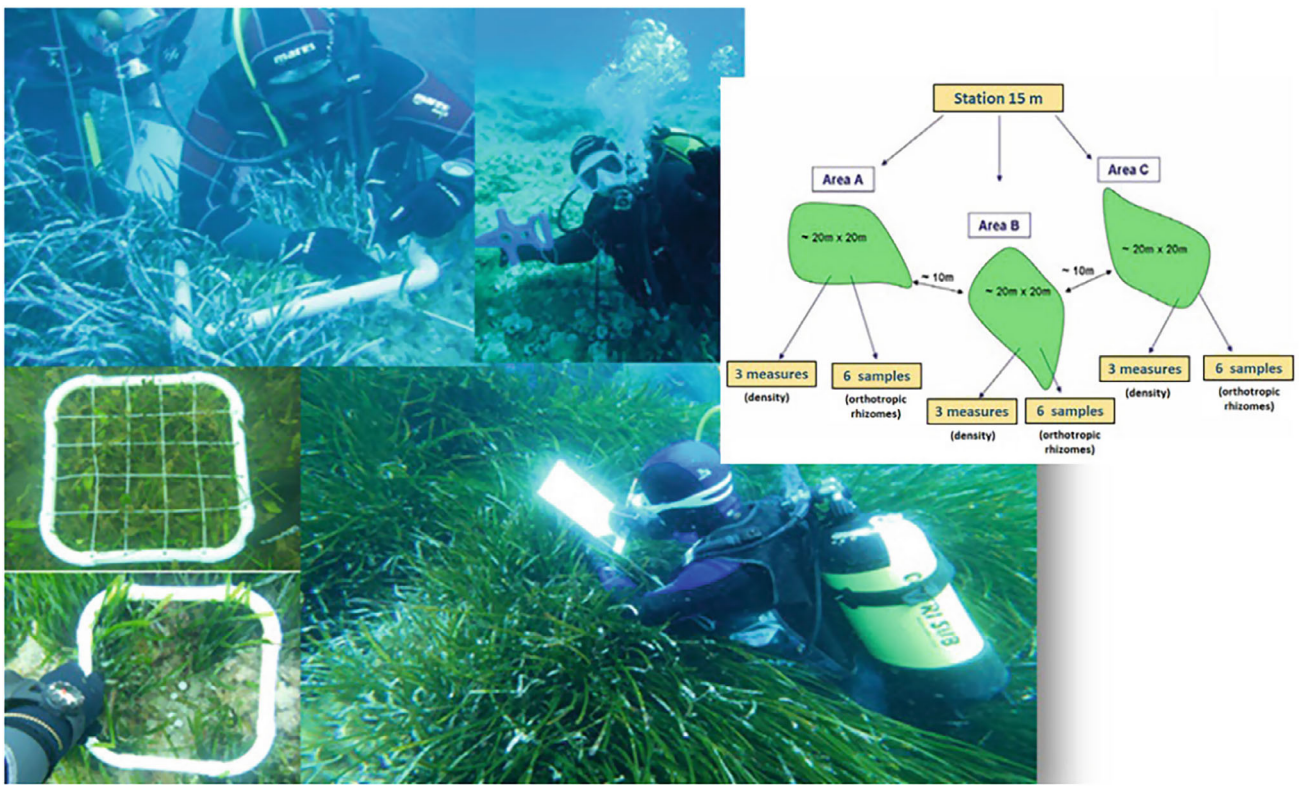


Fig. 1 Divers engaged in the delimitation of an area of a station with transects spaced 10 m deep. Hierarchical sampling scheme at station areas and number of sample replicates for each area. Divers while measuring the shoot density by using 40x40 cm frame. Plant coverage using a 40x40 cm square frame divided in sub-frames

Table 1 Classification of sites using the Giraud and Pergent indices

Site	Shoot density (no/m^2)	Giraud class (1977)	Pergent class (1995)
Cirella	305 ± 66	Sparce	Normal
Reggio Calabria	226 ± 60	Very sparse	Low
Scilla	409 ± 48	Sparse	Normal
Capo Vaticano	376 ± 58	Sparse	Normal
Mirto Crosia	331 ± 31	Sparse	Normal
Isola capo Rizzuto	319 ± 26	Sparse	Normal

Table 2 EQR reference classes (A); EQR value and class assigned to each SCA (B)

A		B		
EQR	Ecological status	SCA	EQR	Class EQR
1–0.775	**High**	Cirella	*0.65*	*Good*
0.774–0.550	**Good**	Reggio Calabria	*0.62*	*Good*
0.549–0.325	**Sufficient**	Scilla	*0.60*	*Good*
0.324–0.100	**Scarse**	Capo Vaticano	*0.67*	*Good*
<0.100–0	**Bad**	Mirto	*0.60*	*Good*
		Le Castella	*0.64*	*Good*

In field, lower and upper limit of the *Posidonia* meadow, type of lower limit (shaded, sharp, erosive, and regressive) were also evaluated.

2.2 Descriptors Used and Indices

Density of leaf shoot: Leaf shoot density is the number of shoots per unit area of the seabed. Shoots are counted in 40x40 cm areas and calculated as shoots/m^2 (Fig. 1). Mean value of density was from three measurements in three different areas. *Coverage*: This descriptor is measured through the visual estimate of the percentage of seabed covered by living plants. The measure is made using a 40x40 cm square frame divided into sub-squares. Measurement is repeated along a 10 m transect, and then averaged over the entire 10 m transect. In order to make the estimate comparable between different years, transepts should be extended following a given angle from the fixed square. Seagrass coverage was estimated for each of the four fixed sample point areas and then averaged to represent the station's seagrass coverage percentage. Leaf wide and length, quality of leaf apex, were evaluated.

Using the descriptors the following indices were calculated: *Coefficient "A"* of Giraud (1977), corresponding to the percentage of leaves that have lost the apex; *PREI* (*P. oceanica* rapid easy index) (Gobert et al. 2009) that is a multimetric index based on univariate statistics and on the analysis of five different descriptors (leaf area, leaf density, depth of the lower limit, type of lower limit, and the ratio of the epiphytic biomass to the leaf biomass) of the *P. oceanica* meadow under study. *L.A.I index* (leaf area index) (Drew 1971), corresponding to the leaf area per shoot or per square meter; evaluation of the quality status (EQS) of the meadow on the basis of the shoot density according to the classification by Giraud (Pergent et al. 1995; Giraud 1977) was done.

3 Results

In summary, the tables relating to all SCA analyzed are shown. Tables 1 and 2 show the summary values of the main parameters and indices.

The classification of Giraud (1977) does not take into consideration the depth of the meadows under examination, while that of Pergent et al. (1995) takes it into account.

As far as Giraud's classification is concerned, all meadows had a low shoot density and just in the Reggio Calabria site it was very low. According to Pergent's classification, on the other hand, all the meadows have a normal shoot density and only for Reggio classification was low density.

Table 2 showed the EQR values (PREI index) of the sites under examination.

All the SCA analyzed received a good ecological status classification.

4 Discussion

Parameters at macroscale, mesoscale, and at individual level, allowed us to assess the PREI values of *P. oceanica* in all analyzed meadows. Index values appeared to be discordant with the real ecological behavior evaluated by the operators during the seasons. This was caused by the thresholds of the qualitative reference classes of the index itself; as

example, whatever the plant density classification was, e.g., "very sparse" or "normal," the PREI index always fell into the "good" quality class. In agreement with Oprandi et al. (2021), the present study noted the tendency of the multimetric PREI (Gobert et al. 2009) to dampen the variability of the individual parameters, positively overestimating the result (Mancini et al. 2020). On the basis of these results, it can be stated that the overestimation of the ecological status negatively affects the formulation and updating of management plans which could therefore be unresponsive to the real conditions of the meadows.

To confirm that the index does not describe the real ecological quality at meadow, plants subjected to acute thermal stress in mesocosms from the Ionian Marine Protected Area of Isola Capo Rizzuto did not survive the stress, while ones from the meadow at the Cirella Island, on the Tyrrhenian side, not only survived but also had high resilience potential as, after seven months from sampling, plants are currently vegetating in mesocosm.

5 Conclusions

This highlights that several constrains, more al local scale, determine the resilience or sensitivity of *P. oceanica* to environmental constrains and future research has to be oriented to update and integrate the parameters widely used by national and regional agencies responsible of the monitoring the Mediterranean coastal environments.

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Double Helix's Platinum Anniversary: From Paper to Bioplastic, a New Hands-On/ STEM-Based Project Training Innovators of Biodiversity Conservation

Rosanna del Gaudio

Abstract

Our era is characterized by a profound crisis of biodiversity. In the last hundred years, at an impressive speed compared to the slow times of biology, man's activity has profoundly altered the planet and its ecosystems, causing a vast fragmentation of natural environments and the consequent reduction in the size of natural populations, both animals and plants. These conditions, often associated with competition with domestic and/or alien species introduced are the causes of the dizzying increase in the risk of extinction for many species. It therefore become essential to undertake actions for the conservation of biodiversity before is too late and that the extinction of too many species characterizes our near future. Here are presented education activities conceived as part of the innovative experimental educational project Next-Land on STEAM themes characterized by experiential insights. Integrated theoretical-practical activities with the aim of catalyzing the observation and understanding of the physicochemical properties of DNA, the biological macromolecule repository of genetic information in all living cells on Earth. The young students were involved in some simple experimental activities and equipped with paper, pencil, ruler, multicolored sticky notes and imagination, they have build 3D DNA models with "poor" and/or edible (candies and/or milk) and/or recycled materials. They were involved through the game to deduce the numbers related to genetic complexity of different organisms or microorganisms, discovering C-value paradox, K-value, or N-value paradoxes and other key concepts of biodiversity. The manual activities were integrated with online quiz games using remote platforms (www.mentimer.com and quizziz.com) that I have implemented with my original quizzes with the aim to teach to the students that the genetic information is encoded by genome and that the DNA study can be applied to biodiversity conservation by pointing out that genetic tools with non-invasive methods from biological traces (such as blood, feathers, or hair collected in the field) are able to identify the species they belong to, the presence of hybrid individuals, the monitoring of alien species, but also useful for the fight against poaching to conserve the biodiversity of ecosystems and/or territories.

Keywords

Tailor-made education · Hands-on learning · Biodiversity conservation · Creativity · Sustainable science · eDNA

1 Introduction

Biological diversity or biodiversity refers to the wide variety of living being within a given area and embraces the variety of genes, living species, and ecosystems that constitute life on our planet, including bacteria, fungi, plants, and animals. Specifically, these terms are used to mention all the species in an ecosystem (United Nations 1992). Scientists have estimated that, living on our Earth planet, there are almost nine million species of animals and plants. Only just over one million species, most of which are insects, have been identified and described so far. This means that about eight million of other species organisms remain mysterious (https://www.nationalgeographic.org/encyclopedia/biodiversity/). While Earth's biodiversity is enormously rich and a lot of species are likely yet to be found, many species, due to the activities of human society, are now threatened with extinction, putting at risk global biodiversity which is declining at an unprecedented rate. Today, everyone is related to sustainable development and biodiversity particularly teachers, researchers, journalists, and politi-

R. del Gaudio (✉)
Department of Biology, University of Naples Federico II, Naples, Italy
e-mail: rosanna.delgaudio@unina.it

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cians. Currently, global ecosystems face increasing pressure from climate change accompanying human social development, thus the rate of biodiversity loss is becoming the key ecological challenge globally (Cardinale et al. 2012). In recent decades, the dramatic global decrease in species variety, richness and abundance, due to the degradation of habitat quality and diversity in marine and freshwater ecosystems, as well as terrestrial ones, has become indisputable (Cardinale et al. 2012; Audrin 2022). Even protected areas, cornerstones of biodiversity conservation, which host a higher variety and richness of species than non-formally protected areas, are not immune to the decline in biodiversity.

Environmental DNA (eDNA)-based methods represent a promising approach that can be useful for monitoring and conserving biodiversity in the protected areas and can facilitate field investigations by improving measurements. Feathers, skin, fur, gametes, urine, or feces can be examined for the presence of DNA shed into surrounding environments by organisms by analyzing water, ice, soil, sediment, organic materials, such as feces, stomach contents and/or honey containing both the plant pollen varieties and the genetic molecules of passing pollinators (Pascher et al. 2022).

Indeed, DNA it is the hereditary macromolecule that carries genetic information for the correct development and functioning of all living cells of all life forms including humans. The encoded genetic information is responsible for the identity and uniqueness of each living beings but, also dictates the structural and functional similarities (homologies) in different organisms belonging to different phylogenetic groups (species).

The flower scents and colors are encoded in the DNA of their cells, also fruit flavors, the hairline of our hair too are genetic characters written in the DNA molecule.

Typically, the risk for certain health problems has something to do with DNA.

Although the entire DNA needed to code an organism is generally presented in two copies, sometimes individually mechanisms for its duplication or expression go awry leading change or alteration of local stretches of DNA. Mutations, and other errors in a person's DNA can result, for example, in differences in how each of us is able to replay to a drug. April 25, 2024, was the day on which was celebrated the 71st DNA Day, the anniversary of the discovery of the DNA double helix, a very important turning point in Biology history (Watson and Crick 1953). Believing that a broad knowledge of the properties of DNA is important to understand and preserve biodiversity, the main objective of this work is to inspire communicators and teachers with some gamification activities and engaging experiments that involve students.

2 Settings, Methods and Materials

Background Information

DNA molecule is the blueprint of all living things, starting from bacterial microorganisms to mouse, fruit fly, blue whales, and long-extinct *Scipionyx samniticus* dinosaurs. It has the same chemical structure (to be explained as teaching class activity) and function in all living cells. An almost infinite number of nucleotide combinations can be obtained by repeating these four bases in sequences of different lengths, which leads to very precise instructions on how to build different organisms.

Instructions

1. Begin class with a question: "Have you ever wondered how DNA, the genetic blueprint of every life form, can encode and transmit information about how to cultivate and maintain that life form?"
2. Stimulate reflections on the following statement: "Just as a cookbook contains a complete recipe for a dish, DNA stores the recipe for the entire life of every cell of an organism or microorganism."
3. Stimulate reflections on the following statement: "Although each human has a unique DNA sequence, the DNA in all of us is about 99.9% identical!" To be calculated the number of nucleotides corresponding to a 0.1% of differences.
4. Explain that information in DNA is encoded in genes and each gene contains instruction for building a particular protein. Proteins do most of the work in every cell and make it possible for living cells to perform special jobs and give their differentiated shapes, etc.
5. Introduce gaming activity let discovering C-value (total number of genomic DNA nucleotides), *K*-value (number of pair of chromosomes), and N-value (gene total number for each living specie) discovering whether if complexity of animal's cell genome is correlated or not with cell nucleus size.
6. Have student working with a partner(s) to built DNA models for a short section of DNA-enough to get a sense of what DNA is like and how it encodes life.

Correct Misconceptions

Be sure to explain that cells only build the proteins they need to perform their specialized functions. Because the genomic DNA is the same in every cell of an organism, student may have the misconception that all cells use every gene and build every protein.

3 Results

3.1 Defining and Teaching Biodiversity Using DNA Models and Gamification

With the aim to teach that DNA study can be applied to biodiversity and SDG numbers I integrate manual activity on 3D DNA models (see Fig. 1) with quiz games using interactive polls (https://quizizz.com/; https://www.mentimeter.com) implemented with completely personalized and original ones. My game on biodiversity cover biodiversity as a resource (food chain: what changes if …), it addresses which animal lives where and why, gives relevance to plant roots (quizziz.com games). Two more games are focused on the right identification of plants, flowers, or fruits by their seeds (Game A) and on attributing a particular egg to an organism (Game B) (see Fig. 2). Here I also report the two links (and https://www.menti.com/ald9j4i1hgjn). In Fig. 3 are shown respectively their QR code never expires that I've prepared in order to create a more inclusive environment, engage and assess knowledge, kickstarting discussion with audience and/or students on the topic of biodiversity and its conservation.

4 Conclusions

Biodiversity education is a pivotal issue for everyone: researchers, scientists, journalists, politicians, and teachers too. It is now recognized that it is necessary to teach young learner not only about biodiversity, but also about its conservation and sustainable use. In this contribution, I'm present a new way of addressing the issue of biodiversity centered in the context of a broader environmental education, to evaluate whether it could be a path to follow raising awareness and training the future generation of innovators of terrestrial biodiversity conservation. Based on environmental DNA metabarcoding, it is possible to identify a range of taxa and species generally present in an environment from a single environmental sampling. Therefore, this approach is an excellent surveillance tool for evaluating the composition of species that are present in an examined habitat aquatic or terrestrial (Audrin 2022). The ability to detect much lower population levels than conventional survey is one the many advantages benefits of eDNA metabarcoding tool in monitoring the biodiversity conservation of ecosystems compared to conventional morphology-based identification methods.

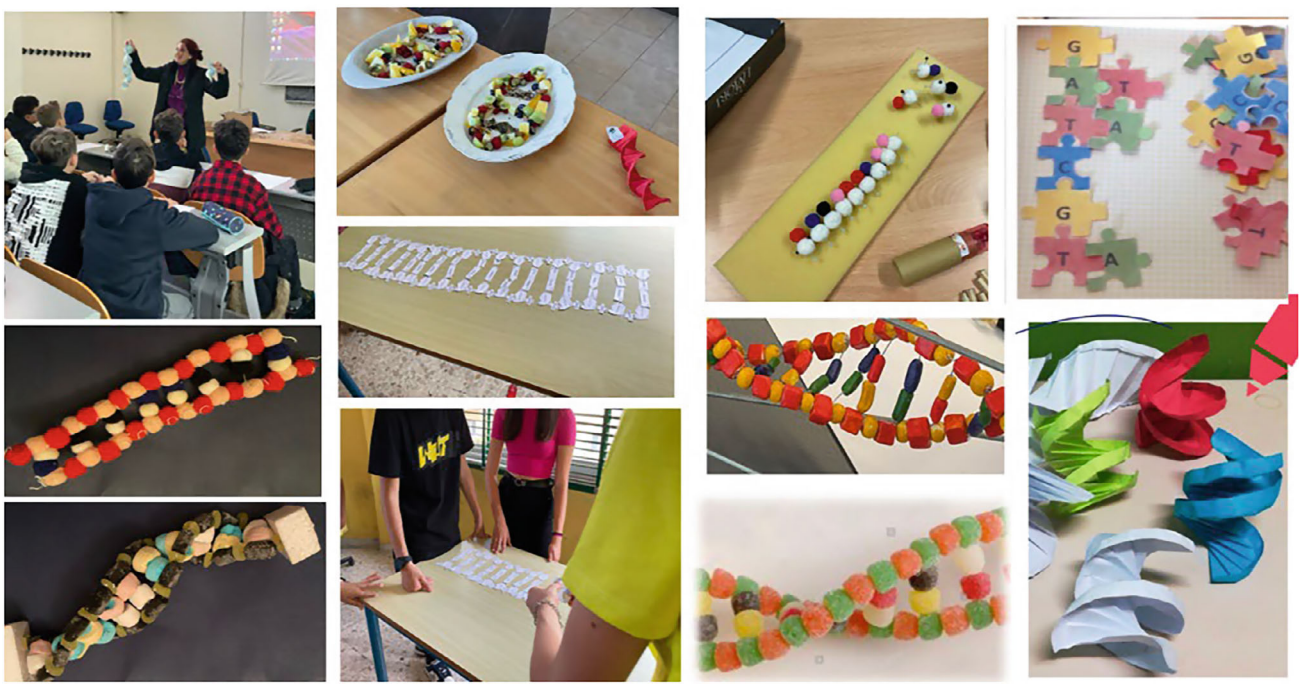


Fig. 1 Training innovators of biodiversity conservation. A limitate variety of 3D or 2D DNA structures built with candies, recycled paper (DNA origami), or poor materials. Last panel on the bottom at right site. Firs panel at left site its me explaining the genetic complexity concept using origami DNA



Fig. 2 Training innovators of biodiversity conservation: two examples of gamification activities in which players are engaged to do the right identification of some plants, flowers, or fruits by their seed (Game B) and on identification of immature insects comparing adult specimens (Game A)

Fig. 3 Two QR codes as additional examples of online activity here presented corresponding to voting link reported in the text (never expires) for online audience engagement, assessing knowledge and kickstarting discussion on biodiversity and its conservation

GAME A

GAME B

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Generational Cohort Differences in Environmental Attitudes According to the New Ecological Paradigm (NEP) Scale

Irene Eirini Kamenidou, Stergios Gkitsas, Spyridon Mamalis, Ifigeneia Mylona, Stavros Pavlidis, and Aikaterini Stavrianea

Abstract

This paper aims to examine intergenerational cohort differences in environmental attitudes according to the New Ecological Paradigm (NEP) scale. The NEP scale is one of the most widely used scales to assess people's ecological worldview and reveal their environmental concern. Although it is widely used, and a plethora of studies exist, a handful address intergenerational cohort differences. Therefore, this paper contributes to the existing body of knowledge by providing new insights into four different cohorts' environmental attitudes. A questionnaire was distributed over ten months through various survey channels, employing convenient sampling. Specifically, the internet aided self-administrated questionnaires and face-to-face interviews (for older individuals) were implemented. In ten months, data were obtained and analyzed from a sample of 2295 valid responses. Items on the NEP scale were rated with the 7-point Likert attitudinal scale. Data analysis included descriptive analysis, reliability, and One-way ANOVA to explore generational cohort differences. The results revealed that no item on the NEP scale had a mean score (MS) > 6.00 on the Likert scale, and MS ranged from 3.40–5.71 (ranging from somewhat disagree to tending to agree). The highest value (MS) was attributed to the statement "Plants and animals have as much right as humans to exist," and the lowest value was attributed to the statement "Humans have the right to modify the natural environment to suit their needs." One-way ANOVA revealed that of the 15 cases examined, there were cohort differences in ten cases. The results suggest that inadequate environmental education through the school curriculum and the absence of social marketing campaigns on environmental issues will ultimately be reflected in the actual environmental behavior of citizens in retail shopping conditions and product consumption. Environmental education and social marketing campaigns must be implemented across cohorts if the goal is to change citizens' environmental attitudes.

Keywords

Generational cohort differences · Environmental attitudes · Environmental education · Social marketing · Marketing communication

1 Introduction

In recent years, humans have caused many major environmental problems, such as climate change, air and water pollution, and loss of habitat and biodiversity, to name a few (Masson-Delmotte et al. 2021; Takahashi et al. 2020). To combat these problems, proposals have been made for a more ecologically sound worldview (e.g., Du Plessis and Brandon 2015). These suggestions are aimed at national governments and large corporations (Ha et al. 2019), but also at ordinary consumers (Khan et al. 2019). Consumers' daily choices, directly and indirectly, affect the production of goods and the sustainability of businesses large and small (Berger 2019).

Consumers' attitudes toward environmental issues seem to be a very important predictor of their behavior (Bamberg and Möser 2007; Stern et al. 1995). The New Ecological Paradigm (NEP) scale is the most commonly used instrument to assess environmental attitudes (Hawcroft and Milfont 2010), first developed by Dunlap and Van Liere (1978) and revised by Dunlap and colleagues (2000). The

I. E. Kamenidou (✉) · S. Mamalis · I. Mylona · S. Pavlidis
Democritus University of Thrace, Drama, Greece
e-mail: eikamenidou@vo.duth.gr

S. Gkitsas
Aristotle University of Thessaloniki, Thessaloniki, Greece

A. Stavrianea
National and Kapodistrian University of Athens, Athens, Greece

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revised NEP scale consists of 15 statements that reflect a person's environmental beliefs by rating their level of agreement.

Since people are already experiencing the consequences of the above-mentioned environmental problems, research on environmental attitudes and values is of utmost interest. Therefore, researching the environmental attitudes of several generational cohorts is of greatest importance, as it provides information about the behavioral tendencies of almost all citizens. The theory of generational cohorts states that cohorts include people who were born at a particular time and place and experienced the same life-changing events at their "coming of age" which shape the behavior of the cohort (Kamenidou et al. 2020; Mannheim 1970). Today, there are six cohorts worldwide, namely Generation Z, Generation Y, Generation X, Baby Boomers, Silent Generation, and the GI Generation.

Based on the above, this study examines generational cohorts' attitudes toward the NEP scale and whether there are differences between the cohorts. The data come from Greece, specifically from four Greek adult generational cohorts, i.e., Generation Z (1995–2009; Williams and Page 2011); Generation Y (or millennials) who were born between (1978–1994; Williams and Page 2011); Generation X (1965–1977; Smola and Sutton 2002); and Baby Boomers (1946–1964; Smola and Sutton 2002).

This study adds to academia theoretically since it provides insight into the environmental attitudes of four cohorts, a topic that remains very under-researched (to our knowledge, less than ten studies exist). In practical terms, it provides officials with information on the environmental attitudes of the cohorts in order to develop strategies and implement campaigns to change their behaviour in favor of the environment.

2 Methods

A questionnaire was distributed over ten months (March–December 2022) through various survey channels, employing a convenient sampling method. Specifically, the internet aided self-administrated questionnaires. Additionally, face-to-face interviews (for older individuals and with the help of 75-trained students in marketing research) were implemented. In this way, data were collected and analyzed from a sample of 2295 participants. Items of the NEP scale were rated with the 7-point Likert attitudinal scale. Data analysis included descriptive analysis, reliability of scale, and One-Way ANOVA to explore generational cohort differences per statement. The reliability of the scale (Cronbach α) was $\alpha = 0.854$, considered acceptable (Spector 1992). The sample consisted of 53.2% of males and 49.6% of females, while members per cohort were the following: Generation Z (38.5%), Generation Y (25.6%), Generation X (17.3%), and Baby Boomers (18.6%).

3 Results

3.1 Environmental Attitudes

Calculation of mean scores (MS) for all items of the NEP scale for the total sample ranged from 3.40–5.71 on the 7-point Likert scale, indicating that participants tended to agree with some of the statements, but did not completely agree with anyone. The highest rated statement for the total sample was attributed to the statement "Plants and animals have as much right as humans to exist" and the lowest value was ascribed to the statement "Humans have the right to modify the natural environment to suit their needs."

3.2 Generational Cohort Differences

Cohort differences were examined per statement employing One-way ANOVA. One-way ANOVA revealed that statistical differences existed in ten of the fifteen cases. Upon these, multiple comparisons of means (MCM) were calculated (Tuckey's b test) to examine specific differences between cohorts. Table 1 presents only the MCM results that are statistically different. In Table 1, MS per row with the same letters does not express statistically significant different attitudes, while those with different letters do (the letter "a" carries the highest mean per cohort per statement).

3.3 Discussion, Conclusion, Limitations

This study found that the overall environmental attitudes of the sample were not very high, as participants tended to agree with some statements on the NEP scale. This is partially in line with the findings of Mandić and Vuković (2022) who found that millennials (Generation Y) rated the items of the NEP scale from 2.83–6.29 (7-point Likert scale) with the highest MS on the statement "Plants and animals have as much right as humans to exist" as our study did. As regards the statistical differences found in our study, this is partially consistent with the findings of Darkson et al. (2020), who found that the Baby Boomers scored highest on the NEP scale followed by Generation X, millennials and the Silent Generation. Our study, on the other hand, found that in most cases, the highest MS of the NEP scale items were by Generation X and only in three cases did Baby Boomers have higher MS. Moreover, the youngest cohort (Generation Z) had the lowest MS in all cases excluding one. The latter reveals the need for educating the younger cohorts on environmental issues as well as the

Table 1 Cohort differences with NEP scale statements (Tuckey's b test)

Statements of NEP scale	Gen Z	Gen Y	Gen X	BB
We are approaching the limit of the number of people the earth can support	4.20b	4.47ab	4.65a	4.42ab
Human ingenuity will ensure that we do not make the earth unlivable	4.24b	4.38ab	4.47ab	4.52a
The earth has plenty of natural resources if we just learn how to develop them	5.66ab	5.69ab	5.88a	5.61b
Plants and animals have as much right as humans to exist	5.68ab	5.80a	5.82a	5.53b
The balance of nature is strong enough to cope with the impacts of modern industrial nations	3.71b	3.83ab	3.90ab	4.02a
Despite our special abilities, humans are still subject to the laws of nature	5.39b	5.64a	5.72a	5.39b
Humans were meant to rule over the rest of nature	3.43b	3.55b	3.66ab	3.84a
The balance of nature is very delicate and easily upset	5.00b	5.23ab	5.36a	5.13ab
Humans will eventually learn enough about how nature works to be able to control it	4.40b	4.41b	4.68a	4.58ab
If things continue their present course, we will soon experience a major ecological catastrophe	5.65ab	5.69ab	5.79a	5.49b

application of social marketing campaigns. In addition, it is somewhat in line with the results of Loverio et al. (2022), which indicate that students of the Z cohort had high MS for the environmental statements, some of which are consistent with our study's high MS.

The results of the study make a significant academic contribution, by shedding light on an unexplored research area regarding environmental attitudes and perceptions of Greek citizens and across different generational cohorts. Furthermore, the findings of the study also offer valuable insights to marketers and public authorities who are responsible for communicating environmental issues, as the above information is critical to strategically design and implement social marketing and communications campaigns that can effectively target different audiences.

Thus, integrated campaigns, including traditional and digital media with the use of interactive platforms and innovative tools and methods, can be employed to target different generations with a focus on teenagers and younger adults (Madden 2019; Stahl and Literat 2023; Pham et al. 2019). Engaging content and celebrity and influencer endorsement can increase the dissemination of communication messages for these generations (Stahl and Literat 2023). However, any communication efforts should be integrated into national educational policies and strategies that are also of great importance to educate, raise awareness, and develop pro-environmental attitudes and behaviors in younger generations and inform them about the societal benefits of such actions (Kamenidou et al. 2020; Kareklas et al. 2014).

Finally, in urban planning (Córdoba Hernández and Camerin 2023; Longato et al. 2021), it would be beneficial to assess the ecological attitudes of planners, the public and stakeholders using a scale such as the NEP scale (Wallhagen and Magnusson 2017) to achieve more sustainable results.

The main limitations of the study are that only one country was studied, while environmental commitment issues, as well as actual sustainability practices, were not explored, leaving room for future research.

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Assessing the Capacity of Some Plant Species to Store CO_2 in Order to Reduce the Effects of Climate Change

Abdelraouf Moustafa, Lamiaa Ghowail, Mohamed Zaghloul, Giulia Guerriero, and Samira Mansour

Abstract

Global warming is negatively impacted by greenhouse gases, particularly carbon dioxide (CO_2). Even though a lot of companies release large amounts of CO_2, it is still possible to reduce the gas's concentration both before and after emission. Plants are ubiquitous green elements in many Egyptian cities. The selection of plant types can be suggested for urban greening projects to decrease pollution levels. At this end, carbon dioxide (CO_2) sequestration capability is analyzed in three plant types. The present study employed the non-dispersive infrared (NDIR) technique in a closed system to identify the impacts of three different plant species on high CO_2 concentration, relative humidity, and temperature over an 8-h period. The liquid release value system, rubber tube, closed system, CO_2 capsule, and monitoring tool (LUTRON MCH-383SD data logger) were among the test apparatuses. The closed system kept the studied plants under a controlled environment with a high enough CO_2 emissions 5000 ± 30% ppm. The first selected plant group in this study was Hedge including *Dodonaea viscosa*, *Lantana camara*, and *Clerodendrum acerbianum*; the second selected plant group was wild including *Moringa peregrina*, *Acacia raddiana,* and *Calotropis procera;* and the third selected plant group was Citrus including *Citrus aurantifolia*, *Citrus sinensis*, and *Citrus reticulata*. The sequestered CO_2 for all studied plants and the effectiveness of each plant sequestration with respect to their weights and volumes were calculated. It was discovered that *Dodonaea viscosa* is the most effective choice for sequestering CO_2 concentration in terms of its weight and volume followed by *Moringa peregrina* then *Acacia raddiana.* Although the reduction in CO_2 concentration by *Clerodendrum acerbianum* is more than *Moringa peregrina*, it is clear that *Moringa peregrina* is more effective than *Clerodendrum acerbianum* in absorbing CO_2 with respect to their weights and volumes. The biochemical reaction of photosynthesis is the same for all plants but the rate of photosynthesis was at its highest level in *Dodonaea viscosa* other than in the other studied plants. The results showed the potential of the selected plants to sequester atmospheric CO_2 and mitigate global warming.

Keywords

Climate change · Sequestration of carbon · Green plants and carbon · Storing carbon · *Moringa* · *Acacia* · Mitigation of carbon dioxide

1 Introduction

Global climate change has already impacted freshwater, terrestrial, and ocean ecosystems, with numerous local and regional effects already noticeable. Climate resilient and mitigations are already challenging at current global warming levels (Badr and Rl-Shazly 2024). Increasing the amount of heat-trapping greenhouse gases (GHGs) has resulted in a rapid rise in the planet's average surface temperature which is leading cause of global warming and consequently the world's climate change. CO_2 is the most prevalent heat-trapping greenhouse gas (GHG) and is mainly responsible for the greenhouse effect's radiation forcing, which causes global warming. As of right now, estimates for the rise in the average world surface air

A. Moustafa (✉) · L. Ghowail · M. Zaghloul
Faculty of Science, Suez Canal University, Ismailia, Egypt
e-mail: raoufmoustafa2@hotmail.com

G. Guerriero
EClab, Department of Biology, Federico II University, Naples, Italy

S. Mansour
Department of Botany and Microbiology, Faculty of Science, Suez Canal University, Ismailia, Egypt

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temperature by the year 2100 range from 1 to 3.5 °C by the year 2100. Global grain yields may begin to decline in the 2030s as temperatures rise and extreme weather events grow more intense; ecosystems and biodiversity may also suffer possible losses (Parisi and Antioxidative 2019; Moustafa et al. 2023). Storing carbon (C) in biosphere is one of the strategies accepted by the United Nations for mitigating high atmospheric concentrations of carbon dioxide and other greenhouse gases that cause global warming (Saha 2008). Through the processes of photosynthesis, carbohydrate synthesis, and biomass storage, plants significantly reduce the amount of carbon dioxide released into the atmosphere. Plant species differ in their relative capacity to assimilate and store CO_2 (Subhan et al. 2018). The aim of this study is to detect the potentiality of *Dodonaea viscosa*, *Lantana camara*, *Clerodendrum acerbianum*, *Moringa peregrina*, *Acacia raddiana*, *Calotropis procera*, *Citrus aurantifolia*, *Citrus sinensis*, and *Citrus reticulata* to sequester CO_2 in a high CO_2 environment.

2 Materials and Methods

2.1 Instrument Description

A multipurpose instrument with a data logger (developed by LUTRON, model MCH-383SD by NDIR method) was used to record the temperature, relative humidity (RH), and CO_2 in the closed system of the experiment. The data is stored on an SD card to be transferred to a computer. The non-dispersive infrared (NDIR) approach, which is the basis for measuring CO_2 measurement, is suitable for long-term use, high repeatability, and high precision. This hand-held meter ensures reliability and long-term stability (see Fig. 1).

2.2 Plant Selection

Three plant types were selected for this study (Hedge, wild, and Citrus) which include nine species, three species in each type. There were three reasons for choosing these species. Firstly, these species have economic importance as they are used in folk medicines, and recently they are a target for drug discovery. Also, some of them such as *Moringa* and *Citrus* are edible plants. Secondly, most of these plants are included in ecological studies. Thirdly, these species are popular, easily accessible, and native to Egypt.



Fig. 1 LUTRON MCH-383SD data logger

2.3 Experimental Design

Every plant species was entered into a closed, acrylic system of 50 * 50 * 50 cm^3 that was connected via a rubber tube, a liquid release value system, a CO_2 capsule, and a monitoring device (a LUTRON MCH-383SD data logger) for CO_2 concentration, humidity, and temperature readings. The two holes in the closed system have different radius of 0.5 and 12 cm. The larger hole is sealed off before to testing when the plant and monitoring equipment are added to or removed from the closed system, and the smaller hole is sealed off following rubber tube installation and prior to testing. The gas in carbon dioxide capsules has a 99.99% purity grade (see Photo 1).

2.4 Experimental Tests

The experimental testing consists of two stages. The first stage was examining the closed system isolation while there was no plant present in the closed system and the CO_2 content remained constant. The experiment is characterized as an affiant test that indicates the closed system's isolation. In the second stage, every plant was entered into the closed system with a high concentration of CO_2 for a period of 8 h. All tests were conducted in Ismailia, northeastern



Photo 1 Closed system of the experiment

Egypt, throughout the summer, from 10 a.m. to 6 p.m. The CO_2 level was fixed to be around 5000 ppm ± 30% ppm. The monitoring device recorded CO_2 concentration (ppm), humidity (%), and temperature (°C). Every five minutes, all parameters were recorded. The test was performed three times for every plant, and the average values were reported.

2.5 The Statistical Analysis of the Data

The data analysis was carried out using SPSS version 25 (SPSS Inc., PASW statistics for windows version 25. Chicago: SPSS Inc.). The results were evaluated for significance at the ($\leq$ 0.05) level. Repeated measures ANOVA test was used to compare various follow-up periods, and One Way ANOVA test was used to compare more than two independent groups. Post Hoc Tukey test was used to identify pairwise comparisons.

3 Results

3.1 The Change in Carbon Dioxide Concentration by the Nine Selected Plant Species in Three Groups (Hedges, Wild, and Citrus)

Since that the plants' weight and volume are taken into account as significant factors, *Dodonaea viscosa* is the most effective choice for absorbing CO_2 with regard to both its weight and volume. While *Clerodendrum acerbianum* reduce CO_2 concentration more than *Moringa peregrina*, *Moringa peregrina* is obviously more effective than *Clerodendrum acerbianum* in absorbing CO_2 with respect to their weights and volumes, followed by *Acacia raddiana* and the least efficient one is *Calotropis procera* (Table 1).

Table1 Effectiveness of each plant of the nine selected plant species to sequester CO_2 with respect to weight and volume

Results	Mean sequestered CO_2 (ppm)	Plant fresh weight (g)	Plant volume (ml)	CO_2 sequestered by1gm plant weight (ppm)	CO_2 sequestered by1ml plant volume (ppm)
Dodonaea viscosa (L.) Jacq	3455	5	4	691	864
Clerodendrum acerbianum (Vis.) Benth. & Hook.f	1457	20	29	73	50
Lantana camara L	254	36	54	7	5
Moringa peregrina (Forssk.) Fori	778	9	13	86	60
Calotropis procera (Aiton) W. T. Aiton	118	90	129	1.3	1
Acacia raddiana (Savi) Brenan	158	2	3	79	53
Citrus aurantifolia (Christm.)	208	23	31	9	7
Citrus sinensis (L.)	246	64	112	4	2
Citrus reticulata (Blanco)	237	59	80	4	3

4 Discussion

This study found that all of the selected plants reduced the CO_2 concentration to a certain extent during the day. The CO_2 concentration decreased 3455 ppm in case of *Dodonaea viscosa*, 778 ppm in case of *Moringa peregrina,* and 158 ppm in case of *Acacia raddiana*. Similar result was observed (Balasubramanian et al. 2017). They found that the shrub *Dodonaea viscosa* had the greatest biomass carbon content, at 1391.42 kg ha^{-1} which is higher than *Acacia leucophloea* tree at 532.32 kg ha^{-1}. If the plants' weight and volume are taken into account as significant factors, it becomes evident that *Dodonaea viscosa* is the most effective choice for mitigating CO_2 followed by *Moringa peregrina.* Although *Clerodendrum acerbianum* reduced the CO_2 concentration by 1457 ppm which is higher than 778 ppm in *Moringa peregrina*, *Moringa peregrina* is more effective than *Clerodendrum acerbianum* in reducing CO_2 concentration with respect to its volume and weight concentration. The effectiveness of the plant to absorb CO_2 with respect to its weight and volume was previously studied (Shishegaran et al. 2020).

5 Conclusions

Increasing carbon dioxide level and other greenhouse gases trap more energy and disturb the earth's solar radiation balance. Plants play an important role in sequestering CO_2 in photosynthesis by producing carbohydrates and store carbon as biomass. *Dodonaea viscosa* is the best option to capture CO_2 and mitigate climate change followed by *Moringa peregrina*, *Acacia raddiana,* and *Citrus aurantifolia.*

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Are Romania's Natura 2000 Sites Well Connected? An Assessment Based on Connectivity Metrics

Mihaita Iulian Niculae, Gabriel Ovidiu Vanau, Athanasios Alexandru Gavrilidis, Lavinia Corina Pindaru, Cristiana Maria Pioarca-Ciocanea, and Iulia Viorica Miu

Abstract

According to the EU Biodiversity Strategy for 2030 and European Green Deal, the Member States need to find solutions to protect 30% of the EU's land and sea and improve the conservation status of biodiversity. The solution implies designating new protected areas to be included within the Natura 2000 network and improving their connectivity. Our study aims at evaluating the efficiency of the Natura 2000 network from Romania, especially of the designated terrestrial Sites of Community Importance in terms of connectivity. We also desire to assess how the connectivity levels have evolved since Romania became an EU member state in 2007, and the first Natura 2000 sites were established. For addressing the aims of our study, structural connectivity metrics such as Protected Network (ProNet) were used in the assessment. The analysis covers the entire national territory, including five EU Biogeographical regions located in Romania. We calculated and compared the connectivity metrics for three different years: 2007, the start of Natura 2000 sites designation at national level, 2011, and 2016, when this network was updated and the number of sites has increased. We used four threshold distances to establish clusters defined by protected areas, which correspond to the median dispersal distance of the most terrestrial species: 1 km, 10 km, 30 km, and 100 km. Our findings revealed that the connectivity of natural protected areas has slightly increased in the last 15 years at national level, especially for mammals with a long dispersal distance. Our analysis endorses the role of designed SCI's in Romania in reaching the global goals and targets regarding the connectivity of protected areas and biodiversity conservation. Further actions are required for increasing connectivity levels, such as expanding the land falling under conservation status by designating new Natura 2000 sites and improving their management, both at European and national level.

Keywords

Connectivity metrics · Biodiversity conservation · Biogeographical regions · Natura 2000 network · National scale

1 Introduction

At a global level, biodiversity is in decline, with some of the causes being attributed to the increase in fragmentation and decreased connectivity, as well as habitat loss (Pereira et al. 2010).

Enhancing and maintaining structural and ecological connectivity between protected areas are important priorities for biodiversity conservation in Europe, as well as on a global scale. According to the European Green Deal and the EU Biodiversity Strategy for 2030, Member States need to find solutions to protect 30% of the EU's land and sea, and improve the conservation status of biodiversity (European Commission: EU Biodiversity Strategy for 2030). The main solution entails designating new protected areas to be included within the Natura 2000 network and enhancing their connectivity and management at the European level. This represents a real benefit for species conservation, as good connectivity between habitats and even between protected areas allows species to disperse over much larger areas, ensuring the maintenance and improvement of the conservation status.

In Romania, the first Natura 2000 sites were established in 2007, the year of Romania's integration into the EU,

M. I. Niculae (✉) · G. O. Vanau · A. A. Gavrilidis · L. C. Pindaru · C. M. Pioarca-Ciocanea · I. V. Miu
Centre for Environmental Research and Impact Studies, University of Bucharest, Bucharest, Romania
e-mail: mihaitaiulian.niculae@g.unibuc.ro

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and the number of sites increased progressively in 2011 and 2016. Currently, the Natura 2000 network covers approximately 22.7% of the terrestrial surfaces and includes 435 Sites of Community Importance (SCIs), of which 426 are terrestrial sites (Tucker 2023; Manolache et al. 2017).

Our study aims to evaluate the efficiency of the Sites of Community Importance (SCIs) within the Natura 2000 network in Romania as an important way to improve biodiversity conservation, particularly in terms of connectivity. The objectives are as follows: (i) to analyze the coverage and evolution of the Natura 2000 sites at the national level, starting from 2007, with a focus on the designated terrestrial SCIs, and (ii) to assess how connectivity levels have evolved since the establishment of the first Sites of Community Importance in Romania.

2 Materials and Methods

To conduct our study, we have considered the boundaries of the Sites of Community Importance, part of the Natura 2000 network, for the years 2007, 2011, and 2016. We exclusively focused on terrestrial sites (marine protected areas were excluded). The data are available within the Eionet Portal (The European Environment Information and Observation Network)—The Central Data Repository (Agency et al. 2023), and they can be downloaded from https://cdr.eionet.europa.eu/ro/eu/n2000.

Regarding the coverage and evolution of the designated terrestrial SCIs at the national level, starting from 2007, the proportions of protected areas have been analyzed both nationally and within each EU Biogeographical regions identified in Romania.

To assess the structural connectivity of the Natura 2000 network (only terrestrial SCIs) in Romania, we utilized the Protected Network metric (ProNet) (Theobald et al. 2022). The ProNet metric is calculated as the ratio between the sum of the squared areas of protected areas within each component (cluster) and the square of the sum of the total area for all protected areas included in the network. The calculation formula is as follows (Theobald et al. 2022):

$$\text{ProNet} = \sum_{k=1}^{m}\left(\sum_{i=1}^{n} a_{ik}\right)^2 / \left(\sum_{i=1}^{n} a_i\right)^2 \quad (1)$$

where a is the area of protected area i for n protected areas, k is a component for m components of protected areas network.

The ProNet values are ranged between 0 (unconnected) and 1 (fully connected) (Theobald et al. 2022).

We calculated and compared the connectivity metrics for three different years: 2007, the start of Natura 2000 sites designation at the national level, 2011, and 2016, the years when this network was updated and the number of sites has increased.

We used Conefor 2.6 software and four threshold distances to establish clusters (components) defined by protected areas, which correspond to the median dispersal distance of the most terrestrial species: 1 km, 10 km, 30 km, and 100 km (Theobald et al. 2022; Saura et al. 2017).

3 Results

The analysis regarding the coverage of terrestrial SCIs at the national level highlighted that in the year 2011, the number of terrestrial SCIs increased by 40.5% compared to the year 2007, reaching a total of 375 sites, compared to 267. In the year 2016, the total number of terrestrial SCIs was 426, indicating an increase of 59.6% compared to 2007.

At the national level, the percentage of terrestrial SCI within the total country area has increased by 28.5% in 2016 compared with 2007 (~ 8970 km^2), from 13.07% of the country's territory in the year 2007, to 16.8% in 2016 (see Fig. 1).

Regarding the proportion of terrestrial SCIs within the five EU Biogeographical regions defined for Romania, the largest increase during the analyzed time period was recorded in the Continental (+67%) and Pannonian (+38.8%) regions (Table 1).

Regarding the connectivity assessment, our findings revealed that the connectivity of terrestrial SCI has slightly increased in the last 15 years at the national level, especially for species with a long dispersal distance.

A greater increase in the ProNet metric value was observed in the analysis that considered a dispersal distance of 10 km, yet the connectivity of the network remains relatively low. For species with very large dispersal distances (100 km), the network is fully connected for all analyzed years (Table 2).

For small dispersal distances, such as 1 km, the ProNet index values are very low, indicating very limited connectivity among the analyzed sites.

4 Discussion

Our results highlighted the effectiveness of terrestrial SCIs within Romania's Natura 2000 network in enhancing habitat connectivity and supporting biodiversity conservation. Over the analyzed period, the number and area of terrestrial SCIs have increased due to the implementation of European goals at the national level. Also, connectivity status has evolved since the establishment of the first SCIs in Romania, but not for all species categories, each characterized by their own specific dispersal distances. The creation of new SCIs has led

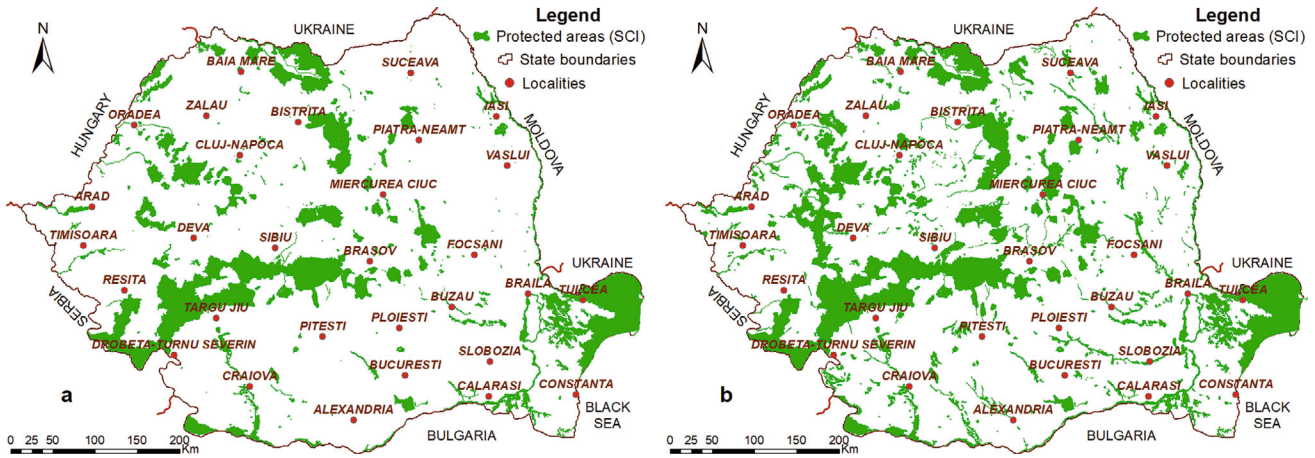


Fig. 1 Coverage of the Sites of Community Importance for 2007 **a** and 2016 **b**

Table 1 The percentage of terrestrial SCIs within the five EU biogeographical regions

Year	EU biogeographical regions				
	Alpine (%)	Continental (%)	Pannonian (%)	Black sea (%)	Steppic (%)
SCI 2007	30.36	6.16	5.96	93.75	13.01
SCI 2011	35.04	10.01	8.11	93.84	14.74
SCI 2016	35.11	10.31	8.27	93.35	14.86

Table 2 The ProNet index values according to the average dispersal distance of species

Year	Dispersal distance			
	1 km	10 km	30 km	100 km
SCI 2007	0.165	0.2	0.983	1
SCI 2011	0.188	0.371	0.998	1
SCI 2016	0.181	0.456	1	1

to good connectivity for species with large dispersal distances of over. 30 km However, these sites are insufficient for species characterized by short dispersal distances.

Our analysis endorses the role of designed SCI's in Romania in reaching the global and European Community goals and targets regarding the connectivity of protected areas and biodiversity conservation.

Further actions are required for increasing the connectivity levels, such as expanding the land falling under conservation status by designating new Natura 2000 sites and improving their management, both at European and national levels.

5 Conclusions

This study has demonstrated the necessity of applying a series of methods and tools for evaluating the connectivity of protected areas relevant for species in order to obtain a more well-balanced and successful network of protected areas. In an effort to decrease landscape fragmentation and enhance landscape connectivity, a range of measures needs to be integrated into the management plans of protected areas at both national and European levels, such as those related to ecological restoration, establishing ecological corridors and stepping stones habitats between existing protected areas, and more.

The limitations of our study are represented by the non-inclusion in the analysis of landscape characteristics, the resistance surfaces or matrix resistance, with the dispersal distance being equivalent to the Euclidean distance calculated edge-to-edge. These aspects can influence the values of connectivity metrics. Additionally, it is necessary to calculate other connectivity metrics, such as Protected Connected (ProtConn), in order to validate the results obtained for this analyzed index.

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Nanomaterials' Role in Increasing Water Thermal Properties of Decentralized Solar Still

Hebatullah Megahed and Nahed El Mahallawy

Abstract

Solar still is a simple decentralized setup used to obtain desalinated water from different water sources. Increasing water productivity from the still is of prime importance. The presence of nanofluids in the basin of the still increases the contact volumetric area between nanoparticles and water and also the solar irradiance absorption rate. This will enhance heat and mass transfer thus increasing the desalination rate of the single basin solar still. The study includes a mathematical model reflecting the effect of different nanoparticles on the desalination rate. The model predicts the cumulative water productivity with the presence of nanoparticles in the input water. CuO nanomaterials are characterized by scanning electron microscope with an integrated EDS analyzer to collect the powder x-ray diffract gram patterns in the range of 10–60° (2θ) at room temperature. The optical properties of the powders including absorptivity and emissivity are determined using Ultraviolet/Visible/Infrared spectrophotometry and Fourier transform infrared spectroscopy. Thermal properties are measured using Differential scanning calorimetry. CuO shows 0.91 absorptivity, and 0.002 emittance. The selectivity S is evaluated and found to be 0.919 using equation $S = \alpha\text{-}0.5\varepsilon$. The average particle size was 40 ± 5 nm and with a specific heat capacity 450.7 J/kg•°K. These results are inserted in the model to predict the desalination rate and to compare between CuO and Al_2O_3 nanoparticles. The model predicts an increase in the cumulative productivity by 98% in the case of adding 0.01% by volume Al_2O_3 and by 105.8% by adding a similar concentration of CuO nanoparticles.

Keywords

Nanofluids · Desalination · Solar still · Water scarcity · CuO

1 Introduction

Desalination using a single-basin solar still is a process that utilizes the sun's energy to evaporate water and then condenses the resulting vapor to produce fresh water. The process is simple and used to produce fresh water from seawater, brackish water, or even contaminated water. Due to its simplicity and affordability, the single basin solar still can be used as a decentralized fresh water source, which is highly dependent on the solar radiation intensity. The solar still consists of an insulated container with a basin for the input water, and a transparent glass cover to allow sun rays to heat up the water in the basin (Srivastava and Agrawal 2013; Agrawal et al. 2017), which evaporates and condensates on the glass cover. The condensed water is collected and is generally of high quality, as the process removes most impurities, including salt and other minerals. However, the output of single basin solar still is limited and several attempts have been made to improve its productivity (Hebatullah Megahed 2021).

There are several ways to increase the output of single basin solar stills by increasing the size of the basin (Rajaseenivasan and Srithar 2016), adjusting the tilt of the glass cover to maximize the surface area of the water exposed to sunlight, and enhancing the rate of evaporation (Bouchekima et al. 2020). Other methods include; improving insulation of the still (Manokar et al. 2020), using a more efficient conden-

H. Megahed · N. E. Mahallawy (✉)
Faculty of Engineering and Materials Science, German University in Cairo, Cairo 11865, Egypt
e-mail: nahed.elmahallawy@guc.edu.eg

H. Megahed
e-mail: hebatullah.alieldin@guc.edu.eg; hebatullah.shwa@gmail.com

N. E. Mahallawy
Faculty of Engineering, Ain Shams University, Cairo 11865, Egypt

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sation surface (Goshayeshi and Safaei 2019), improving the airflow around the basin (Omara et al. 2017a), using multiple basin stills in series (Yeang et al. 2023), increasing the water temperature (Omara et al. 2017b; Prakash and Velmurugan 2015), and modifying the design (Megahed and El Mahallawy 2022).

Nanomaterials in desalination have several advantages. They provide a high surface area to volume ratio, which can increase desalination efficiency. By proper selection of the nanomaterials, selective removal of certain contaminants such as heavy metals or organic pollutants from water can be achieved. Nanomaterials can be produced in large quantities at a relatively low cost, making them suitable for large-scale desalination applications (Alarifi et al. 2021).

Nanomaterials can increase rate of heat transfer in the basin (Xia et al. 2016), resulting in a rise *i* the water temperature. Using Al_2O_3-water nanofluids in the basin of a single slope solar still led to improving water daily production by 76% (Kabeel et al. 2014). By connecting an outer condenser and adding nano–CuO or Al_2O_3 in the water still, the thermal efficiency increased by 73.85% and 84.16%, respectively (Kabeel et al. 2017). In another attempt (Sahota and Tiwari 2016), a 35 kg and 80 kg mass of 0.12% conc. Al_2O_3 nanoparticles are added in a double slope solar still. The results showed improvement in productivity by 12.2% and 8.4%, respectively.

The performance of single slope solar still after adding Al_2O_3, ZnO, and SnO_2 nanoparticles to water was also found to have a high impact on the solar still water production (Elango et al. 2015). Water production with ZnO-water, Al_2O_3-water, and SnO_2-water nanofluids was improved by 12.67%, 29.95%, and 18.63%, respectively. In Ref (Saleh et al. 2017), hydrothermal synthesis method is used in preparing several solvents of synthesized ZnO-NPs to obtain nano-rod particles. Accordingly, the thermal efficiency and water productivity of the nano-rod particles in the system were enhanced by 30% and 38%, respectively.

This work aims at investigating the effect of adding 1% CuO and Al_2O_3 nanoparticles to water in the basin of the single slope solar still using mathematical modeling as an extension of the previous work (Megahed and Mahallawy 2022). The more efficient nanoparticles were selected to test the evaporation rate experimentally after characterization using XRD, TEM, UV–Vis, FTIR, and DSC.

2 Methodology

The mathematical model is based on heat and mass transfer equations solved using MATLAB R2021a. The input parameters include the design of the still, environmental conditions, physical and optical properties of the materials of the basin, insulation and glass cover, as well as the characteristics of the nanoparticles in the input water. The details of the model are given in our previous work (Megahed and Mahallawy 2022).

Based on the results of the model, CuO were selected to test the evaporation rate experimentally. Copper Oxide nanoparticles purchased from Nanotech Company in Egypt for Photo-Electronics Communication Center were characterized for chemical, physical, thermal and optical properties. The nanofluid was prepared by ultra-sonication for 15 min at room temperature. A mixture of 1%V_f CuO NPs and distilled water for obtaining uniform distribution of the particles in water. The evaporation testing of the obtained nanofluid was achieved using a 250-Watt thermal infrared light bulb. The position of the lamp was controlled using a solar radiation sensor where the output is set to be equivalent to 1000 W/

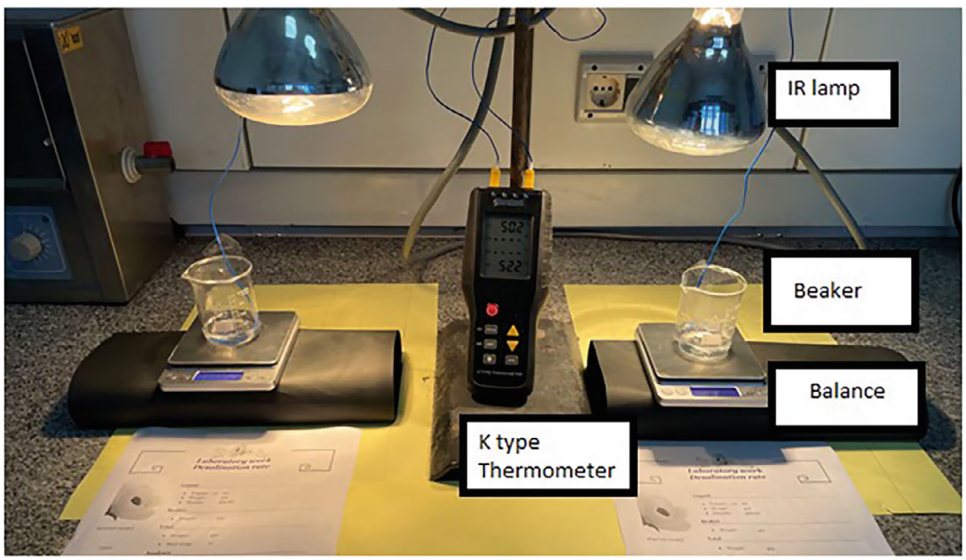


Fig. 1 Setup for measuring the evaporation rate

m^2. The setup includes K-type thermometer, beakers, scale (balance), and graduated cylinder as shown in Fig. 1.

3 Results and Discussion

For characterization, most of CuO NPs in TEM image were spherical in shape with an average size of 40 ± 5 nm, Fig. 2a. XRD results revealed that the particles matched the Monoclinic CuO standard pattern (JCPDS 48–1548) and also matched with XRD results in Ref. (Siddiqui et al. 2018; El-Trass et al. 2012). The major peaks in Fig. 2b were located at $2\theta = 35.7°, 38.9°, 48.9°$, which are the characteristic peaks for the pure monoclinic crystalline phase of CuO NPs. The optical properties, absorptivity, and emissivity, were determined using UV spectrometer and FTIR respectively. The absorptivity was equal to 91.2%, and the emissivity was 0.22%. The heat capacity from DSC measurements was in

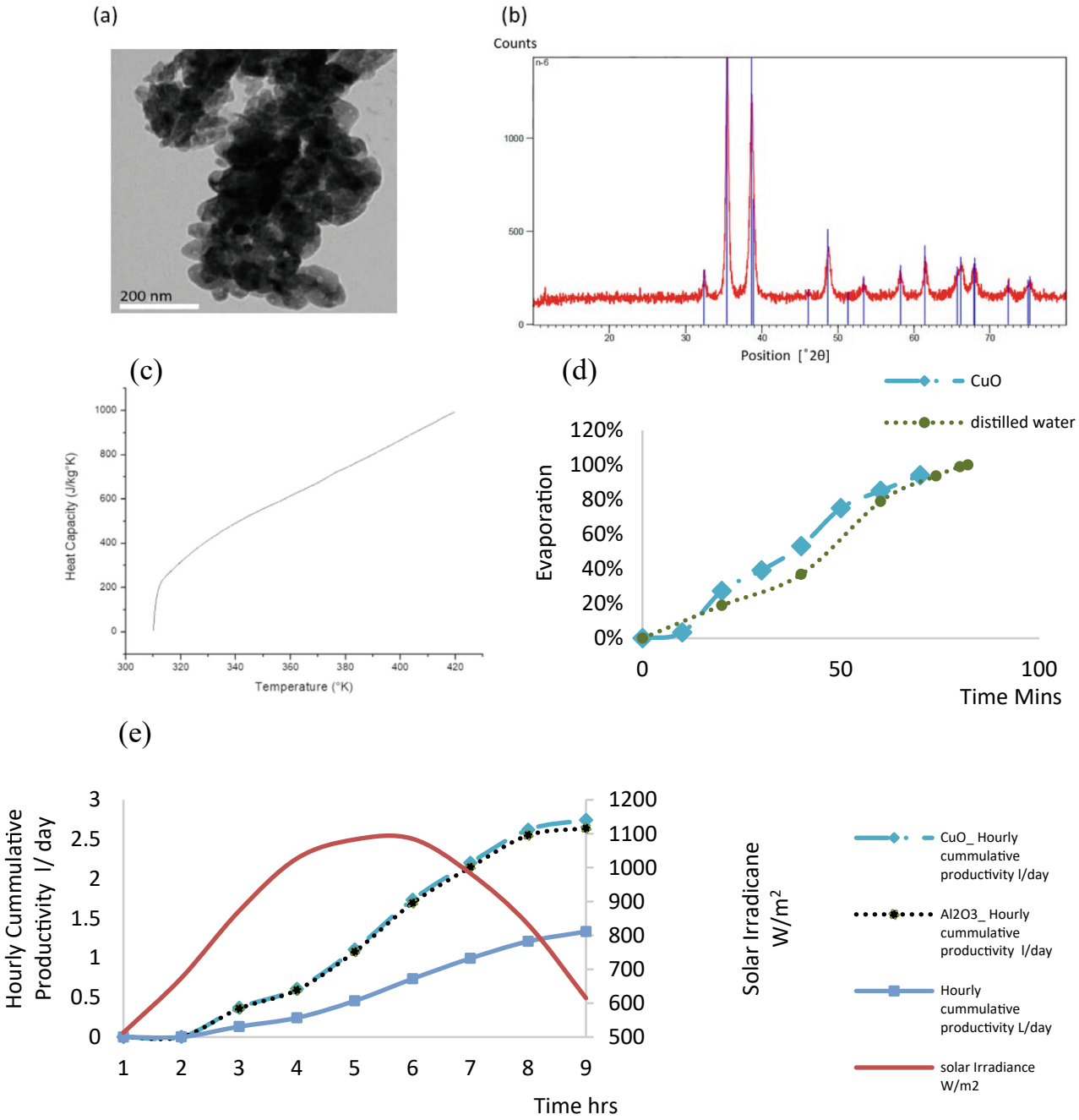


Fig. 2 Results of characterization of CuO Np: **a.** TEM, **b.** XRD, **c.** DSC, and **d.** Evaporation of obtained CuO nanofluid compared to Distilled water, **e.** Mathematical model results by using $1\%V_f$ Al_2O_3 and CuO nanofluids across 8h working system

the range from 400 to 600 J/kg °K for the temperature range from 60 to 80 °C, Fig. 2c. These values will be inserted into the model. After sonication of the nanofluid, most CuO NPs precipitated, while a few were suspended across the solution. The evaporation testing results show a high evaporation percentage for the obtained nanofluid if compared to distilled water with an increase in the evaporation rate by 14.6%, Fig. 2d.

The mathematical analyses using input data of 1% V_f nanoparticles in water, basin area 0.2025 m^2, water depth 20 mm, front side length of basin 450 mm and long side 709 mm with a glass angle inclination of 30° corresponding to Egypt location with thermal conductivity of 0.96 W/m°K and absorptivity of 0.05. The basin was made from galvanized steel with absorptivity 0.9, and considering 100 mm thick glass wool board as the insulation material with thermal conductivity of 0.026 W/m°K. The model results shown in Fig. 2e indicate that both Al_2O_3 and CuO NP increased the cumulative still productivity from 1.33 l/day to 2.64 l/day and 2.74 l/day, respectively. Both nanoparticles had a similar behavior with only a slight difference in favor of CuO.

4 Conclusions

The addition of 1% V_f Al_2O_3 or CuO nanoparticles to water enhanced the evaporation rate of nanofluids and increased the daily cumulative productivity by 98% and 105%, respectively.

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Environmental-Change-Related Impacts on Human, Animal, and Ecosystem Health

Air Pollution, Quality of Life, Anxiety and Depression in Kosovo

Naim Fanaj, Sevim Mustafa, Erika Melonashi, and Milazim Gjocaj

Abstract

Context/Purpose: Air pollution is a worldwide environmental health issue. Increasingly, air pollution has been recognized as potentially affecting mental health. Exposure to annualized PM10 and PM2.5 concentrations was estimated to be associated with mental health problems. Kosovo experiences some of the worst air quality in Europe, while Kosovo's air quality management policies are overall fewer and less stringent than those of the European Union. Methods: The participants were 381 respondents (18 to 69 years, $M_{age} = 27.25$) recruited online, and completed the GAD-7, PHQ-9 and GQOL. Annualized PM10 and PM2.5 concentrations (average and exceedances). Results: Annualized exceedances of PM10 (for years 2020, 2021 and 2022) and annualized PM2.5 concentrations of seven monitoring stations resulted in higher than the standard values established by the EU and WHO. There was no significant difference between the level of anxiety and depression with the levels of PM10 and PM2.5. There was a significant association between the quality of life with PM10 average, $X2$ (54, $n = 376$) $= 0.184$, $p = 0.023$ and with PM10 yearly day exceedances, $X2$ (54, $n = 376$) $= 0.184$, $p = 0.023$ but not with PM2.5 average. Interpretation: Despite air pollution levels above accepted standards and the high prevalence of anxiety and depression symptoms, we did not find a correlation/association between them; but an impact on worse quality of life. Nevertheless, other factors may contribute to anxiety and depression in our case. Conclusion: Air pollution has a significant impact on the quality of life, there is a need to consider multiple factors when addressing mental health issues in areas with poor air quality like Kosovo.

Keywords

Air pollution · Quality of life · Anxiety · Depression · Kosovo

1 Introduction

Air pollution is a global environmental health concern (EEA Homepage 2023a) that is increasingly being recognized as having potential impacts on mental health. The Directive 2008/50/EC specifies that the limit values for PM10 should be 40 $\mu g/m^3$ per year and 50 $\mu g/m^3$ per day, with a maximum of 35 days of exceedance allowed. The limit value for PM2.5 is set at 25 $\mu g/m^3$ (European Commission Homepage 2023). It is worth noting that the World Health Organization (World Health Organization 2021) recommends even lower limit values, suggesting that the annual limit should be 20 $\mu g/m^3$ for PM10 and 10 $\mu g/m^3$ for PM2.5.

In recent studies conducted by researchers (Kanner et al. 2021; Borroni et al. 2022; Hautekiet et al. 2022; Zundel et al. 2022), there is a growing body of evidence indicating that increased levels of air pollution can potentially impact mental health, specifically about anxiety and depression. These studies have frequently observed a connection between exposure to annualized concentrations of PM10 and PM2.5 and the development of mental health issues.

Kosovo has been reported to have some of the most severe air quality issues in Europe (IQAIR Homepage 2023) and ranks 70th out of 131 countries in terms of air quality. In comparison to the European Union, Kosovo's policies for managing air quality are generally fewer in number and less stringent (IQAIR Homepage 2023). The consequences of

N. Fanaj (✉) · M. Gjocaj
Alma Mater Europaea Campus Rezonanca, Prishtina, Kosovo
e-mail: naim.fanaj@rezonanca-rks.com

S. Mustafa
AAB College, Prishtina, Kosovo

E. Melonashi
European University of Tirana, Tirana, Albania

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poor ambient air quality in Kosovo are significant in terms of both health and economy. It is estimated that around 760 individuals in Kosovo die prematurely each year due to exposure to ambient air pollution (World Bank Homepage. Document of the World Bank. Report No: AUS0001229. Western Balkans Regional AQM—Western Balkans Report—AQM in Kosovo 2019). The impact of air pollution in Kosovo is not well-documented, mainly due to limitations in the health information system, as highlighted by Shabani-Isenaj et al. (2022) in their study.

Studies on anxiety and depressive symptoms in Kosovo have revealed significant prevalence rates. Mustafa et al. (2015) found that 32.3% of participants experienced mild to moderate anxiety levels. Kamberi et al. (2019) reported a prevalence of anxiety at 33.6% among college students in Kosovo. During the early stages of the COVID-19 pandemic, showed that 37% of students reported mild to severe anxiety levels (Arënliu et al. 2021). A study in 2009 found that 41.7% of individuals exhibited moderate to severe depressive symptoms (Wenzel et al. 2009). Another study during the COVID-19 pandemic reported that 35.6% of participants experienced moderate to severe depressive symptoms (Fanaj and Mustafa 2021). In a more recent study, 11% of the participants displayed moderate to very severe depressive symptoms (Obas et al. 2023). Furthermore, 18.5% reported mild levels, 7.9% reported moderate levels, and 1.7% reported severe levels of depression (Arënliu et al. 2021).

We have not found any studies in Kosovo on the topic of air pollution and mental health.

This study aimed to explore the relationship between air pollution, anxiety, depression, and quality of life in Kosovo. The significance of this study lies in the fact that these variables are being examined together for the first time in Kosovo.

2 Methods

It's a cross-sectional study. The participants were 381 respondents (18 to 69 years, $M_{age} = 27.25$), 87 respondents or 22.8% were male while 294 or 77.2% were female; recruited online, from the 7 municipalities in Kosovo, where monitoring stations are placed (see Table 1), in May 2023. Based on level of education 127 (33.4%) participants finished high secondary school, 180 (47.2%) bachelor studies, 50 (13.1%) master studies and 22 (5.8%) finished doctoral studies. Participants completed the consent document, and then an anonymous self-report survey, via Google Forms.

General Anxiety Disorder (GAD-7) (Spitzer et al. 2006), was used to assess the anxious symptoms. The measure was internally consistent ($\alpha = 0.79$). Patient Health Questionnaire (PHQ-9) (Kroenke et al. 2001), was used to assess the depressive symptoms. The measure was internally consistent ($\alpha = 0.89$).

Global Quality of Life Scale (GQOL) (Hyland and Sodergren 1996), was used to assess the quality of life. Respondents rate their quality of life on a 100-point scale, with options ranging from 'perfect quality of life' (100) to 'no quality of life' (0).

Annualized particulate matters (PM10 and PM2.5) concentrations (average and exceedances) of seven monitoring stations collected from the National Network for Air Quality Monitoring in the web portal of the Hydrometeorological Institute of Kosovo were published on the KHMI website (KHMI Homepage 2023b). 79.3% of the respondents have lived over 10 years in the same residence. Descriptive statistics, and Chi-square tests analysis, were used to observe the exploratory nature of the study observations. Data processing was performed with SPSS 21.0 and Microsoft Excel 2007.

3 Results

Annualized exceedances of PM10 (for years 2020, 2021 and 2022) and annualized PM2.5 concentrations of seven

Table 1 PM10 and PM2.5 concentrations (average and exceedances for years 2020, 2021 and 2022) of seven monitoring stations and anxiety/depression means

Monitoring station	N of resp.	PM10 Average/Year	PM10 Exceedances Average/Year	PM2.5 Average/Year	Anxiety (Mean)	Depression (Mean)
Gjilan	38	33.93	60.67	25.97	9.50	10.21
Peja	30	29.87	50.67	22.47	7.73	7.79
Mitrovica	31	27.27	37.33	20.07	9.03	10.21
Obiliq	11	25.47	41.67	18.47	9.00	9.89
Prizren	53	23.93	30.67	17.43	6.29	6.12
Drenas	22	21.37	20.00	14.87	10.36	10.58
Pristina	196	34.60	67.00	22.10	7.87	8.74

monitoring stations (see Table 1) resulted in higher than the standard values established by the EU (European Commission Homepage 2023) and WHO (World Health Organization 2021).

Descriptive analysis revealed that 24.9% reported minimal anxiety, 37.5% reported mild anxiety, 19.7% reported moderate anxiety, and 13.4% reported severe anxiety. 31.5% had none to minimal depression, 27.3% had mild depression, 17.1% had moderate depression, 10.5% had moderate to severe depression, and 7.6% had severe depression.

There was no significant difference between the severity levels of anxiety and depression symptoms with the levels of PM10 and PM2.5, based on Chi-square test for independence, there was, however, a significant association between quality of life with PM10 average, $X2$ (54, $n = 376$) = 0.184, $p = 0.023$ and with PM10 yearly day exceedances, $X2$ (54, $n = 376$) = 0.184, $p = 0.023$; but not with PM2.5 average.

4 Discussion

This sample shows prevalence of moderate to severe depressive symptoms in 35.2% of cases, while prevalence of anxiety symptoms is observed in 33.1% of cases. These numbers of symptoms prevalence are more or less consistent with the findings of the previously cited studies (Mustafa et al. 2015; Kamberi et al. 2019; Wenzel et al. 2009; Fanaj and Mustafa 2021); but not with other studies (Arënliu et al. 2021; Obas et al. 2023).

Even though air pollution levels exceed accepted standards and there are high prevalence levels of anxiety and depression, we did not find a correlation/association between them. This contradicts the findings of previous studies (Kanner et al. 2021; Borroni et al. 2022; Hautekiet et al. 2022; Zundel et al. 2022).

Finding that air pollution has a significant impact on worse quality of life we may speculate together with Mujtaba and Shahzad (2021) that air pollution can have economic implications by increasing healthcare costs, decreasing work productivity, and hindering economic development. Nevertheless, other factors may contribute to anxiety, depression and quality of life in our case.

In this online study, it's important to acknowledge several potential constraints, including Sample Bias, Self-Selection Bias, and Response Bias.

5 Conclusions

Air pollution significantly impacts the quality of life, particularly in areas with poor air quality like Kosovo.

A comprehensive strategy is needed to address air pollution and improve air quality. This strategy should include implementing stricter regulations, promoting clean energy sources, and raising awareness about the importance of environmental protection. By implementing these measures, it is possible to reduce air pollution levels and enhance the overall quality of life for the citizens of Kosovo.

However, further research is needed to explore the relationship between mental health issues and air pollution in Kosovo.

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Comparative Evaluation of Anomaly Detection Algorithms for $PM_{2.5}$ Air Quality in Bogotá, Colombia

John Corredor, Camilo Rodriguez, and Martha L. Pinzón-Bedoya

Abstract

Air pollution from particulate matter (PM) is an issue to be considered by all governments worldwide, in the pursuit of improving the quality of life for the population. In Colombia, the government has led the use of instruments such as the 2021 Air Quality Strategy, through which compliance with regulations is sought. For the authorities in Bogotá (Colombia), the most important pollutants to consider are PM_{10} and $PM_{2.5}$. This research develops a study to accurately forecast the behavior of pollutants, with the purpose of preventing the population's exposure to high levels of PM. This paper presents a comparison of anomaly detection algorithms to identify outliers in air quality data, particularly $PM_{2.5}$. The data used was collected hourly from air quality monitoring stations in Bogotá from 2014–2019. The methodological design includes the implementation of synthetic outlier data, processing of time series, selection of statistical methods, and models based on artificial intelligence (AI). Finally, a comparative study is conducted based on performance metrics. The experimental results show that the statistical method (SARIMAX) presents high accuracy in identifying normal data. Regarding AI-based models, the SR and CNN models show higher performance metric accuracy for identifying outliers. The SR model is accurate for detecting anomalous data from a computer vision perspective, as it combines saliency maps and convolutional neural networks. The CNN model forms a conceptual description of inputs based on historical data patterns. The results can be improved by adding a CNN configuration layer, as done in classical clustering methods, or even an auto-encoder. The main idea is to implement CNN solely as a feature extractor.

Keywords

Air-quality monitoring · Deep learning · Outlier detection · Particulate matter

1 Introduction

Air quality is one of the biggest problems of society as it causes great impacts on health and the economy. In recent years, the number of air quality alerts associated with high values of $PM_{2.5}$ has increased considerably (Vincent 1977) and the pollutants concentration surpass the World Health Organization (WHO) limit (WHO, https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-healt), even in the COVID-19 conditions (Saenz et al. 2020; Ministerio de Medio Ambiente y Desarrollo Sostenible, https://www.minambiente.gov.co/wp-content/uploads/2022/03/Informe-Avance-ENCA-2021-Final.pdf). Hence, many cities around the world have begun the design and implement early alert systems that mitigate pollution and reduce the risk associated with particulate matter (González et al. 2018). Typically, an early alert system has three key components: the monitoring network, the simulation setup, and the mitigation or protection protocol. Many of the countries had an operational air quality monitoring network, but some of them (especially in Latin America) do not have enough stations to cover all the cities. Thus, new approaches are needed to validate the data in order to improve the quality of the measurements. The simulation setup is one of the most studied, and some authors (e.g. Cohen et al. 2017; Kumar et al. 2016; Mendez-Espinosa et al. 2020; Pearson 2002) have validate physicochemical models to simulate air pollution.

J. Corredor (✉)
Pontificia Universidad Javeriana, Bogotá, Colombia
e-mail: corredor-johnj@javeriana.edu.co

C. Rodriguez
Universidad Sergio Arboleda, Bogotá, Colombia

M. L. Pinzón-Bedoya
Universidad de Pamplona, Pamplona, Colombia

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In this paper, we perform a comparative study of anomaly detection algorithms that can be suitable for detecting outliers in air quality data for $PM_{2.5}$ data. We explore both traditional statistics approaches and new methods based on artificial neural networks. In the study, we considered historical $PM_{2.5}$ measurements captured in the megacity of Bogotá, which is the capital of Colombia and has more than 8 million. Bogotá has a latitude of 4.5° N and an altitude of 2550 meters above sea level in the tropical Andean Mountain ranges. This study is the first part of the design and implementation of an air quality monitoring and early alert system that will be coupled with machine learning, numerical models, and a protocol to reduce the risk of the population.

2 Methodology Overview

2.1 Data Description

We considered the $PM_{2.5}$ data of Bogotá city. The data are taken from the Air Quality Monitoring stations of Bogota from 2014 to 2019 (Saenz et al. 2020). These stations measure air pollutants that can produce health problems, i.e., Carbon Monoxide (CO), Ozone (O_3), Particulate Matter (PM_{10} and $PM_{2.5}$), Nitrogen Dioxide (NO_2), Sulfur Dioxide (SO_2), among others. Data is collected hourly by monitors. Thus, we consider discrete time-series, $t \in \mathbb{N}$, perceived in equal time intervals. The highest concentrations correspond to the stations in the southwest of the city, Carvajal-Sevillana, and Kennedy, registering an excess to the annual norm in the first station (Saenz et al. 2020). Carvajal-Sevillana also recorded the highest number of daily exceedances, with daily concentrations of 40.70 $\mu g/m^3$ and the lowest annual average was 14.1 $\mu g/m^3$, at the Usaquén station which coincides with the identification of risk performed by Celis et al. (2021). In addition, Bogotá suffers from Long-Range Transport (LRT) of pollutants in the first quarter of the year due to forest fires, as was mentioned by Mendez-Espinosa et al. (2020) and Sokhi et al. (2021) for particulate matter and in Ballesteros-González et al. (2020), for ozone. For this reason, as a case of study for the comparative evaluation, the data captured by the "Carvajal-Sevillana" station is selected since it is the one with the higher pollution and risk.

2.2 Synthetic Outliers Generation

As mentioned, an outlier is an entry in a data set that is anomalous with respect to the behavior seen in most of the other entries in the data set (Pearson 2002; Stefatos and Ben Hamza 2007; Tan et al. 2018). There is no clear way to know the correct value in order to give a clear definition of a true outlier in the processed air quality data. For example, suppose there is a value (s) in a data set that is high compared to the rest of the values. Using the statistical definition of an outlier, s is considered an outlier. However, it could be that on that day there is a forest fire near the station, or that there is a lot of vehicular traffic. Since the air quality, and consequently the $PM_{2.5}$ is greatly affected by vehicular traffic, it is expected that a weekday and rush hour day will have a higher value of $PM_{2.5}$ than the weekend or holiday days. Therefore, in this paper, we assume that values close to the historical patterns followed by most of the data are the correct data. Data points that are far enough away from their immediate neighbors are outliers after considering all factors affecting air quality. The outliers in the $PM_{2.5}$ are mostly due to errors in the processing of the data files or faulty monitor measurements.

2.3 Anomaly Detection Methods

The following is a list of the methods that have been selected with different approaches ranging from statistical methods to methods using machine learning (supervised and unsupervised):

- SARIMAX: Seasonal AutoRegressive Integrated Moving Average with eXogenous regressors model.
- Spectral Residual (SR) outlier detector, a method for unsupervised online anomaly detection in univariate time series data.
- Auto-encoders are artificial neural networks capable of learning dense representations of the input data, called latent representations or codings, without any supervision.
- Convolutional Neural Network (CNN) is a kind of deep neural network commonly applied to analyze visual images.

3 Results

Table 1 presents the average and the standard deviation of 20 executions of the methods. The metrics correspond to "Precision", "Recall", F1_score, MAE, and AUC, and the execution time for each method is presented.

4 Discussion

Table 1 presents the summary of the results obtained from the metrics and the execution time of the experiments. All the metrics show a high precision in the outlier detection, especially the SR and CNN. The SR model has the highest Precision (97.9%), Recall (93%), F1_Score (95.3%), and AUC (96.4%), but for the MAE the best value is produced by CNN (0.0002), which could be related to the ability of the CNN (and

Table 1 Methods comparison: performance metrics

Metrics	SARIMAX	SR	Auto-encoder	CNN
Precision	0.9626	0.9787 ± 0.013	0.9083 ± 0.011	0.9558 ± 0.002
Recall	0.8393	0.9296 ± 0.046	0.8519 ± 0.052	0.9002 ± 0.002
F1_score	0.8983	0.9527 ± 0.021	0.8783 ± 0.027	0.9286 ± 0.001
MAE	0.0038	0.0019 ± 0.001	0.0050 ± 0.001	0.0002 ± 0.000
AUC	0.9195	0.9645 ± 0.022	0.9250 ± 0.026	0.9510 ± 0.001
Time (s)	1403.23	0.0241	1403.26	211.9943

CNN part of SR) to recognize the peaks, tendencies, and more important features of the data due to the filters. On the other hand, the SARIMAX has the lowest percentage (83%) for the Precision metric, which means that this model produces the largest number of false positives.

5 Conclusions

Air quality has been one of the main public health problems in many countries. To study air pollution, reliable monitoring networks are necessary to identify if the contaminants have higher values than the limits established by the local authorities or the WHO. This paper compares four methodologies (i.e., SARIMAX, SR, Auto-encoder, and CNN) to detect outliers and to avoid removing real large values that could be produced due to LRT or abnormal trucks activities. For that, we include artificial outliers in the data of the Carvajal-Sevillana air quality station, to identify if the models can remove the artificial outliers of the data.

The results show that the four models have high precision, but the SR and CNN are the best models, with a precision higher than 95% in all the statistical parameters evaluated. The SR method is the most accurate, possibly for the detection of abnormal data from the computer vision point of view (combination of saliency maps and convolution neural networks).

The CNN method forms a conceptual description of the inputs based on the patterns of the previously seen data. New data that are less like the training data are not well compressed and reconstructed, representing a high error, and identified as abnormal data. On the other hand, the Auto-encoder model is not able to reconstruct a sample that behaves anomalously, resulting in a high reconstruction error. So basically, the higher the reconstruction error of a sample, the more likely it is to be an anomaly. Both methods (CNN and Auto-encoder) are also very accurate in general. The postprocessing could be faster, and the integration of this data as input for air quality machine learning (e.g., Celis et al. 2021) or physical models (e.g., Ballesteros-González et al. 2020; González et al. 2018) can be improved in time and precision. In Bogotá, the creation of air quality scenarios with physicochemical models is very important (e.g., Ballesteros-González et al. 2020; Sokhi et al. 2021), since they could help understand the behavior and changes in the pollutants, and to do this a precise measurement station with a good validation is essential.

As future work, the results can be improved by adding the last CNN feature layer and passing it to an anomaly detection model, as done in classical clustering methods, or even an Auto-encoder. The main idea is to implement the CNN as a feature extractor only.

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Coronavirus Crisis Has Cleaned Up the Air

Nihel Chekir and Yassine Ben Salem

Abstract

Since the beginning of 2020, the Coronavirus crisis has sowed horror around the world and day after day panic spreads in humans. Nevertheless, in this dark situation, a beam of light is shining, and the earth's planet is recovering. The outbreak of the Coronavirus imposed some measures consisting of limiting population movement and displacement, tough social distancing, home isolation, and reduction of industrial activity in various countries of the world. People's densities in the streets decreased, thus the number of cars declined too. Many industrial facilities exhausting pollutants were closed, which brings back a healthy life to the earth. We investigate, in this paper, the results of governmental actions done to face the COVID-19 virus distribution on the rates of air contaminants over four Tunisian cities (Tunis, Sfax, Sousse, and Tataouine). The evolution of Nitrogen dioxide, Sulfur Dioxide, Carbon Monoxide, and particulate matter concentrations during January, February, March, and April of 2020 shows an important drop from mid-March, when lockdown measures take effect. Hence, the air quality is improved. A potential relation between urban air quality and pathological complications of the virus infection leading to mortality is also highlighted and treated. This study reveals that In Tunisia, coincidentally, polluted cities are those concerned by high Covid-19 mortality rates (data up to the end of April 2020).

Keywords

COVID-19 · Tunisia · Air contamination · Lockdown · Environment · Pollutant emissions

N. Chekir (✉) · Y. Ben Salem
National Engineering School of Gabes, University of Gabes, Gabes, Tunisia
e-mail: chekir.nihel@gmail.com

1 Introduction

Since the outbreak of COVID-19 (Corona VIrus Disease of 2019), caused by the "novel coronavirus" (SARS-CoV-2), at the end of December 2019 in China, millions of people in the world have been infected. On Thursday, 30th of April, there were more than 994 confirmed cases in Tunisia, among them 41 deaths. Due to the recent and fast arrival of the worldwide COVID-19 pandemic, the World Health Organization proposed emergency measures attempting to reduce virus spread rates and contamination. These actions involve restricting population movement and travel, tough social isolation, and can go up to general lockdown (Lai et al. 2020). Moreover, it has been observed that the quality of the air in cities in confinement circumstances is being improved, so this imposed human behavior is altering air pollution levels in cities (He et al. 2020).

In this study, we analyzed the evolutions of six air pollutants for the four first month January to April of 2020 year in four Tunisian cities concerned by the COVID-19 pandemic crisis and the protection measures comprising the confinement. These cities present distinct attributes: urban or rural, traffic, residential and industrial. We gathered, treated and explored free air monitoring data for the proposed cities to evaluate the spectacular effect of coronavirus epidemic on air contamination.

2 Settings and Method

Four Tunisian towns earlier concerned about COVID-19 virus were designated for this research. The four towns were chosen principally according to their location, social/economic interest, and number of inhabitants. These towns are the capital Tunis, in the north of Tunisia, Sfax, Sousse, both in the center of the country and Tataouine, in southern Tunisia. The four studied cities have different characteris-

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tics. Another reason assumed in this analysis is when the first infection by the COVID-19 virus occurred. In fact, these cities were infected with COVID-19 much earlier (from 9th to 18th of March).

In this study, we collected air contaminant concentrations from the Air Matters monitoring platform, a worldwide Air Quality Service Provider (www.air-matters.com). For each investigated city, the typical daily concentrations of six main air contaminants for four months duration from the first of January to 30th of April 2020 are treated. Considered pollutants are fine particulate matter ($PM_{2.5}$), rough particulate matter (PM_{10}), nitrogen dioxide (NO_2), ground-level ozone (O_3), sulfur dioxide (SO_2), and carbon monoxide (CO). We assume air quality in January and February of 2020 was under the usual conditions and hence considered normal. Change in quality of the ambient air in March and April of 2020 is caused primarily due to the country-specific response to containing the propagation of COVID-19. We examined the rates of air contaminants in Tunisia and evaluated whether there are immediate straight tendencies in contaminant concentration values due to lockdown measures. Then, we compared before and after COVID-19 air quality across impacted cities.

3 Results

Plotted values of the average monthly data of $PM_{2.5}$, PM_{10}, NO_2, O_3, SO_2 and CO for the four studied Tunisian cities are shown in Figs. 1, 2, 3, 4, 5 and 6. We assessed the evolution of concentrations of air contaminants for January and February to those of March and April when sanitary measures took place. The observed effects for practically all contaminants of each city showed significant reductions and the curves displayed the substantial differences between the situations before and after the early of March 2020.

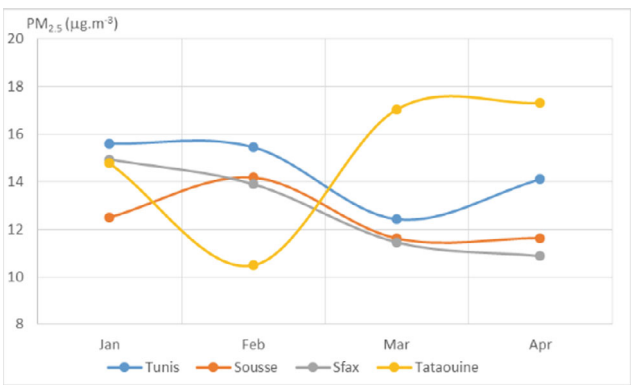


Fig. 1 Monthly average concentrations of $PM_{2.5}$

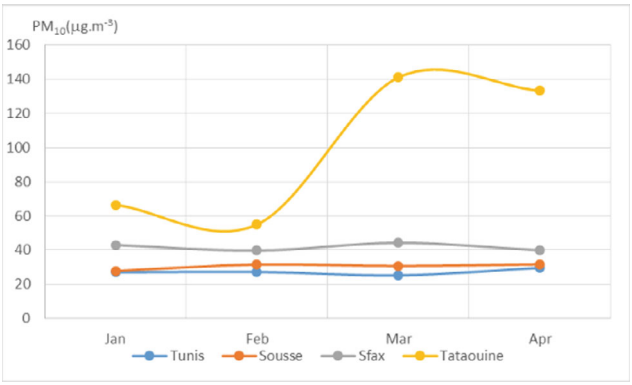


Fig. 2 Monthly average concentrations of PM_{10}

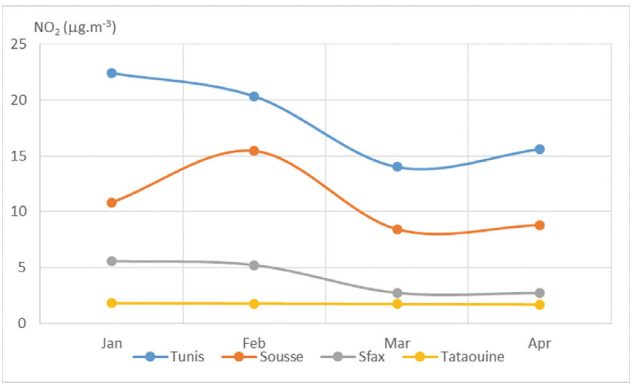


Fig. 3 Monthly average concentrations of NO_2

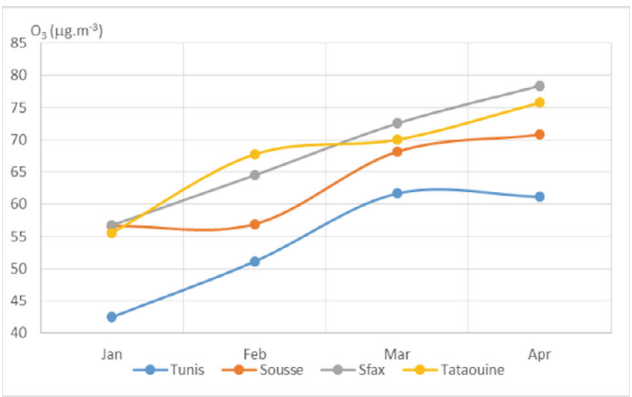


Fig. 4 Monthly average concentrations of O_3

4 Discussion

Starting from the middle of March to the end of April, chemical contaminants had decreased compared to early January values when power stations and industrial plants were running normally. The remarkable drop in $PM_{2.5}$ concentrations could be attributed to the decrease of vehicular traffic and the reduc-

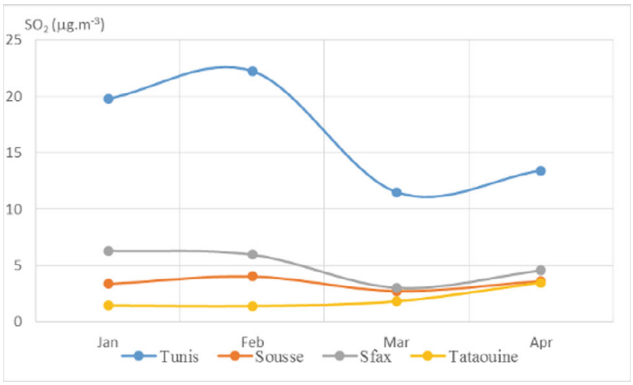


Fig. 5 Monthly average concentrations of SO_2

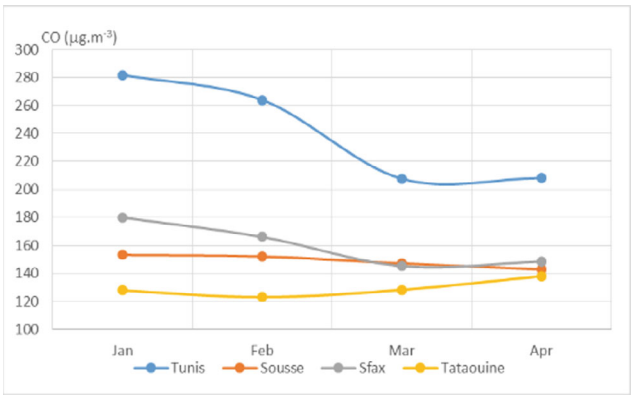


Fig. 6 Monthly average concentrations of CO

tion of emissions from industrial activities. The increase in Tataouine's $PM_{2.5}$ concentrations is due to meteorological conditions. Moreover, Tataouine is a southern town, opening the door to the Sahara of southern Tunisia. Saharan storms, characterizing the spring period, are accompanied by a lot of dust, which explains the increase of $PM_{2.5}$ for the two months of March and April.

The noteworthy evolution of Tataouine's PM_{10} for March and April is mainly due to natural weather conditions too. For Tunis, Sfax, and Sousse cities, the origin of big particulate matter is, generally, human activity. The residence time of PM_{10} in the atmosphere might be implicated in their constant trends.

For NO_2, SO_2, and CO, the decreasing trend for March and April compared to values of January and February months is essentially due to the reduction of the activity of power production plants and other industrial companies and restriction over vehicle circulation to limit the COVID-19 spread over the last months (Chekir and Ben Salem 2021). Tunisian authorities, gradually, stopped transport and travel inside and outside the country. They also forbade local business travel, restricted local transport, closed universities, colleges, and schools to face the wideness of the epidemic, and established numerous quarantines in infected areas. Those governmental actions carried out in March (limitation of transportation and shutdown of educational institutions on the 12th of March) rapidly changed individual and collective behavior in response to reduce human displacement and motion. Social avoidance and almost all economic activity put to a halt because of this specific crisis caused a significant decrease in air pollution emissions over the four examined cities.

When observing the results of prevention actions and lockdowns across studied cities we note that these effects varied differently because the lockdown restricts many industrial activities. The impact on Tataouine, which is an agricultural city, was slightly different from the other industrial towns. Therefore, industrial towns could be more significantly affected by such measures. Similarly, big cities having great traffic activity might incur considerable impact when the lockdown is implemented.

5 Conclusion

Conducted analysis on the evolution trends of monthly average air pollutant concentrations for four towns in Tunisia (Tunis, Sfax, Sousse, and Tataouine) during the four first months of 2020 showed a drop of $PM_{2.5}$, NO_2, SO_2, and CO from the 12th of March when protection measures took place. The comparison of the air quality before and after the crisis in the Tunisian cities showed the concentrations of almost all the contaminants thrown down. Thus, the gradual restriction of industrial activities, vehicle traffic, and decrease in electricity demand in Tunisia because of the COVID-19 crisis had been associated with a visible decrease in air contamination and air quality index. Therefore, this villain virus had contributed to cleaning up the Tunisian air.

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Insect as Sustainable Food: Examination of Predictors of Consumers' Acceptance and the Effect of the Origin and the Social Influence

Martina Morando and Silvia Platania

Abstract

Among the promising and sustainable alternatives in food, entomophagy, a new form of food that uses insects as food, recently emerged. The environmental and nutritional benefits of this diet are numerous; however, there are many consumers worldwide with a strong resistance and aversion to its consumption, which in turn makes its effective implementation complex. This study aims at examining the attitudes of potential consumers towards insects to derive determinants of consumption and possible approaches to make them more popular. For this purpose, we carried out a study examining the predictive effect of the variables Food Neophobia, Environmental Concern and Intensity of Consumption on the willingness to consume insects in their food. Furthermore, it was studied, in a more original perspective, the moderating effect that social influence and controlled and local origin and production have on the previously described variables. A sample of 285 Italian consumers was recruited through random sampling and completion of an online questionnaire. It was found that all predictors were significant predictors of this willingness. In addition, both moderators showed a significant impact. The moderation effects results showed that both Social Influence and Ethnocentrism dampen the negative relationship between Food Neophobia and willingness to eat insect. The same moderators, however, strengthen the positive relationship between Environmental Concern and Healthy Life and willingness to eat insect. This knowledge could become important in terms of practical implications, as it may give suggestions on how consumers can be introduced to a more sustainable type of food, although further studies are needed.

M. Morando (✉) · S. Platania
Psychology Section, Department of Educational Science, University of Catania, Catania, Italy
e-mail: martina.morando@gmail.com

Keywords

Food sustainability · Consumer acceptance · Edible insects · Origin · Social influence

1 Introduction

Among the most important challenges facing the world's population are climate change, loss of biodiversity and hunger. By 2050, food production will need to double to ensure the security and quantity of food needed by the entire population. The current food system is not sufficiently capable of supporting these rhythms sustainably, and thus it is necessary to find alternative sustainable sources and strategies to produce enough food for future generations and, at the same time, maintain a healthy environment. In recent years, food insects have been indicated as a possible alternative to more conventional protein sources, with positive environmental impacts compared to other animal products. The environmental and nutritional benefits of this food alternative are numerous; however, although consumed in many cultures, most Western societies have a strong resistance and aversion to its consumption, which in turn complicates its effective implementation. Given the emergence and importance of the issue, it would therefore be crucial to focus on the attitudes of potential consumers towards insects to derive determinants of consumption, predictors and possible approaches to make them more popular. Literature on the topic suggested potential factors influencing insect consumption, identifying age, gender, country of origin, entomophagy awareness, neophobia, disgust, health effects, environmental sustainability, etc. (Florença et al. 2022; Ayensu et al. 2019; Dossey et al. 2016). Few studies, however, focused on the benefits and barriers of insect consumption, and only in Western countries. For this purpose, we carried out a study examining the predictive effect of the variables Food Neophobia, Environmental Concern and Intensity of Consumption on the

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willingness to consume insects in food diet. Furthermore, it is studied, in a more original perspective, the moderating effect that social influence and controlled and local origin and production have on the previously described variables. Food neophobia refers to the tendency to reject new and unfamiliar foods (Hartmann and Siegrist 2017; Hartmann et al. 2015). According to the current literature, there emerged a negative correlation between consumers' food neophobic tendencies and the likelihood of eating insects (Hartmann and Siegrist 2016). Neophobia is also an important predictor of Western consumers' willingness to eat insects when it is associated with other explanatory variables such as perceived healthiness, gender, etc. (Verbeke 2015; Verlegh and Steenkamp 1999). Environmental Conscientiousness (ECO) can instead be described as the set of psychological factors that influence individuals' propensity towards pro-environmental behavior. The greater the concern and interest in environmental issues and its protection, the greater the willingness of consumers to follow sustainable behaviour and decisions. Consequently, their determinants of choice will shift towards more sustainable products and/or foods because they perceive and desire that they will have less impact on the environment than conventional ones. The effects of country of origin and social influence on consumer behavior are widely explored (Platania et al. 2023); the results concur that both variables play a role in influencing product evaluation and the determinant of choice. Indeed, especially in relation to social influence, consumption has a strong symbolic value.

2 Materials and Methods

A sample of 285 Italian consumers (Female = 171, Male = 114) who consumed local and green products was recruited through random sampling. The sample aged between 18 and 72 years (Mean = 27.52; S.D. = 8.34). Participants were recruited using an online and quantitative survey. A survey link was posted on social media platforms, such as Facebook, X and Instagram, and sent to acquaintances. By clicking on the link, participants received an information sheet and an informed consent form, which, once accepted, led to the survey with instructions on how to complete it. Participation was voluntary. The questionnaire was composed of several scales: Food Neophobia scale (FNS) for the measurement of the food neophobia; Environmental Consciousness Scale (ECO) for the measurement of the environmental concern; Consumption Intensity divided in four factors (healthy life, interest in gastronomy, social activity, ethnocentrism) for the measurement of health interest, social influence and controlled and local origin; Willingness to consume for measuring the willingness to consume insect as food.

Data were analyzed with Statistical Package for Social Science (SPSS 27.0) and Analysis of Moment Structure (AMOS 27.0). Structural Equation Modeling are used for testing for moderation. Descriptive statistics, discriminant validity, reliability and bivariate correlations between the variables were calculated. To check reliability, convergent validity was calculated by calculating the average variance extracted (AVE) and construct reliability (CR). Both, the AVE must be > 0.50 and the CR > 0.60.

3 Results

Table 1 showed the mean scores and the intercorrelations of the variables of the sample. The most impressive findings, consistent with literature, suggest that willingness to include insects in the diet food is negatively correlated with willingness to try new foods, but on the contrary is strongly related to sustainable practices and healthy lifestyles.

The goodness of fit of the model to the sample was tested, reporting good fit: [($\chi 2(118) = 326.14$, $p < 0.001$, $\chi 2/df = 2.75$, RMSEA = 0.065, CFI = 0.93, SRMR = 0.05]. Results of test moderation are shown in Table 2. Environmental Concern and Healthy Life had a significant and positive impact on willingness to eat insects. Conversely Food Neophobia had a negative impact on this willingness. Also, for the moderators emerged the same positive impacts. Regarding the moderation interactions the results showed that both Social Influence and Ethnocentrism dampen the negative relationship between FSN and willingness to eat insect. The same moderators, however, strengthen the positive relationship between ECO and Healthy Life and willingness to eat insect. The idea is that the emphasis on social influence and ethnocentrism are partly responsible for the way in which personal lifestyle (sustainable, healthy, neophobic) influences the willingness to eat insects. This implies that lifestyle is not the only aspect that needs to be looked at, and that the role of 'group' and 'belonging' must be equally examined when analysing these new consumption behaviours.

4 Discussion and Conclusion

Keeping in mind the importance of understanding the different aspects that influence people's propensity towards edible insects based on their knowledge, attitudes and lifestyles (Platania et al. 2023), in order to support policies, actions and/or programmes that promote the necessary food transition, this study focuses on the analysis of predictors of the willingness to consume insects and the role played by social influence and production ethnocentrism. The most interesting findings of the study consist of both the literature's support for predictors of willingness to consume insects and the influential role played by moderators, individually and in interaction with the independent variables.

Table 1 Means, reliability, composite reliability, average variance extracted, and intercorrelations

		A	CR	AVE	Mean (SD)	1	2	3	4	5
1	FNS	0.92	0.89	0.75	5.4 (1.1)	1				
2	ECO	0.89	0.84	0.81	4.5 (0.9)	0.35	1			
3	Healthy Life	0.89	0.85	0.81	4.3 (0.6)	0.22**	0.44*	1		
4	Social Influence	0.90	0.87	0.91	5.3 (1.42)	0.23**	0.15**	0.44**	1	
5	Ethnocentrism	0.92	0.79	0.80	5.6 (1.10)	0.14**	0.09	0.34*	0.46**	1
6	Willingness To Eat Insect	0.88	0.77	0.81	3.9 (1.3)	− 0.56*	0.39**	0.25**	0.13*	0.14**

** $p < 0.001$; * $p < 0.05$

Table 2 Results from moderations analysis

	Willingness to eat insects
Step 1	β
FSN	-0.24*
ECO	0.34**
Healthy life	0.26**
Step 2	
Social Influence	0.18*
Ethnocentrism	0.22**
Step 3	
FSN × social influence	0.13*
ECO × social influence	0.11**
Healthy life × social influence	0.09**
FSN × ethnocentrism	0.10*
ECO × ethnocentrism	0.10*
Healthy life × ethnocentrism	0.08*

** $p < 0.001$; * $p < 0.05$

Social influence in modern society plays a powerful role, especially considering social media and influencers. Reference groups behave as real vectors that guide and influence purchases, becoming often figures to imitate. In this way individuals, even in the process of selecting a product, express simultaneously their need to be a member through behaviour consistent with that of their loved ones, and also a need for autonomy through differentiated behaviour to assert their individuality. This information is crucial for the promotion of sustainable behaviour and for the possible alternative food choice, as it explains how a 'generational' and age-differentiated intervention can have a greater impact for consumers both at an individual and group level, influencing each other. Similarly, origin assumes a considerable role that needs to the attention in the development of policies and practices as it is capable of modulating meanings of quality, personality and values. The place of origin conveys multiple meanings to the brand and products. This happens because the territory itself has a rich heritage of meanings, traditions and characteristics, rooted in time and widely recognized which creates a special bond with the locals and the consumers and confers quality. In the production of these new food alternatives, attention should therefore be given to the deep connection with the territory, which is very strong for Italy with its long wine and food tradition. Clearly, the multiple benefits of these products (nutritional, environmental, economic, etc.) will need to be more fully communicated and concerns such as fear, disgust and possible allergies will need to be addressed for consumers to accept the use of insects as part of their diet. Therefore, our study is an initial tool to explore and understand attitudes towards more sustainable food consumption and behaviour, knowing that future research is still required.

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The Relationship Between the Sustainable Development Goals and the ESG Concept

Olesya Dobryakhina, Vadim Beketov, Anastasia Brazhnikova, and Andrei Trofimov

Abstract

The article analyzes the interrelationships between the UN Sustainable Development Goals (SDGs) (social, ecological and economic components) and the Environmental, Social and Governance (ESG) concept. The history of the development and practical use of SDGs and ESG are considered, and their role in the corporate and public sectors is analyzed. The main components of sustainable development and the ESG approach concepts are compared. The ecosystem of ESG research is considered, and the factors that depend on assessing the company's activities in sustainable development are highlighted. General scientific methods were used in the work: analysis and synthesis, ascent from the abstract to the concrete. The authors analyzed the theoretical basis of sustainable development and socially responsible management. Based on the theoretical analysis, a study of the current situation in implementing SDGs and ESG transformation in the public and corporate sectors was conducted. To form a complete picture of the studied sphere of economic and social relations, theoretical and practical material was used. As a result of the long-term crystallization of the concept of sustainable development, the SDGs are a guideline for forming ESG standards, a plan that requires implementation. At the same time, the ESG Principles are a tool for involving the private sector and civil society in the global sustainable development agenda. Without them, it is impossible to successfully implement the SDGs and achieve the set indicators to benefit social development while preserving the environment. In order to achieve the SDGs, integrating all the components that make up these goals is crucial. This idea is also extrapolated to ESG principles, which are considered in a certain unity, especially in the long term. On the one hand, there is an apparent strengthening of the environmental aspects of the SDGs, which gives hope for their more concrete perception within the framework of the ESG. On the other hand, one of the main qualities of the SDGs (social, ecological and economic components) is their focus on raising awareness between public institutions and private companies regarding the transformation that must take place if humanity wants to follow the path of sustainable development.

Keywords

Sustainable development · SDGs · ESG · Responsible investment · Environmental impact · Social impact

1 Introduction

The problems of business social responsibility and ecology began to worry humanity relatively recently. With the growth of industry, humanity, on the one hand, received the problem of increasing environmental pollution; on the other the growth of well-being, which allowed us to pay attention to long-term problems. In 1987, the UN adopted the Concept of Sustainable Development of Society (United Nations 1987), according to which the needs of the current generation can be met only without prejudice to future generations.

The concept of sustainable development has become an important direction in the search for the well-being of the world community, including in the context of discussing the application of the ESG approach (Environmental, Social,

O. Dobryakhina (✉)
Oxford University, Oxford, UK
e-mail: dobryakhina@gmail.com

V. Beketov
Novosibirsk State Technical University, Novosibirsk, Russia

A. Brazhnikova
Lomonosov Moscow State University, Moscow, Russia

A. Trofimov
Université de Picardie Jules Verne UFR d'Économie et de Gestion, Amiens, Hauts-de-France, France

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Governance) in business. Experts are actively discussing what an ESG agenda is and how businesses can implement it into their processes. However, the origins of this approach are predetermined by the concept of sustainable development.

This work analyzes the relationship between Sustainable Development Goals and the ESG concept.

2 Materials and Methods

The work strategy was to collect, analyze and interpret information from various secondary sources. Analytical reviews of international organizations, scientific literature, Internet publications, marketing research reports, case studies, and statistical data were used as sources. Various rating models, regulatory documents, and guidelines for sustainable development and diagnostics of ESG factors were also used in the work. Previously conducted scientific research and articles used in work on the disclosure of the theory and methodology of sustainable development were also used to analyze critical factors related to the ESG transformation of management systems.

The theoretical basis of sustainable development and socially responsible management were also analyzed. Based on the theoretical analysis, a study of the current situation in implementing the Sustainable Development Goals and ESG transformation in the public and corporate sectors was conducted. In order to form the most complete picture of the studied sphere of economic and social relations, theoretical and practical material was used. General scientific methods were used in the work: analysis and synthesis, ascent from the abstract to the concrete. Elements of deduction and induction were used, which makes it possible to characterize the approach used as abductive in general.

3 Results

The concept of sustainable development is firmly entrenched in the international and national agenda and has become an essential aspect of many large companies. In 2015, the UN adopted the 2030 Agenda for Sustainable Development (United Nations 2015) as a plan for transforming the world, including 17 goals and 169 tasks. The SDG serve as guidelines for developing and adjusting strategies and plans in both the public and private sectors.

Gradually, the principles of sustainable development began to penetrate the financial sphere. Funds focusing on social and ethical investments have appeared.

So, a further stage in the development of the concept of sustainable development was the emergence of the concept of ESG (Environmental, Social, Governance). The ESG Principles were formulated for the first time in 2004 (United Nations and Swiss Federal Department of Foreign Affairs 2004) and became a sustainable business development model. Based on review carried out the Fig. 1 shows an approximate list of elements characterizing various aspects of ESG.

ESG factors generally correspond to the sustainable development agenda but mainly focus on the companies' activities. A comparison of the components of sustainable development and ESG factors is presented in Fig. 2.

It should be noted that there is no unity of approaches in the constituent elements of ESG factors. Companies and investors can independently construct their pool of ESG components. As the importance of ESG grows and the influence of these factors on companies, it is possible to form unified approaches. The development of ESG approaches and the formation of a request from stakeholders to obtain non-financial reporting data, focusing on companies acting with

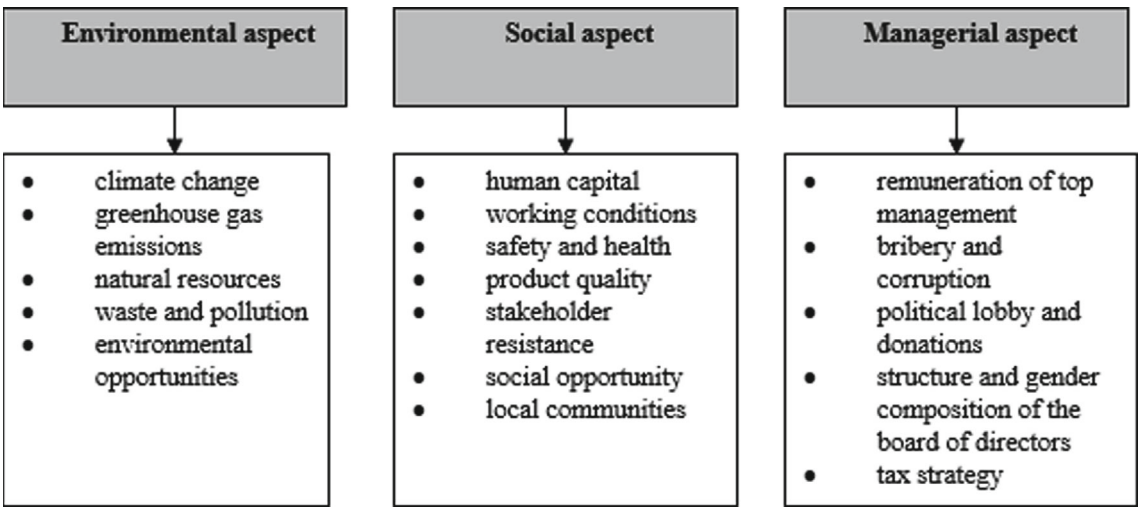


Fig. 1 Examples of elements that make up various ESG factors. Compiled by the author on the basis of Makarov (2021), PwC (2018) and MOEX (2021)

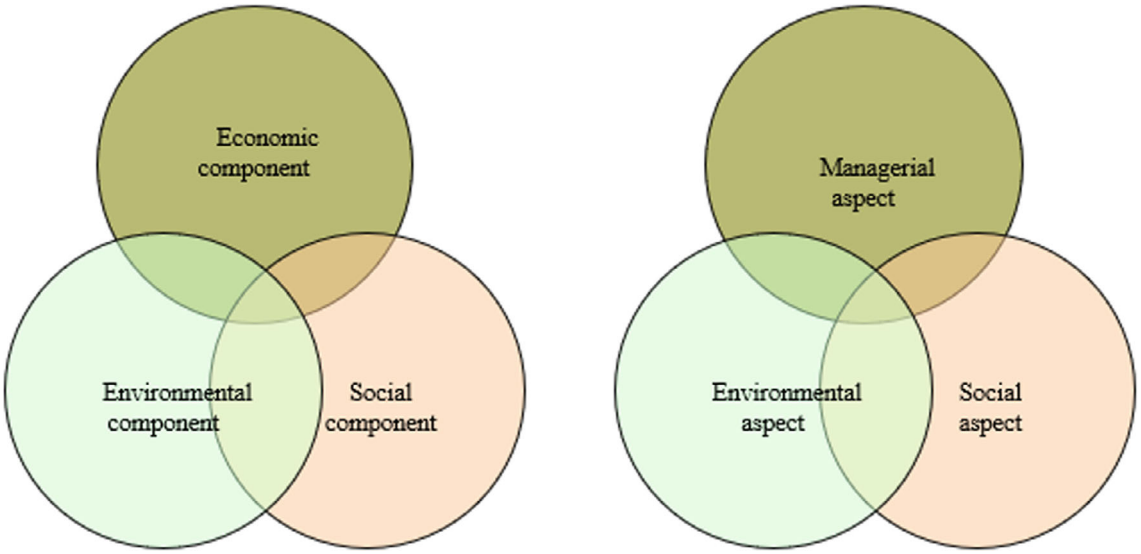


Fig. 2 Components of the sustainable development concept (left) and the ESG approach (right) Recourse: Makarov (2021)

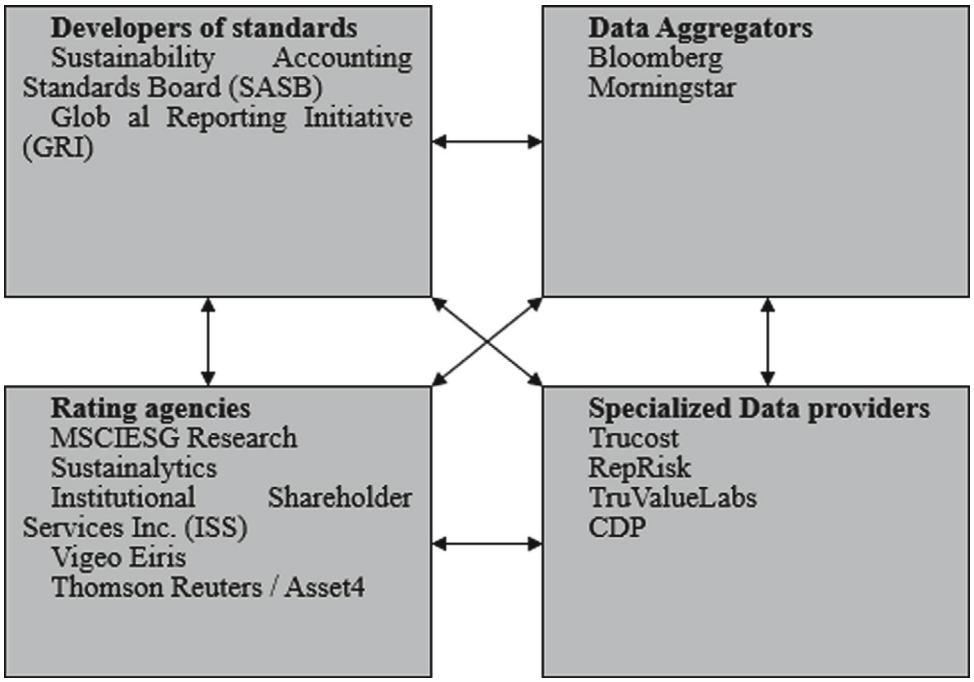


Fig. 3 Ecosystem of ESG research. Compiled by the author on the basis of IShares (2021)

the principles of sustainable development, led to the creation and development of an ecosystem of ESG research IShares (2021) (Fig. 3).

The inclusion of ESG factors in investment analysis and the promotion of ESG information disclosure are the fundamental principles of responsible investment. Figure 4 shows the factors that depend on the assessment of the company's activities.

4 Discussion

Promoting ESG principles entails emerging new "green" tools that demonstrate a link with environment and social goals.

One of the critical legal issues in this regard is the question of the correlation between rapidly scalable ESG standards and international and national law, that is, the assessment of legal risks and conflicts. No less significant are the

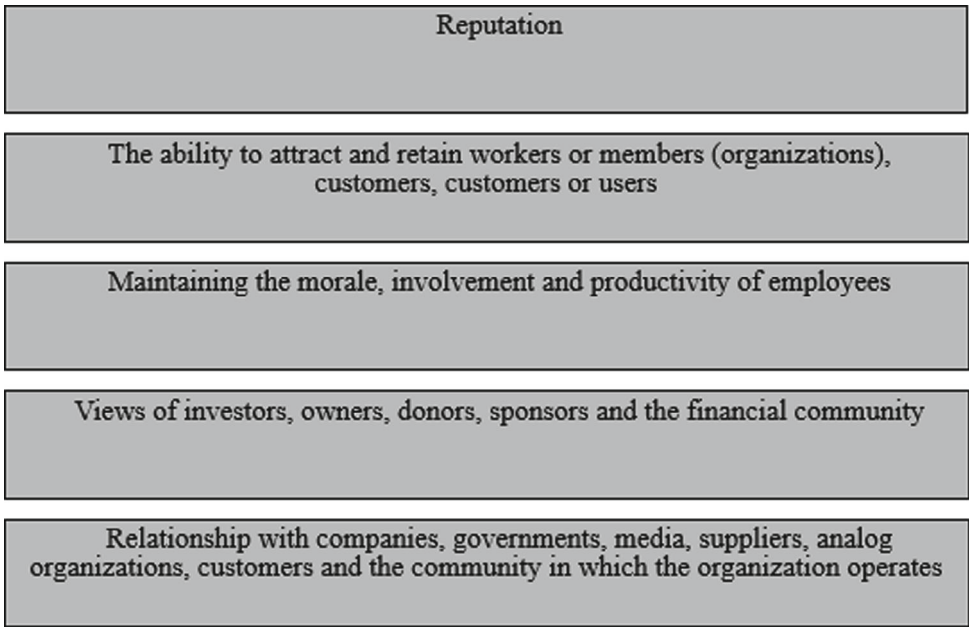


Fig. 4 Factors depending on the assessment of the company's activities in the field of sustainable development. Resource (Makarov 2021)

economic dangers of the impact of ESG principles on the stock markets and investment policy. Given that ESG factors are embedded in investment decision-making, ESG approaches are also becoming significant for public administration.

On the one hand, ESG principles are also integrated into investment strategies at the regional level. On the other hand, potential investors may pay attention to ESG factors in specific regions. Based on ESG factors, potential investors can assess projects' social and environmental risks. The ESG agenda should become an essential element of interaction between regional authorities and stakeholders (Nazarenko 2020).

Thus, a new paradigm of responsible business management is emerging, aimed at ensuring sustainable development and based on a new regulatory architecture of ESG principles and standards and sustainable development strategies of companies.

5 Conclusions

So, the SDGs, due to the long-term crystallization of the concept of sustainable development, are a guideline for forming ESG standards, a plan that requires implementation. At the same time, the ESG principles are a tool for involving the private sector and civil society in the global sustainable development agenda. Without them, it is impossible to successfully implement the SDGs and achieve the set indicators for the benefit of social development while preserving the environment.

In order to achieve the SDGs, the integration of all the components that make up these goals is essential. This idea is also extrapolated to ESG principles, which are considered to be of a certain unity, especially in the long term.

It is worth noting that, despite the many works devoted to the topic of sustainable development, the body of knowledge about the factors and mechanisms of ESG transformation and sustainable development of management systems is in the process of formation.

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From Awareness to Action: Empowering Students for a Sustainable Future Through Fostering Environmental Awareness

Suzan Al Abidi, Khaleel Alarabi, Linda Pagani, Othman Abu Khurma, Aktham Alarabi, and Razan Taani

Abstract

This study investigated how pre-service teachers' environmental awareness influences their participation in ecological activities, knowledge of environmental issues, attitudes toward sustainability, and current environmentally friendly actions. It also explored factors like personal motivations, peer influence, educational background, and parental support that affect both awareness and sustainable behavior. By surveying 240 pre-service teachers et al. Ain University, the study found: A strong link between higher environmental awareness and more frequent participation in ecological activities. More environmentally conscious individuals had more positive attitudes towards sustainability and engaged in more eco-friendly practices. Integrating environmental education and awareness initiatives into the curriculum can empower students to make sustainable choices and contribute to a better future. The study highlights the importance of raising environmental awareness among students to inspire them to take sustainable actions and become a more ecologically responsible generation. Further research is needed to confirm these findings and develop effective strategies for boosting awareness and motivating sustainable behavior.

Keywords

Environmental awareness · Sustainability · UAE · Preservice teachers · Environmental education

S. Al Abidi · K. Alarabi (✉)
Department of Postgraduate Professional Diploma in Teaching, Al Ain University, Al Ain, UAE
e-mail: khaleel.alarabi@aau.ac.ae

L. Pagani
School of Psycho-Education, Université de Montréal, Montréal, Canada

O. Abu Khurma
Pedagogy, Technology and Teacher Education Department, Emirates College for Advanced Education, Abu Dhabi, UAE

A. Alarabi
Electrical Engineering/Network Systems and Security Department, Al-Balqa' Applied University (BAU), Amman, Jordan

R. Taani
Independent Scholar, Abu Dhabi, UAE

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1 Introduction

The younger generation urgently needs to prepare itself as the future leaders of this world, as the global need for environmental conservation and sustainable development grows day by day. Therefore, this study highlights that need for students and helps them to gain better insights into their power to promote a sustainable future.

It is essential to apprehend how environmental awareness instigates ecological behaviors. Environmental awareness refers to both a comprehension of the importance of taking steps to safeguard the natural world as well as the ability to do so (Boca and Saraçlı 2019). This is a critical skill that students need to develop, as they become the heirs of our planet and are required to make decisions eventually about their future (Hicks 2001).

Students' environmental engagement hinges on several key factors. Baseline knowledge of environmental issues fosters appreciation and action (Schröder et al. 2020; Iwaniec and Curdt-Christiansen 2020). This study delves into their awareness, allowing educators and policymakers to identify knowledge gaps and tailor educational programs (Mach et al. 2020). Building a generation equipped with knowledge empowers effective decision-making on environmental challenges (Mach et al. 2020). Additionally, positive attitudes toward sustainability fuel student action (Broska 2021; Qazi et al. 2020; Handoyo et al. 2021; Debrah et al. 2021). Finally, the study examines existing engagement levels, as active students often continue their involvement and inspire others (Schanes and Stagl 2019). By understanding these influences, we can cultivate a generation of environmentally conscious leaders.

Finally, Participants' environmental awareness and inclination toward sustainable behavior can be shaped by motivations, peer pressure, educational background, and parental support (Zsóka et al. 2013). Motivations encompass personal beliefs and values, inspiring individuals to care for and act on behalf of the environment (Barszcz et al. 2022). Peer pressure delves into social interactions, examining peers' roles in shaping attitudes and behaviors toward environmental sustainability (Stevenson et al. 2019). Educational exposure highlights how schools instill environmental awareness and sustainable conduct (Corrochano et al. 2022). Lastly, parental support explores the impact of parents' involvement, guidance, and modeling on students' environmental behavior (Grønhøj and Thøgersen 2017). This study aims to bridge the gap between theory and practice, empowering students to construct a sustainable future through enhanced environmental awareness in future classrooms. Based on that, the study is geared by the following research questions:

1. Is there any correlation between participants' environmental awareness and their participation in ecological activities?
2. Is there any correlation between participants' baseline knowledge of environmental issues and their engagement in ecological activities?
3. Do participants' attitudes towards environmental sustainability impact their engagement in ecological activities?
4. What is the level of participants' current participation in ecological activities?
5. What is the relation between participants' environmental awareness and tendency to engage in environmentally sustainable behavior (individual motives, peer pressure, educational exposure, and parental support)?

2 The Objective of the Study

The study investigates the connection between students' environmental awareness and their involvement in ecological behaviors. Through analyzing baseline knowledge, attitudes, current participation, and potential influencing factors, the study aims to comprehend how to promote a sustainable future by enhancing student engagement. The objective involves exploring correlations between environmental awareness and ecological contribution, identifying motivating factors for sustainable behaviors, and using the findings to develop strategies that encourage student participation in eco-friendly practices. Ultimately, the goal is to bridge the gap between understanding environmental issues and actively participating in solutions, empowering students to become effective stewards of the planet.

3 Methods

Questionnaires are a widespread and effective method for collecting data in academic research since they allow participants to reply to a series of items (Stoet 2017). (Cohen-Mansfield et al. 2016) and (Takase et al. 2015) define a questionnaire as collecting self-reported data from participants on their views, beliefs, principles, practices, standards, and insights. A validated Environmental Awareness Scale (EAS) has been used to assess participants' environmental awareness. The EAS evaluates participants' knowledge of key environmental concerns. The scale consists of 28-item multiple-choice questions and Likert-type statements providing quantitative data on participants' levels of awareness. Meticulously, these items were organized into five key constructs as shown in Table 1: participation in ecological activities (PEA) (4 items), participants' baseline knowledge of environmental issues (PBKEI) (4 items), attitudes toward sustainability (ATS) (4 items), current participation in ecological activities (CPEA) (4 items), and tendency to engage in sustainable behavior (TESB) (12 items). On a 5-point Likert scale, responses to each questionnaire item have ranged from 1 (strongly disagree) to 5 (strongly agree).

Data collection methods are structured for consistency and ethical adherence. Participants from the professional diploma department were purposefully sampled, representing diverse academic levels, subjects, and age groups. Those who agreed were provided questionnaires, aiming for a sample size of $n = 240$ to adequately represent the population. Cronbach's Alpha coefficient assessed scale validity, revealing a reliable questionnaire, as shown in Table 2, with a coefficient of 0.793. This indicates the components effectively connect and accurately measure the study's constructs, ensuring robustness in data collection and analysis.

The data has been computed using descriptive statistics, which includes measures such as means, standard deviations, and percentages. The study employs inferential statistics, specific correlation analysis, and multiple regressions for examining the associations between variables and determining the factors significantly impacting individuals' involvement in ecological activities.

Table 1 The environmental awareness scale constructs

Construct	Number of items	Questionnaire items
PEA	4	1, 2, 3, 4
PBKEI	4	5, 6, 7, 8
ATS	4	9, 10, 11, 12
CPEA	4	13, 14, 15, 16
TESB	12	17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28

4 Results

Statistical analysis revealed a significant positive correlation between participants' environmental awareness and engagement in ecological activities. Elevated awareness prompted students to take concrete steps toward sustainability. The study also identified a positive correlation between baseline knowledge of environmental issues and ecological participation. Some students displayed knowledge gaps in specific areas. Notably, individuals with greater prior knowledge showed a higher inclination to engage in ecological activities, underscoring the importance of educational exposure in promoting environmentally conscious behavior. Positive attitudes toward sustainability were linked to increased active participation in ecological activities. Findings highlighted varied degrees of current engagement, with some consistently participating in practices like recycling, energy conservation, and clean-ups, while others showed restricted or sporadic involvement.

The findings highlighted that individual motivations, peer pressure, educational exposure, and parental support significantly contribute to students' environmental awareness and inclination toward sustainable behavior. A substantial 55% of participants recognized the strong influence of environmental awareness on their behavior. However, 15% felt individual motivations played a minor role in their sustainable decisions. Peer pressure's impact on sustainable behavior is minimal, with only 23% experiencing such pressure, while 77% reporting negligible influence. Participation in environmental education programs positively impacted 70% of participants, with 80% acknowledging its favorable influence. Nonetheless, 30% note limited educational exposure, and only 40% within this subgroup report a discernible impact on their awareness. Parental support proves crucial, with 82% receiving encouragement positively affecting subsequent actions, while 18% report a lack of parental support for sustainable behaviors. Overall, the study underscored the multifaceted influences shaping students' environmental awareness and sustainable behaviors.

5 Discussion

The study revealed a strongly positive correlation between participants' environmental awareness and their engagement in ecological activities. Higher levels of environmental

Table 2 Reliability coefficients for the questionnaire

Constructs	N of items	Mean	Std. Deviation	Cronbach's alpha (α)
PEA	4	3.876	0.3865	0.766
PBKEI	4	4.438	0.4231	0.753
ATS	4	4.672	0.3342	0.794
CPEA	4	3.506	0.3138	0.815
TESB	12	4.645	0.3661	0.834
All the Constructs	28	4.008	0.3006	0.793

awareness align with increased involvement in sustainable efforts among students, consistent with prior research (Abdelwahed et al. 2022; Kolb et al. 2017). This study underlines the crucial role of environmental education that goes beyond raising awareness to empower students to make sustainable choices. It should actively empower students to make sustainable choices. Notably, the diverse levels of baseline environmental knowledge among participants highlight the need for targeted and comprehensive educational initiatives to fill knowledge gaps. By improving baseline knowledge, teachers can equip students to make informed decisions and embrace more sustainable behaviors (Georgiou et al. 2021). Furthermore, the study demonstrated that participants' attitudes toward sustainability significantly influenced their likelihood of engaging in ecological activities. Positive attitudes encourage students to adopt eco-friendly practices and support environmental conservation in their daily actions (Qazi et al. 2020; Handoyo et al. 2021; Debrah et al. 2021). Therefore, fostering positive attitudes towards sustainability within environmental education programs is crucial, allowing students to internalize sustainable values and behaviors as inherent aspects of their identity.

The results indicated a diverse range of student participation, influenced by factors like peer influence, parental support, and the availability of eco-friendly infrastructure (Zsóka et al. 2013; Gulzari et al. 2022). This underscores the need for a conducive atmosphere fostering collaborative engagement among peers, incentivizing parental involvement, and providing readily available avenues for ecological endeavors. The study highlighted the significance of individual motivations as the driving force behind sustainable behavior engagement. Encouraging a personal connection and intrinsic commitment to environmental challenges is crucial for promoting long-term sustainable behavior. Peer pressure emerged as a noteworthy determinant affecting participants' environmental attitudes and behaviors (Casaló and Escario 2018). The findings suggested that social influence, particularly peer-induced pressure, significantly impacted fostering sustainable behaviors. Creating a supportive social environment that encourages and incentivizes sustainable conduct can effectively harness the positive impact of peer influence (Schanes and Stagl 2019; Stevenson et al. 2019).

Furthermore, the study underscored the necessity of integrating environmental education into curricula, providing students with structured and comprehensive opportunities to learn about sustainability. Additionally, participants' environmental awareness and sustainable behavior were significantly predicted by parental support. Students engaging in environmental discussions with their parents and receiving positive reinforcement demonstrated a greater understanding of environmental issues and a heightened willingness to adopt sustainable behaviors (Zsóka et al. 2013). These findings emphasize the crucial role of families in nurturing environmental awareness and sustainability in students.

6 Conclusion and Recommendations

The study underscored the crucial role of environmental awareness in readying students for a sustainable future. Teachers and policymakers can empower students by addressing information gaps, fostering positive attitudes, and creating an enabling environment for engagement. Emphasizing holistic and targeted approaches is essential to cultivate environmentally conscious individuals actively contributing to a sustainable planet. Collaborative activities harness students' potential as change agents, guiding them from awareness to action to pursue a more sustainable future (Elia et al. 2020; Ali et al. 2021).

Here are some recommendations for raising students' environmental knowledge and participation in environmental activities: (1) Environmental issues such as climate change, pollution, and deforestation should be taught in schools; (2) Integrate hands-on lessons on recycling, composting, and energy conservation into the curriculum. By actively engaging in these practices, students will gain the knowledge and confidence to become contributing members of a sustainable future; (3) through field trips, guest speakers, and environmental clubs, schools should provide children with chances to learn about environmental issues. Engaging with environmental issues in the real world allows students to see the bigger picture and develop

a stronger sense of responsibility for our planet's well-being; (4) they can also urge students to conduct their research on environmental issues; (5) Bridge the gap between environmental knowledge and student action by investing in teacher training. By continuously developing their skills in environmental education, teachers become better equipped to inspire the next generation of environmental stewards; (6) Nurture student leadership by encouraging the formation of environmental clubs. These clubs empower students to become agents of change within their schools and communities.

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Unlocking the Power of Synergy: Leveraging AI and Change Management to Achieve Environmental Integration and Sustainable Development

Narcisa Roxana Moșteanu

Abstract

Environmental degradation and unsustainable development practices have become major concerns in the modern world. To address these issues, there is a need for effective integration of environmental considerations into decision-making processes, policies, and practices. This paper trains to explore the role of integrating AI and change management in achieving environmental integration and sustainable development. This study utilized a literature review to analyze existing studies on the mixing AI and change management for environmental integration and sustainable development. The data were collected through an extensive search of relevant peer-reviewed journals, conference proceedings, and books. The results of this study show that the integration of AI and change management can be an effective approach to achieving environmental integration and sustainable development. AI can be utilized to identify and address environmental challenges through data analysis, while change management can be applied to enhance strategies and policies to respond to these challenges and promote environmental integration and sustainable development. The integration of AI and change management provides an opportunity to leverage the power of technology and organizational change to promote sustainability. By identifying and addressing environmental issues through data analysis and strategic planning, organizations can make more informed decisions about environmental management and sustainability, leading to more effective and efficient use of resources, reduced environmental impact, and improved overall sustainability outcomes. In conclusion, this study demonstrates that the integration of AI and change management can play a crucial role in achieving environmental integration and sustainable development. By leveraging the power of synergy, organizations can make more informed decisions about environmental management and sustainability, leading to a more sustainable future for all.

Keywords

Sustainable development · Environmental integration · Artificial intelligence · Change management · Organizational management

1 Introduction

As organizations strive to remain competitive in an increasingly complex and dynamic business environment, the need for sustainable change has become more critical than ever. One of the key drivers of sustainable change is the implementation of AI and change management. AI has the capability to transform the way organizations operate, giving novelty perceptions, improving efficacity, and releasing additional perspectives. The successful implementation of AI requires effective change management. Goralski and Tan imply that new tech is rapidly bringing novel visions in business, corporate practice and government policy. The integration of AI is inevitably linked with business management as well as for the education of future business leaders (Goralski and Tan 2020). Thomas argues that change is becoming an increasingly dominant factor in a company's day-to-day operations. To effectively manage this, specific management techniques are necessary, which can be collectively referred to as change management (Thomas 2021). In exploring the significant influence of combined effect relating AI and Change Management, the last one confirms that staff, processes, and logistics/machine are collectively involved to achieve the desired outcomes of this initiative (Valtiner and Reidl 2021; Moșteanu 2020).

N. R. Moșteanu (✉)
America University of Malta, Bormla, Malta
e-mail: narcisamosteanu@yahoo.com

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This article explores the ability of interaction among AI and Change Management, and how this incorporation can lead to sustainable change keeping environmental integration present. The paper discusses how this advancement will lead institutions to release the great benefits from new tech, AI and drive perform change that will profit both the corporation and community.

2 Settings

The study aims to explore the role of integrating AI and change management in achieving environmental integration and sustainable development. The data for this study were collected through an extensive search of relevant peer-reviewed journals, conference proceedings, and books. This indicates that existing literature was the primary source of data. The collected literature and interviews were reviewed and analyzed to understand the existing studies on the application of AI and change management on environmental integration and viable development.

The answers presented in this paper revealed that the integration of AI and change management can be an effective approach to achieving environmental integration and sustainable development. AI can be utilized for data analysis to identify and address environmental challenges, while change management can be employed to develop strategies and policies to promote environmental integration and sustainability.

3 Findings and Discussions

3.1 The Necessity for Sustainable Transformations

The fast developments in AI already have substantial consequences for the national wealth and community. These advancements started to affect business operations and characteristics of goods and services, which disturb the outcomes such output, HR management, competition, and environment. AI is coming with a crucial change the development of modernization, thus having vital effects (Cockburn et al. 2018).

RPA (robot process automation) targets the new developments, the machines, which are increasingly beginning to replace repetitive human tasks. At the same time, these advancements call for entire staff to work together to fulfill the business objectives. According to Raisch and Krakowski, each institution would do well to allocate adequate resources to growth, to maintain a continuous level of performance. It is believed that businesses can overcome diverging potentials by adopting a broader perspective that combines intelligent automation with sustainable growth (Raisch and Krakowski 2021).

Environmental integration is essential for sustainable development, as it promotes the responsible and efficient management of scarce resources, ultimately reducing poverty and inequality. The utilization of AI modeling plays a significant role in enhancing resource efficiency by streamlining information processing. This enables data-driven decision-making through the combination of numerical AI tools and the application of human intellectual skills. By leveraging the power of AI, organizations can optimize resource allocation, minimize waste, and make informed decisions that contribute to sustainable development and environmental stewardship (Xiang et al. 2021).

The utilization of AI has opened up new possibilities in tackling environmental sustainability challenges that were previously deemed insurmountable. AI-optimized models can propose alternative strategies for safeguarding biodiversity. Through monitoring energy usage, AI can reduce energy consumption and prevent electricity wastage. AI offers effective solutions for addressing water pollution and scarcity. By leveraging AI, it is possible to develop transportation networks that are more environmentally sustainable. AI has the capability to uncover previously unknown patterns in manufacturing processes or operations. It can play a role in minimizing air pollution and enhancing air quality (Johnson 2023). However, the existence of numerous challenges that the business environment is now facing was observed. The specialized literature, and results of the implementations already done, show that AI helps to solve many challenges faced in the current business environment, but it is not a panacea. AI should be considered as a tool that can be used together with other strategies and approaches to give the expected efficiency (Fig. 1).

Addressing the challenges that corporations can face now requires smart and lasting change. This will lead to a constant profitable development of the business; in time, it will emphasize the ability to adapt and respond to economic life in continuous movement; it will strengthen the brand and increase the reputation of the business, all on the support of a good administration of risk management (Fig. 2). Understanding and correctly implementing change management certainly helps to build a real foundation for long-term success.

3.2 The Aptitude of AI for Sustainable Change

A recent study carried out by Ricardo et. al. (2020), shows that AI intervenes as an enabler for 134 objectives (79%) for all sustainable development goals (17, developed by UNESCO, https://en.unesco.org/sustainabledevelopmentgoals), by improving technology, which can allow certain

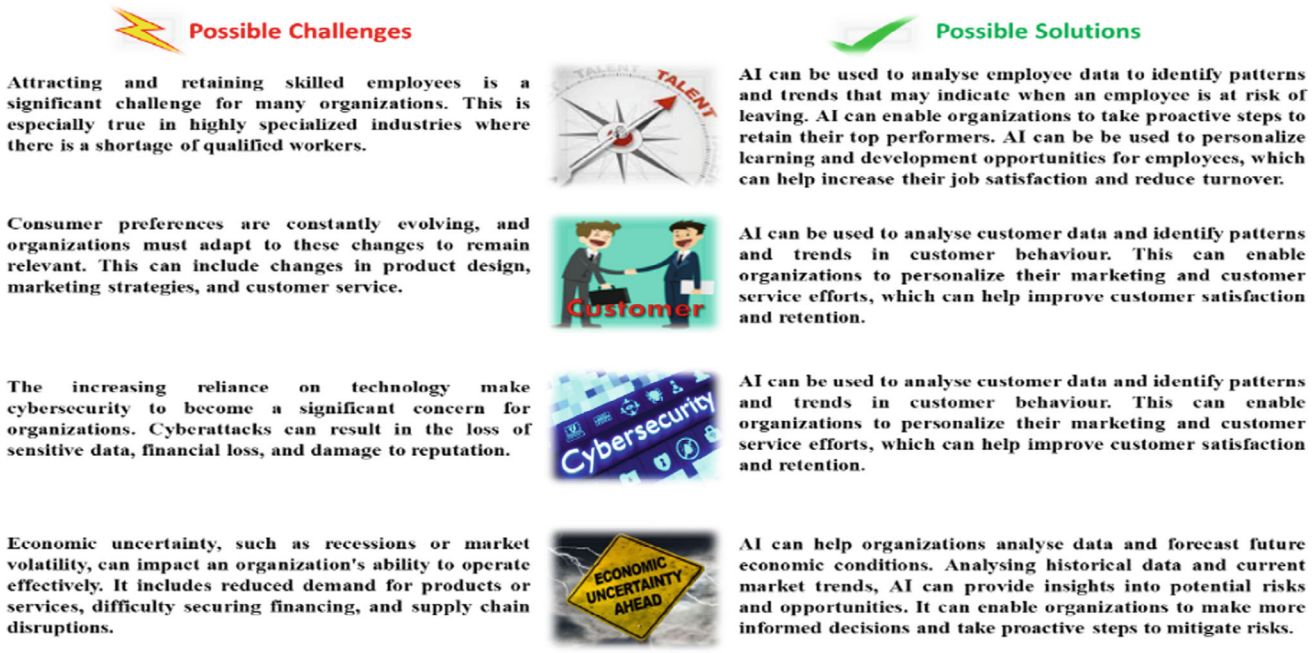


Fig. 1 Possible solution to mitigate organizational challenges

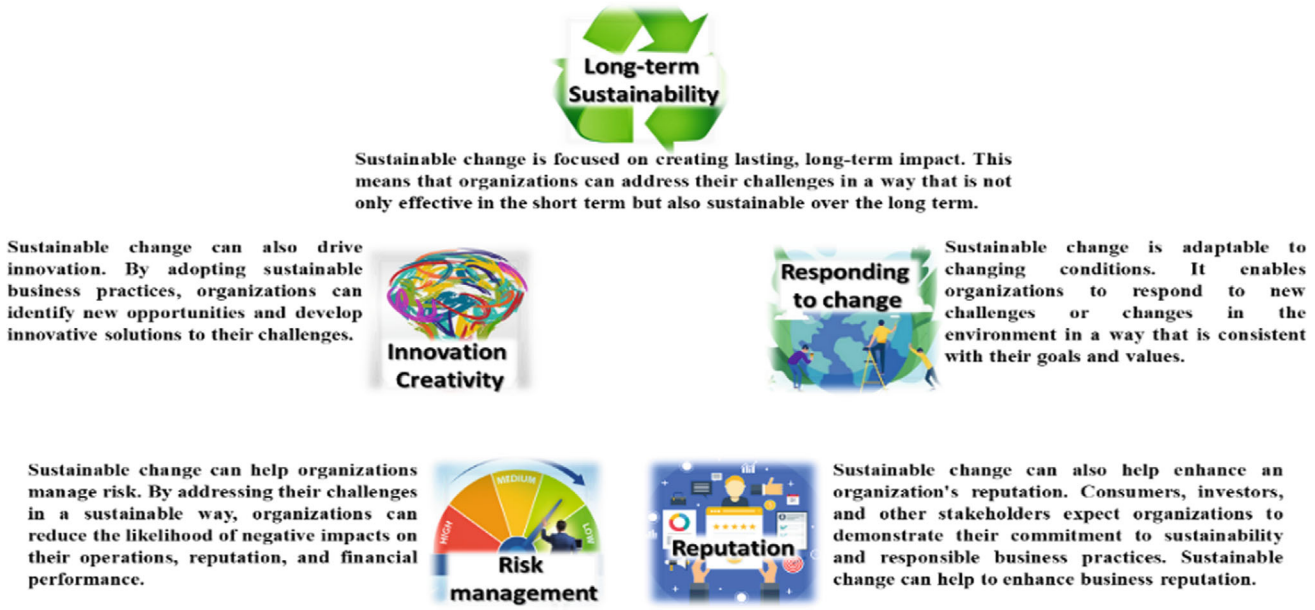


Fig. 2 Possible reasons to address sustainable changes

current limitations to be overcome. As Fig. 3 shows, the 17 objectives are classified into 3, according to the three pillars of sustainable development—Society, Economy and Environment (Ricardo et al. 2020). It can be seen that 59 objectives (35% and for all objectives) may be adversely affected due to AI development.

Figure 3 visually shows how AI can facilitate or limit progress towards each of the Sustainable Development Goals, represented by colored squares with corresponding numbers. The figures at the top show the participation of all levels that could be affected by AI, while the inside shows the participation in each SDG. The outer area shows the results for the main groups: society, economy, and environment. The inner area and values in parentheses show the results when the record type is considered.

Thus, AI can be applied in a variety of fields to drive sustainable change, including energy efficiency, waste reduction, sustainable agriculture, sustainable supply chain, envi-

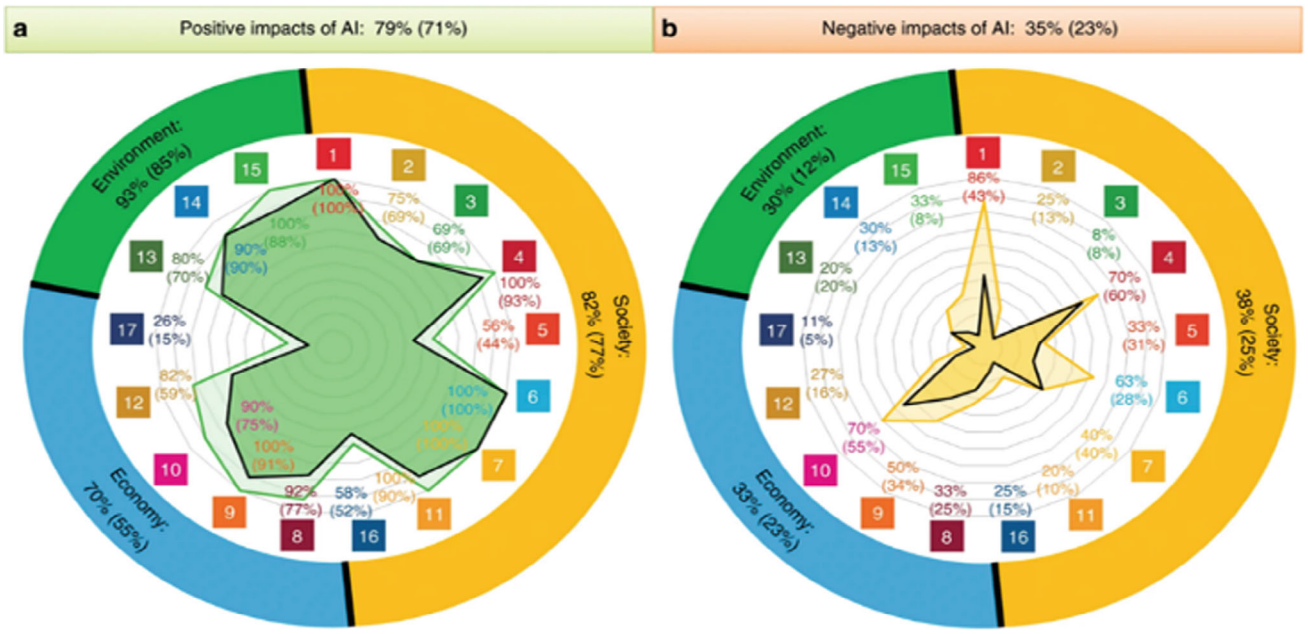


Fig. 3 Impact of AI on businesses [10]

ronmental monitoring, procurement management, human resource management, function operation, financial and optimal use of resources. At least two or three of these areas are relevant to any type of business. Certainly, waste reduction is of particular importance, and we will emphasize it in particular. Here's how AI can be used to optimize energy use in buildings and factories. For example, AI-based HVAC systems can automatically adjust temperature and ventilation settings based on occupancy and external weather conditions. This can reduce energy consumption and evening gas emissions. In terms of waste reduction, AI can optimize waste management systems. For example, AI-powered sorting systems can also identify materials separated from recyclables from non-recyclables. AI can also optimize logistics systems to reduce emissions and waste associated with transportation.

4 The Synergy of AI and Change Management to Achieve Environmental Integration and Sustainable Development

Environmental degradation and unsustainable development practices have become major concerns in the modern world. To address these issues, there is a need for effective integration of environmental considerations into decision-making processes, policies, and practices. AI and Change Management can work together for driving Sustainable Change with Environmental Integration. The synergy aims to identify opportunities for AI; analyze and evaluate the impact of AI implementation; and engage all stakeholders in the process.

By working together, AI and Change Management can help organizations achieve their sustainability goals while also driving innovation and growth. The present study learns that there are many examples of organizations that have successfully integrated AI and change management for sustainable change to: (1) optimize data center energy usage, reduce waste in manufacturing, and improve supply chain efficiency; or to optimize energy usage in manufacturing and to improve predictive maintenance of industrial equipment; (2) optimize fuel usage, reduce emissions, and improve maintenance of aircraft; (3) improve efficiency, reduce waste, and promote sustainability across their research and academic operations.

In all industries where AI and Change Management were implemented it was observed that it is provided a continuous training and support and promoting a culture of sustainability, environment protection, to be able to create a sense of shared purpose and drive adoption of new technologies and practices.

5 Conclusions

Environmental integration is the process of incorporating environmental considerations into decision-making processes, policies, and practices to promote sustainable development. AI and Change Management can play a crucial role in environmental integration by helping to identify and address environmental issues through data analysis and strategic planning. AI can be used to analyze data from various sources, such as satellite imagery, weather sensors,

and social media, to identify environmental problems and patterns. Change Management can then be used to develop strategies and policies to address these issues and promote sustainability.

By integrating AI and Change Management, organizations can make more informed decisions about environmental management and sustainability, leading to a more effective and efficient use of resources, reduced environmental impact, and improved overall sustainability outcomes.

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The Role of Environmental Factors in Settlement Plan Decisions of UMED Łódź's Medical Students

Brygida Klemens , Diana Rokita-Poskart, Danuta Jędrzejewska, and Anna Jędrzejewska

Abstract

While limited research exist on the motivations for migration choices, particularly settlement and post-graduation work decisions, natural environment factors are often marginalized. At a time of intense phenomena resulting from climate change, it is necessary to conduct a broad debate on the role of environmental factors. The subject research can contribute to such considerations. The pilot study was conducted in April 2023 among 29 third-year military medical students at the Medical University of Łódź in Poland. The study was conducted by using the PAPI and the snowball methods. For the purpose of this paper, the authors focused on the determinants of the students' post-graduation settlement decisions, specifically analysed environmental determinants and compared them with economic and social determinants. The research shows that natural environmental issues play a fairly important role in settlement decisions, although students don't find them to be a priority. It is not surprising that post-graduation settlement and employment decisions are affected by economic factors, social factors or opportunities for professional development, which in the case of the medical profession plays a special role, as the choice of medical specialties or working with modern medical equipment is limited depending on the place of work. The study emphasizes the increasing importance of natural environment factors, underscoring the ongoing need for awareness and further research in this area.

Keywords

Determinants of settlement decisions · Environmental factors · Environmental quality

1 Introduction

For a long time, it has been believed that economic factors are the most important factors influencing settlement decision. The first migration studies showed that the most significant motive for choosing the place of residence was the desire to improve living conditions (Ravenstein 1896). Economic theories of migration also shed light on this issue (Todaro and Easterlin 1980). According to the neoclassical approach, individuals weigh benefits and costs of moving versus staying in their current place of residence when choosing where to live. The micro-economic viewpoint assumes that migrants aim to maximise their expected benefits and satisfaction by changing their place of residence (Jończy et al. 2021). Previous studies have shown that labour market performance has a positive effect on settlement intentions (Connelly et al. 2011; Huang et al. 2018a; Sheng and Yang 2020). Many studies have focused on the differentiation of economic factors (Chen and Wang 2018). For example, authors in Wang and Shen (2022) found that the role of economic factors varies depending on different economic statuses. However, due to growing importance of environmental protection, non-economic factors influencing settlement decision are becoming increasingly important. Consequently, numerous studies have been conducted on demographic characteristics (Huang et al. 2018b), health conditions (Twigger-Ross and Uzzell 1996), integration (Hass, and Fokkema 2011) or housing (Jensen and Pedersen 2007). In particular, increasing importance is being given to environmental factors.

There is no doubt that climate change has a huge impact on living conditions and quality of life. It is largely caused

B. Klemens (✉) · D. Rokita-Poskart · D. Jędrzejewska
Opole University of Technology, Opole, Poland
e-mail: b.klemens@po.edu.pl

A. Jędrzejewska
Medical University in Łódź (UMED), Łódź, Poland

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by human activity and its effects harm the economy and generate social losses in the future (Wąs et al. 2021; Klemens et al. 2022). The highest temperatures ever measured in the world were recorded in July 2023, with record heat waves reaching Europe causing fires, droughts and health problems for many inhabitants. Heat waves are believed to be one of the leading causes of death from extreme weather events (Robinson 2001; Krzeszowiak and Pawlas 2015). Other natural disasters, such as floods, hurricanes or weather anomalies, among others, also have a negative impact on the quality of life and health of the population (Diaz 2007). The global policies being undertaken do not seem to be having the positive effects expected (IPCC 2021), and the negative consequences for health, life and quality of life are only getting worse (Mora et al. 2017).

Natural environment factors become even more important for high-end talents, i.e. people who are aware of the existing risks and are educated in the health professions. For this reason, the main objective of the study was to determine the role of environmental factors such as access to green spaces in settlement decisions. The main hypothesis states that factors related to natural environment quality are important and constitute a significant determinant of settlement intensions and the choice of place of work among respondents representing medical practice students in Łódź.

2 Materials and Methods

The presented paper focuses on the pilot study conducted among students at the Medical University in Łódź. This study served as a preliminary investigation to identify the determinants of migration among medical practice students and validate the survey questionnaire. In April 2023, the pilot study was conducted with 29 third-year students enrolled in the Minister of National Defence (MND) medical practice course at the Medical University in Łódź, which is part of the quota set by the MND. The pilot study employed a diagnostic survey method in the form of a 14-question survey questionnaire, which included multiple-choice questions and opportunities for respondents to provide their own answers to supplement the main study. The questionnaire utilised a five-point Likert scale to assess the importance of various motivations indicating the level of importance from "very important" to "completely irrelevant". The respondents were asked about their post-graduation plans regarding work and place of residence, as well as the importance of different factors in their anticipated internal and external migration. The pilot study employed the PAPI technique, involving face-to-face interviews with respondents using a hard-copy questionnaire. The respondents were selected using the snowball method. The primary objectives of the pilot study were to validate the research issue related to the main determinants of educational and professional choices, as well as internal and external migration among the analysed course of study.

3 Results

Access to green spaces was identified as one of the determinants analysed in the study. This factor is generally viewed positively both as a determinant of the post-graduation choice of place of work (Fig. 1) or place of residence (Fig. 2).

Interestingly, in both cases, this factor is very relevant and important in terms of returning to the respondents' original place of residence. However, this factor will have a diminished impact if the respondent chooses to live or work in a smaller town (or rural area) in Poland. This is an interesting outcome, as it contrasts with the traditional belief that rural areas or smaller towns can attract potential residents and businesses due to favourable environmental conditions.

Furthermore, students were queried about factors that would drive them want to live abroad after graduation. They indicated that natural environment factors, such as environmental quality and the climate/weather abroad, played a notably lesser role compared to economic and social factors. Securing employment emerged as the most pivotal factor, followed by the prospect of staying abroad with a partner and then the local community's mindset (implicitly referring to different mentality).

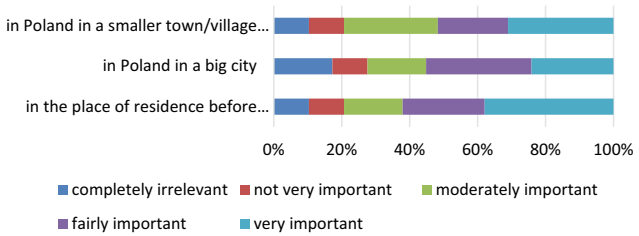


Fig. 1 Access to green spaces as a factor influencing taking up employment after graduation

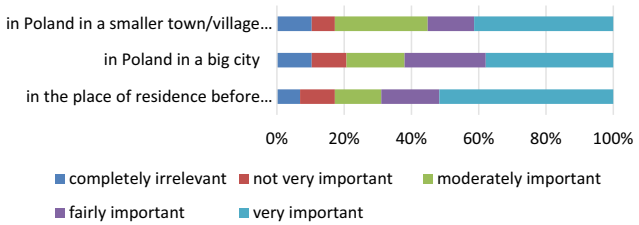


Fig. 2 Access to green/recreational areas as a factor influencing the place of residence after graduation

4 Discussion

The results of this study shed light on the importance of environmental factors in decisions regarding settlement and work locations in Poland among medical students at UMED in Łódź, Poland. Our findings indicate that the significance of this environmental factor is noteworthy, particularly when considering the decision to return to the original place of residence. Interestingly, the study revealed that environmental factors play a role not only in the respondents' hometowns but also when smaller cities or rural areas in Poland are analyzed. This supports the notion that such areas can attract residents and human capital due to favorable environmental conditions (Mianabadi et al. 2023). Understanding the intricate interplay between environmental considerations and broader societal and economic dynamics (Kubiciel-Lodzińska and Ruszczak 2016) is crucial for developing targeted strategies that address the diverse preferences and needs of individuals when making decisions about settlement and employment locations.

5 Conclusions

Our findings suggest that natural environment factors are considered important in the context of choosing the place of residence or work for medical practice students. However, they are not the most crucial factors. Among the 14 factors analysed, students identified green spaces as significant, but they ranked as the tenth most important factor. They were surpassed by economic and social factors, as well as those strictly related to the course of study (e.g. availability of the chosen medical specialty in the workplace). Notably, green spaces play a greater role as a determinant for choosing the place of residence than the workplace, irrespective of the locality's size. The results of the pilot confirm the research hypothesis that factors related to the environmental quality are important and significant determinant of settlement intension and the workplace choices. Ongoing efforts to raise awareness about the importance of natural environment factors should be an integral part of the education process. The study has highlighted that substantial work remains to be done in the area.

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Connecting with Own Emotions to Connect with the Environment: An Intervention for Promoting Pro-environmental Behaviors in Organizational Settings

Giulia Ballarotto, Raffaella Abate, and Patrizia Velotti

Abstract

Context/Purpose: Numerous studies have highlighted the difficulties encountered in interventions aimed at promoting long-term pro-environmental behaviors. While cross-sectional literature has emphasized the essential role of certain emotional factors in promoting pro-environmental behaviors (such as empathy, connection to nature, emotional regulation), interventions in the literature primarily focus on contextual factors and informational or feedback interventions. The present study aimed to test the effectiveness of two interventions designed specifically to enhance emotional connection to the natural environment, with the goal of promoting greater pro-environmental behaviors. Methods: N = 85 firm managers participated in 4 different groups. The interventions were conducted with the managers of the firms, but the impact was measured not only on the managers themselves but also on the team members who worked in direct contact with them (N = 467 firm employees). It was hypothesized that a change at the emotional/relational level would result in a stable behavior change that could trigger cascading effects even among team members in close contact with the leader. Results: The results showed that managers who participated in the two interventions (in-person and remote) focused on increasing emotional connection with a focus on future generations reported higher pro-environmental behaviors ($F = 5.82$; $p < .05$), greater empathy towards natur e ($F = 13.47$; $p < .001$), and improved emotional regulation ($F = 4.42$; $p < .05$). Additionally, the results demonstrated that both managers and team members exhibited greater empathy towards nature following the intervention (managers: $F = 13.47$; $p < .001$; team members: $F = 17.65$; $p < .001$). Interpretations: The results demonstrated the greater effectiveness of interventions aimed at fostering emotional connection with nature compared to informational interventions and the control group. Furthermore, the behavioral change was observed not only in firm managers but also in their team members. Conclusions: The results highlight the cost-effectiveness of an intervention that enables behavioral change in a large sample (team members), by directly involving a small sample of firm managers.

Keywords

Pro-environmental behaviors · Behavioral changing · Nature connection · Empathy · Firms

1 Introduction

To reduce and counter the effects stemming from climate change, various studies have highlighted that top-down interventions (policies and new technologies) are not sufficient, and a change in individual behaviors is also necessary, underscoring the need for bottom-up interventions (Gifford 2011; Dietz et al. 2009). As a result, several interventions have been implemented to enhance individual pro-environmental behaviors. These interventions primarily aimed to increase people's information regarding pro-environmental behaviors and the consequences of climate change, or to provide feedback to individuals in order to make them more aware of the environmental impact of their daily actions, or with incentives (Grilli and Curtis 2021).

However, several studies have indicated that the effectiveness of these interventions was limited and, crucially, long-term effectiveness studies are scarce (Grilli and Curtis 2021). Recent cross-sectional studies have examined the role of various emotional factors in promoting greater envi-

G. Ballarotto (✉) · R. Abate · P. Velotti
Department of Dynamic and Clinical Psychology, and Health Studies, University of Rome "La Sapienza", Rome, Italy
e-mail: giulia.ballarotto@uniroma1.it

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ronmentally supportive behaviors: empathy (Ienna et al. 2022), compassion (Zelenski and Desrochers 2021), and emotional regulation (Panno et al. 2020). While these associations have been identified in several cross-sectional studies, research that has implemented emotion-based interventions to promote pro-environmental behaviors is scarce and comes with various limitations (Geiger et al. 2020; Böhme et al. 2018).

Based on these premises, the present study aimed to investigate whether different types of interventions (informative, based on enhancing connection with emotions in the present moment, based on connecting with emotions directed towards future thinking, conducted remotely or in person) were effective in promoting pro-environmental behaviors. The effectiveness of the interventions was sought to be verified across different groups of firm managers, with the hypothesis that a change at the emotional/relational level would result in a stable behavior change that could trigger cascading effects even among team members in close contact with the leader.

2 Materials and Methods

After contacting N = 15 firms operating in different sectors (telecommunications, energy, transportation, banking services), a random selection of N = 85 managers was made. The inclusion criteria were: age between 35 and 60 years, having worked in the company for at least two years, and having a team size ranging from 5 to 20 members.

The managers were randomly assigned to 4 groups: A = In-person and remote intervention group (in person intervention: two sessions of 6 h each; remote intervention: 8 sessions of 90 min each) focusing on enhancing their emotional connection to pro-environmental behaviors and climate change. B = In-person and remote intervention group (in person intervention: two sessions of 6 h each; remote intervention: 8 sessions of 90 min each) focusing on the emotions that future generations may experience regarding pro-environmental behaviors. C = Informational intervention group, receiving weekly emails (for 8 weeks) containing information about climate change and pro-environmental behaviors useful for mitigating/counteracting its effects. D = Control group, not participating in any intervention.

Before the interventions began, a battery of questionnaires was administered through an online survey to both managers (N = 85) and team members (N = 467). All managers and team members provided informed consent, in which the study phases were thoroughly explained. The study was approved by the Ethics Committee of the Department of Dynamic and Clinical Psychology, and Health Studies, University of Rome "La Sapienza" (Prot. no. 0001713, 19/10/2022). The same battery of questionnaires was administered again at the end of the intervention, to both managers and team members. The battery included the following questionnaires:

Pro-environmental Behaviors Scale (PEBS; Markle 2013), a self-report questionnaire designed to assess individuals' engagement in environmentally friendly actions. The Total score exhibited satisfactory internal consistency, as indicated by a Cronbach's α coefficient of 0.71.

Dispositional Empathy with Nature Scale (DENS; (Tam 2022)), a self-report questionnaire designed to measure one's innate inclination to understand and engage with the emotional experiences of the natural world. The Total score exhibited excellent internal consistency, as indicated by a Cronbach's α coefficient of 0.93.

Difficulties in Emotion Regulation Scale—Short Form (DERS-SF; (Victor and Klonsky 2016)), a 18 item- questionnaire, measuring levels of emotion dysregulation. The Cronbach's α for the DERS-18 Total Score in this study was 0.80, indicating high internal consistency.

3 Results

In order to assess the effectiveness of the different interventions, a repeated measures ANOVA was conducted, using the scores from the various questionnaires as dependent variables. Separate analyses were carried out for the four groups.

As illustrated in Table 1, the results indicated that managers who participated both in interventions focusing on enhancing their emotional connection to pro-environmental behaviors and climate change both in interventions focusing on the emotions that future generations may experience regarding pro-environmental behaviors exhibited an increase in pro-environmental behaviors, greater empathy with nature, and reduced emotional dysregulation.

Furthermore, a repeated measures ANOVA was conducted, using the team members' scores from the various questionnaires as dependent variables. Results revealed that team members working closely with managers who participated in interventions focused on emotions showed an increase in empathy towards nature. This increase was observed both in team members working with managers who underwent interventions focusing on enhancing their emotional connection to pro-environmental behaviors and climate change ($N = 150$; $F\ (1,149) = 7.65$; $p = 0.006$; $\eta_p^2 = 0.049$), and in those working with managers who participated in interventions focusing on the emotions that future generations may experience regarding pro-environmental behaviors ($N = 150$; $F(1,149) = 17.65$; $p < 0.001$; $\eta_p^2 = 0.106$).

Table 1 Means, standard deviations (SD), F-values, and partial eta squared of PEBS, DENS, and DERS-18 total scores in pre- and post-intervention for the four groups

Group	Measure	T1	T2	F	η_p^2
A (N = 28)	**PEBS**	**43.71 (7.44)**	**47.57 (7.19)**	**(1,27) = 5.56**	**0.171***
	DENS	**39.57 (8.97)**	**45.82 (10.55)**	**(1,27) = 10.38**	**0.278***
	DERS-18	**34.07 (7.59)**	**26.04 (10.44)**	**(1,27) = 10.47**	**0.279***
B (N = 30)	**PEBS**	**45.13 (7.68)**	**47.67 (9.35)**	**(1,29) = 5.82**	**0.167***
	DENS	**38.45 (9.81)**	**43.83 (12.13)**	**(1,28) = 13.47**	**0.325****
	DERS-18	**31.77 (7.37)**	**26.77 (9.21)**	**(1,29) = 4.42**	**0.132***
C (N = 14)	PEBS	44.86(8.94)	44.21 (10.33)	(1,13) = 0.12	0.009
	DENS	37.14 (9.66)	40.50 (9.22)	(1,13) = 2.72	0.173
	DERS-18	32.43 (5.79)	27 (9.31)	(1,13) = 3.74	0.223
D (N = 13)	PEBS	41.92 (7.80)	41.46 (11.27)	(1,12) = 0.07	0.006
	DENS	**32.31 (12.32)**	**40 (14.26)**	**(1,12) = 8.12**	**0.404***
	DERS-18	34.85 (10.11)	29.46 (9.87)	(1,12) = 2.44	0.169

Note A = In-person and remote intervention group focused on own emotions; B = In-person and remote intervention group focused on the emotions of future generations; C = Informational intervention group; D = Control group; PEBS = Pro-environmental Behavior Scales; DEN = Dispositional Empathy with Nature; DERS = Difficulties in Emotional Regulation Scale; Bold type indicated significant results.* = $p < 0.05$; ** = $p < .001$

4 Discussion

The results demonstrated the superior effectiveness of interventions aimed at fostering an emotional connection with nature when compared to informational interventions and the control group.

Interventions that have incorporated mindfulness or emotional connection programs so far have yielded inconsistent and limited results (Geiger et al. 2020; Böhme et al. 2018; Ray et al. 2021). It should be noted that some of these interventions did not implement an integrated program that directly linked one's emotions with pro-environmental behaviors, their challenges in implementation, or a heightened connection to others' emotions. The present study, however, demonstrates encouraging results. Moreover, the observed behavioral changes extended beyond firm managers to include their team members.

Direct intervention on managers indeed exhibited an enhancement in the emotional regulation abilities of managers, leading to a heightened emotional connection with the natural environment. This change further translated into effective supportive behaviors for the environment. Furthermore, team members themselves displayed an increase in empathy towards the natural environment. It is noteworthy that the change was measured in the post-intervention phase, and it is expected that relational/emotional shifts will have a more pronounced impact in the long run. A subsequent follow-up administration is anticipated to measure any additional changes.

5 Conclusions

The results of the present study highlight the cost-effectiveness of an intervention that enables behavioral change in a large sample (team members), by directly involving a small sample of firm managers. Currently, companies are becoming increasingly involved in environmental sustainability policies. Our results also show the great potential that companies have to support and encourage a major behavioral change that is becoming increasingly urgent and necessary given rapid climate change.

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Integrating Environmental Governance and Green Financing for Improved Environmental Performance

Muhammad Abid Bodla, Ahad Yousaf Khan, Ali Zeeshan Anwar, and Sana Ghafoor

Abstract

Environmental costs associated with low environmental performance indices prevalent in key resource profiles of Pakistan have led to re-orientation of development strategies in the Punjab province with focus to enhanced environmental governance and green financing in public and private sectors. The paper aims at exploring roles of various public sectors and institutions in improving environmental governance through promulgation of effective regulatory frameworks, adoption of appropriate policy tools, and enforcement of mechanisms to achieve targeted levels of adaptation and mitigation. Particular emphasis is laid on identifying tangible outcomes of introducing institutional restructuring for securing environmentally sound resource management and reduction of hazardous emissions built around a mix of legislation, policies, and financial systems. This article explores the effects of environment friendly practices in transport, energy and industries sectors along with roles of various public sectors and institutions in environmental governance, and significance of developing and enhancing regulatory frameworks, policy tools, and enforcement mechanisms in order to achieve environmental sustainability and in turn improve environmental performance index in the province. Toward achieving the desired outcomes, action plans are being structured for amelioration with regard to ameliorating point and non-point pollution, devising cleaner air and smog dispersion plans, introducing energy efficient techniques, vehicle compliance with emission standards, plastics management and extending support for green financing. The present study shows sufficient evidence to indicate that proper implementation of environmental initiatives, strengthened by effective environmental regulations are yielding positive projections to secure adequate levels of resource conservation and sustainability.

Keywords

Environmental monitoring · Environmental performance indices · Sustainability · Environmental governance · Transition plans

1 Introduction

Although climate change is a global problem that has significantly affected many parts of the world, Pakistan is definitely more vulnerable to its disastrous effects (Kohler and Maseli 2009). Pakistan is less resistant to its impacts because it is a developing nation. Pakistan's eastern province, Punjab, borders Indian Punjab in the east central region of the nation. The Punjab province is experiencing a drought since it is situated in an area with a dry and semi-arid climate (Mueller et al. 2014). Due to increased average temperatures and changing weather patterns brought on by climate change, Punjab province might experience hotter and longer summers, increasing the likelihood of heat waves and droughts in various places. (Program Appraisal Document).

M. A. Bodla (✉)
Planning and Development Board, Punjab, Pakistan
e-mail: memengg@pndpunjab.gov.pk

A. Y. Khan
Program Coordination Unit, Punjab Green, Pakistan

Development Program, Planning and Development Board, Punjab, Pakistan

A. Z. Anwar
Program Coordination Unit, Punjab, Pakistan

Green Development Program, Planning and Development Board, Punjab, Pakistan

S. Ghafoor
Environment and Climate Change, Planning and Development Board, Punjab, Pakistan

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Due to growing industrialization, Pakistan is vulnerable to the effects of climate change, which has significant geopolitical consequences (Patt et al. 2009). The nation currently finds itself at a crossroads leading to a significantly warmer planet. Pakistan is among the top 10 countries in the world affected by climate change during the past 20 years, according to German Watch (World Economic forum) Punjab, Pakistan is experiencing climate change primarily as a result of excessive greenhouse gas (GHG) emissions into the atmosphere from human activities like excessive energy consumption, rapid urbanisation, improper waste management, industrialization, increased transportation, agricultural practices, and poor livestock management (Hussain et al. 2019). Punjab, like other Pakistani provinces, is negatively impacted by climate change. The effects of climate change have caused both gradual changes in the weather and patterns of food production as well as sudden and catastrophic weather events, such as flash floods brought on by high rainfall, droughts brought on by stress and water scarcity, and prolonged heat waves (NDC-Pakistan 2021).

In general, Pakistan is suffering from the fast-paced effects of climate change. Pakistan's geological location places it in a region where the effects of climate change are being felt fairly strongly (Malik et al. 2012). The severe floods and heatwave of the year 2022 serve as a stark warning that disasters brought on by climate change have the potential to seriously impede Pakistan's efforts to alleviate poverty and advance its development goals. Over 1,700 individuals have died and over 8 million people have been displaced as a result of these calamities. There has been extensive damage to properties, crops, cattle, and infrastructure, resulting in losses and damages exceeding $30 billion (Pakistan Country Climate & Development Report 2022).

2 Study Site

Punjab is the second biggest province in Pakistan, and is physically located between 24–37° N and 62–75° E (Fig. 1). The majority of Punjab is dry and semi- arid, with limited spatiotemporal variability in climatic indicators including as precipitation, relative humidity, and maximum, mean, and minimum temperatures (Amin et al. 2018).

3 Methodology

The strategies or approaches adopted to execute the program were based on the following model depicted in Fig. 2. Under this study different policy interventions introduced under PGDP i.e. smog control policy, plastic management strategy, clean air policy, health advisory system were analyzed along with their pertinent action plans. In addition to that, environmental monitoring mechanisms of the government and pertinent enhancements in the system were analyzed and the number of people who applied for

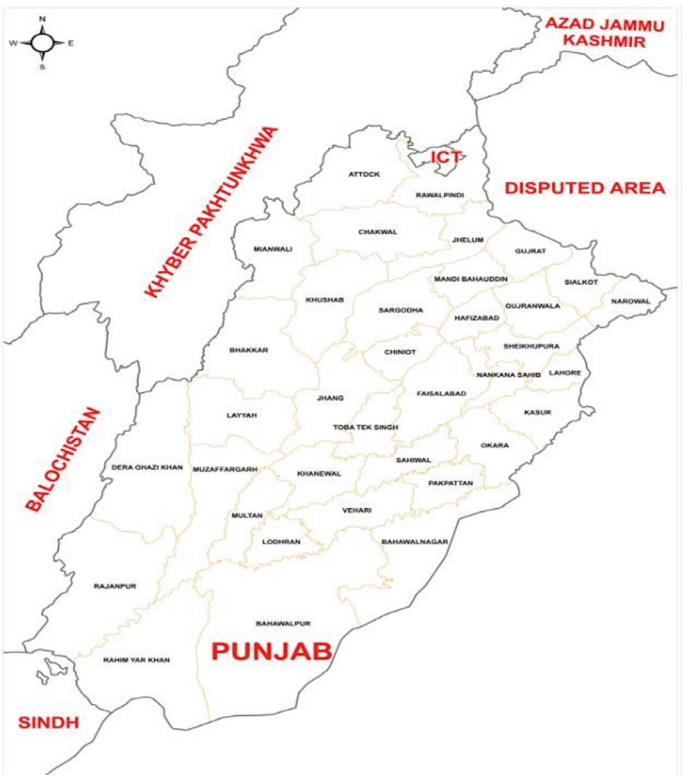


Fig. 1 Study area

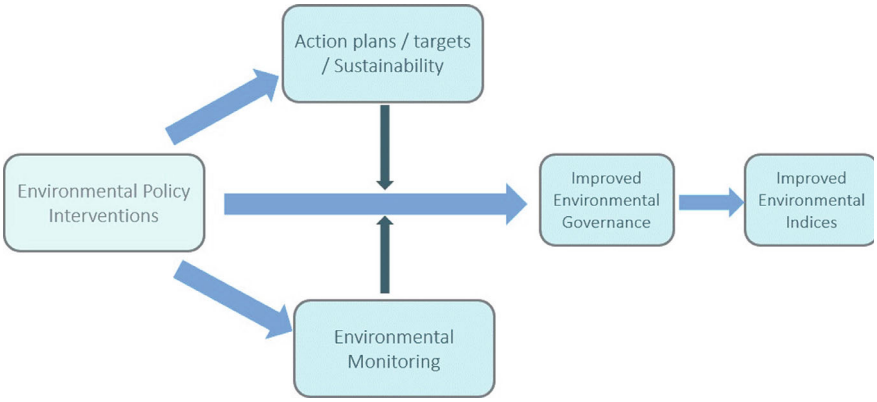


Fig. 2 Diagram illustrating the strategies adopted to implement the programme

green loans for green investments i.e. solar systems, plant nurseries, water filtration systems, biodegradable shopping bags, recycling hammer machinery etc. was determined in Punjab. Confirmation of these financing agreements was conducted with assistance from Industries Department and Bank of Punjab. For energy efficiency this study used deemed saving method to calculate energy saving after installation of energy efficient appliances in public institutions as physical interventions. Through consulting services we managed to analyze data and environmental improvement as a result of newly introduced RECP interventions under PGDP i.e. Pilot/Demonstration of Resource Efficiency & Cleaner Production Investments in key Industrial Sectors. For all the policy and physical interventions on site verification was performed to check the record and verify adoption of these interventions.

4 Results

Through analysis and interviews it was inferred that the policy interventions like Punjab Clear air policy, health advisory system, plastic management strategy etc. had positive impact on implementation and sustainability of environmental interventions and the above policy interventions had a positive impact on the environmental monitoring as it led to more investments towards environmental monitoring initiatives i.e. monitoring of industrial effluents and stack emissions, air and water quality monitoring through monitoring stations etc. EPD, carried out inspections for 509 Inspections for Industrial Effluents & 119 Inspections for Stack Emissions in just two years, and imposed fine on polluters in violation of PEQS. The initial inspection count before policy interventions was only 400 in totality. Financial policy interventions i.e. green financing strategy and environment endowment fund etc. had positive impact on the implementation of physical environmental interventions like introduction of RECPs in industries. Using deemed saving method it was calculated that an estimated amount of 5GWh/annum energy was saved after installation of energy efficient appliances in public institutions. The policy intervention like restructuring of EPD had positive impact on the department's implementation and monitoring capacity entailing fast track implementation of physical interventions as well as environmental monitoring. The policy intervention pertaining to expansion of vehicles expansion and certification systems resulted in 5% of the registered motor vehicles of Punjab (138,171 / 2,763,410) having valid emission certificates. Improved environmental governance is expected to have a positive impact on the improvement in environmental indices as 2125 tons of CO2 emissions were reduced as a result of energy saving of 5GWh per annum (0.85 Pounds of CO2 emissions per KWh). Further, volume of carbon emissions expected to be avoided through green investments is 339,000 tons. The policy interventions, through positive mediating role of physical environmental interventions and robust environmental monitoring mechanisms, have a positive impact on improved environmental governance entailing improvement in environmental indices. The effective execution of the program (PGDP) enabled the government to develop data-driven policies and action plans to tackle the province's worsening environmental condition. This program also facilitated the Punjab Environment Protection Department to improve its organizational structure, modify its regulatory framework, and modernize its administrative procedures and systems. In addition, Plastic Management Strategy has also been developed to tackle plastic pollution in the province. This program also facilitated PEECA to save at least 5GWh energy per annum through installation of energy efficient appliances in public institutions. Furthermore, the program will establish an Environment Endowment Fund to support green technologies in the province. Effective implementation of this program will act as a foundation to expand such initiatives to other provinces of Pakistan.

5 Conclusion

The main goals of Punjab's Green Development Program are to promote green investments and improve environmental governance in the province. The administration was able to address the deteriorating environmental conditions in the province by creating data-driven policies and action plans for the program's efficient implementation. Additionally, this program helped the Punjab Environment Protection Department update its administrative procedures and systems, change its regulatory framework, and enhance its organizational structure. The first status of the environment report for 2022, which provides a thorough overview of Punjab's solid waste management and air, water, and soil pollution, has been successfully released by the Environment Protection Department under this initiative. To address plastic pollution in the province, a Plastic Management Strategy has also been devised. This initiative also made it possible for PEECA to install energy-efficient appliances in public buildings and save at least 5GWh of energy annually.In addition, the initiative would create an Environment Endowment Fund to help the province's green technology sector. The successful execution of this program will serve as a basis for extending similar endeavors to other Pakistani provinces.

6 Discussion

The environment is our shared inheritance as a species, and it is our shared responsibility to protect it. The government and our society must work together actively to conserve and improve the quality of the environment. Beyond health and hygiene, environmental preservation also addresses pollution, waste management, biodiversity protection, natural resource preservation, ecological balance maintenance, and meeting national and international climate targets. The province's attempts to advance environmental management and mainstream green development are bolstered by execution of Punjab Green Development Program (PGDP). During program planning, intensive stakeholder engagements led to the development of the program's priorities and scope. Modernizing the legal and regulatory framework, promoting investments in cleaner technologies at the provincial and federal levels, and bolstering the technical and administrative capacities of the province's Environmental Protection Department (EPD) and its Environmental Protection Agency (EPA) to better serve the public and private sector were among the topics covered in these consultations. To evaluate the pollutant profile for the entire province and create an integrated dashboard for monitoring air and water quality, the number of air quality and water quality monitoring stations can be expanded.

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ICT4D Towards Sustainable Development: A Cross-cultural Study Between Mexico and the Democratic Republic of Congo

Raquel Pérez Estébanez, Elena Urquía Grande, Martha Ríos Manríquez, and Manuela Cañizares Espada

Abstract

A fast spread of Information and Communication Technologies (ICT) occurred in low-income countries and communities. ICT use contributes to the development of emerging economies in several ways. Firstly, accounting and financial software empowers sustainable development in line with the SDGs nº8 and 9: economic growth and innovation of emerging countries in the long term. Additionally, ICT tools can help development by saving money, which is critical for micro-entrepreneurs. This research aims three objectives: first, to determine the ICT4D factors that explain micro-entrepreneur development in Democratic Republic of Congo and Mexico, second, to analyze the importance of mobiles phones in the business transactions and finally, to analyze comparing the level of ICT and accounting information systems (AIS) in Africa and Latin America. We designed a survey to study the impact of AIS and ICT on microentrepreneurs' households in both countries. Regarding the samples, the DRC consists of microentrepreneurs from a rural neighborhood in south Ethiopia whereas the Mexican comprises microentrepreneurs below the poverty level from Celaya (Guanajuato). The survey includes variables about their access to AIS and their ICT adoption level and use. Different multivariate analyses were run. It is interesting to highlight that the countries analyzed, with differences of culture, language, and various idiosyncrasies, have two factors which explain micro-entrepreneur technological development, namely, the training received in using ICT for business and mobile phones 'use for business management and households'. Our findings show that better financial and economic reporting through accounting information systems are key for micro-businesses to promote their sustainability development. The results of this research contribute to the theoretical framework for the DRC and Mexican context about ICT and AIS and lets comparing them with other international studies. This study empirically validates that the use of mobiles and ICT training add to business growth and development impact.

Keywords

ICT4D · Mobile phones · Sustainable development · Micro-entrepreneurs · Mexico · Democratic Republic of Congo (DRC)

1 Introduction

Currently, with the COVID-19 crisis the advance in technology has opened up the possibility of using technology from a strategic viewpoint in low-income countries also. Information and communication technologies (ICT), together with human and financial capital, can contribute to development and economic growth in several ways, by saving money and enabling sustainable development in the long term. In addition, mobile phones play a key role in bridging the digital divide in developing countries, so this study covers the applicability of the technology acceptance model, without changing its focus from high technology and mobile phone adoption, in line with Kabbiri et al. (2018).

The present research aims three objectives: firstly, to analyze the level of AIS used by micro-entrepreneurs in Mexico and the DRC, both with high rates of marginal populations and poverty; secondly, to emphasize the impor-

R. P. Estébanez (✉) · E. U. Grande
Universidad Complutense de Madrid, Pozuelo de Alarcón, Madrid, Spain
e-mail: raperez@ucm.es

M. R. Manríquez
Universidad de Guanajuato, Guanajuato, Mexico

M. C. Espada
UDIMA, Madrid, Spain

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tance of mobiles phones in the business transactions and finally, to determine which are the ICT (including mobile phones) and AIS factors that explain micro-entrepreneur development.

2 Methods

The researchers wanted to analyse the use of ICT and AIS by microentrepreneurs in developing countries and their impact on poverty eradication. Therefore, we designed a survey to measure the ICT impact on businesses and households. The sample comprised 280 microenterprises which are below poverty levels in Celaya (Guanajuato, Mexico) and from a rural neighborhood in the area of Mbujimayi in the south of the DRC. The survey is based on a Likert scale and includes some variables such as AIS, ICT and cell phone usage as independent variables, while the level of ICT development (ICT_Id) is the dependent variable. First we examined the normality of the sample using a Kolmogorov-Smirnoff test, resulting in the sample not being normal. Therefore, to find out if there are differences in the ICT level, mobile phone and AIS use between Mexico and the DRC we run a non-parametric analysis using the Mann–Whitney U test for independent samples. The variable "Country" was coded as 1 = DRC and 2 = Mexico. Then, as the sample is large enough, we run a linear regression weighted by the variable "Country", to discover the ICT and AIS factors that explain micro-entrepreneur development in these two countries. Additionally to study the importance of mobile phone use to achieve sustainable development we analyzed through a PLS weighted by "Country".

3 Results

The differences in the level of ICT and AIS in these two countries are shown in Table 1. In all of them, it can be observed that the Mexican sample clearly has higher figures than the DRC sample. However the variable village ICT use shows no difference between both samples. Finally there are no significant results for the variables, ICT_ec, AIS_ma and AIS_tm, the reason is that there is little use of ecommerce and AIS in both countries.

Regarding "Coefficient B" for Village ICT use level is positive and statistically significant. The use of mobiles, shows in both cases a positive relationship with the dependent variable where in the case of the use of mobiles for household management, the beta is positive and it is statistically significant and the use of mobiles for business management, the beta is positive and it is statistically significant. This indicates that variables are positively related to micro-entrepreneur technological development. The extensive use of mobile phones is explained because the mobile phone is a more accessible, less expensive means to "close" this global digital divide, in line with Mbarika (2002). Whereas the access to electricity has an inverse relationship with the level of micro-entrepreneur technological development and it occurs the same with the variable "Use of AIS for management accounting of micro-enterprise". The remaining variables analyzed in the model show no significant results.

Finally, regarding the use of mobile phones the results show that almost all of the variables included in the model are significant. The positive beta indicates that variables are positively related to microentrepreneur development. However, there is an inverse relationship between the dependent variable and the variable Enterprise access to ICT. This result means that the respondents use mobiles for their household management, as Donner (2010) pose, as well as for their business, because they consider it a useful tool of communication with a low cost, in line with Asongu et al. (2018). So this extensive growth of cell phones use has offered the possibility to increase rural households' access to information.

4 Discussion and Conclusions

It is interesting to highlight that in the countries analyzed, with differences of culture and language, and other idiosyncrasies, there are only two factors which explain micro-entrepreneur technological development. The first variable is the ICT level that the village has, and the second is the use of mobiles for business management. This can be explained because in both countries, authorities and entrepreneurs are conscious about the importance of ICT, and it is necessary to have an adequate level of ICT knowledge to be capable of using them. However, some studies still show that businesses have a combination of low education standards and high access costs, a lack of ICT training for business and government and a lack of long-term competitive vision.

Another interesting theme is that AIS are too incipient still in Southern countries the opposite of what we have seen in developed countries (Urquía et al. 2011). Therefore, this study highlights the need for training and financial support in AIS for entrepreneurs in Southern countries to achieve sustainable development in line with SDG nº 5 and 6.

Finally, in line with Asongu et al. (2018) and Kabbiri et al. (2018), among others, the importance of mobile phones use in both business and households is clear. The respondents use mobiles for their household management Donner (2010) pose, to strengthen their personal relationships. Also, they consider that mobiles are a useful tool of communication for business, with low cost. So, clearly, mobile phones are a key tool in management. Our findings show, in line with Asongu et al. (2018), that policies designed to boost ICT (mobile phone and

Table 1 Differences between Mexico and DRC using Mann–Whitney U test

	Country	N	Mean	Std. Dev	Sig	Decision
ICT_el	DRC	188	1.18	0.637	0.000	Reject
	Mexico	80	**4.29**	0.93		
ICT_ltr	DRC	188	1.31	0.808	0.000	Reject
	Mexico	80	**3.3**	1.226		
ICT_usv	DRC	190	3.11	1.349	0.063	Retain
	Mexico	80	**3.44**	1.251		
ICT_tra	DRC	190	1.01	0.102	0.000	Reject
	Mexico	80	**3.46**	1.158		
ICT_acc	DRC	190	1.01	0.073	0.000	Reject
	Mexico	80	**3.65**	1.264		
MP_bm	DRC	189	1.06	0.428	0.000	Reject
	Mexico	80	**3.55**	1.2		
MP_ma	DRC	190	1.04	0.362	0.000	Reject
	Mexico	80	**4.56**	10.763		

Table 2 ICT factors that explain the micro-entrepreneur technological development

	B	Std. Error	t	Sig
(Constant)	1.374	0.422	3.258	0.001
ICT_el	− 0.094	0.040	− 2.351	0.019
ICT_tr	0.070	0.053	1.327	0.186
ICT_usv	0.130	0.029	4.485	0.000
MP_hm	0.284	0.076	3.734	0.000
ICT_tra	− 0.018	0.107	− 0.170	0.865
ICT_ld	0.011	0.006	1.720	0.087
ICT_acc	− 0.086	0.106	− 0.811	0.418
MP_bm	0.249	0.079	3.146	0.002
MP_ma	− 0.001	0.006	− 0.084	0.933
ICT_ec	0.055	0.192	0.285	0.776
AIS_ma	− 0.822	0.348	− 2.362	0.019
AIS_tm	0.019	0.162	0.120	0.904
R Square = 0.552				

Table 3 Factors that explain mobile technology in technological development

	B	Std. Error	t	Sig
(Constant)	1.549	0.103	14.973	0.000
MP_bm	0.303	0.120	2.533	0.012
MP_ma	0.011	0.008	1.425	0.155
ICT_acc	− 0.280	0.116	− 2.404	0.017
MP_hm	0.288	0.094	3.060	0.002
R Square	0.220			

internet use) penetration will increase inclusive development in the sustainable development agenda.

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Navigating Sustainable Urban Transport in Developing Countries: An AHP Approach to Assessing Social Sustainability

Mohammad Thaher

Abstract

Sustainability is a multifaceted concept that has become increasingly important in various fields, including urban transportation. While there is a growing body of literature on sustainable transport systems, there is still a lack of theoretical and empirical studies on social sustainability in urban development, particularly in developing countries. This paper aims to address this gap by exploring the potential of the analytic hierarchy process (AHP) in assessing the social sustainability of urban transport systems in developing countries. The research argues that socially sustainable urban transport can significantly enhance people's quality of life and promote social sustainability in the built environment. However, assessing the social dimension of sustainability in urban transport is challenging due to the complexity and uniqueness of the interactions between the different variables involved. Therefore, this research proposes the use of indicators as a tool for monitoring sustainability and aiding decision-making. The research applies the AHP methodology to a case study of Amman, Jordan, using experts' opinions to compare and rank the relative importance of these indicators. This results in the development of a site-specific tool for assessing the social sustainability of an existing transport system. Through the inclusion of experts, this research provides insight to decision-makers about the importance of social sustainability and a means for its assessment. In conclusion, this research highlights the need to consider social sustainability in urban transport planning and decision-making. The proposed methodology provides a useful tool for assessing the social sustainability of urban transport systems in developing countries, promoting a more comprehensive and integrated approach to sustainable urban development.

Keywords

Urban transport · Social sustainability · Analytic hierarchy process · Sustainability assessment · Stakeholder perceptions · Sustainability indicators

1 Introduction

Rapid urbanization and population growth are shaping cities and significantly impacting urban mobility, particularly in the developing world. Amman, the capital of Jordan, offers a unique example of these trends. As one of the fastest-growing cities in the Arab region, Amman is contending with severe transportation challenges, making the development of sustainable urban transport a critical focus (UN-Habitat 2021; Shbeeb 2018). Concurrently, the rising demand for transportation services due to population inflow and the expansion of the city is placing massive pressure on the existing urban transport system (Al-Masaeid et al. 2016; Alnsour 2016). The concept of urban sustainability has gained significant attention, recognized as a driving force behind urban planning and policymaking, including urban transportation systems (Chakraborty et al. 2021; Petrushenko and Grunwaldt 2021). Understanding social sustainability in urban transport helps ensure equity and access while enhancing the quality of life (Pojani and Stead 2015). This paper aims to assess the social sustainability of urban transport in Amman through three primary dimensions: accessibility, safety, and livability. Accessibility is a fundamental issue for urban transport, ensuring access to public transportation services and facilities for all, especially for marginalized groups and communities with lower socio-economic status (Martens 2017). Further, safety is a vital aspect of social sustainability, with a focus on reducing

M. Thaher (✉)
Institut Supérieur de l'Automobile et des Transports (ISAT) Université Bourgogne Europe, Nevers, France
e-mail: mohammad.Thaher@u-bourgogne.fr

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traffic-related fatalities and creating safe and comfortable environments for pedestrians and cyclists (WHO 2018). Livability underscores the importance of urban transport systems creating pleasant and healthy urban environments that support a high quality of life, including aspects such as reducing air and noise pollution and enhancing active transportation modes like walking and cycling (Appleyard 1981). Therefore, our research highlights the importance of evaluating and enhancing these vital aspects of urban transport in Amman to build a socially sustainable and livable city.

2 Materials and Methods

For this study, we deployed the ATSSI method as our research methodology. The Adaptive Total Sustainable Social Indicator (ATSSI) provided a comprehensive approach that encapsulated social, economic, and environmental factors of sustainability in urban transport. Thus, the method allowed for a tailor-made social sustainability indicator system, specifically suited for Amman, Jordan's urban transport dynamics. Our first step involved an extensive literature review to discern key methodological techniques for developing sustainable urban transport indicators. By defining stringent search parameters and applying robust inclusion/exclusion criteria, the review remained concentrated and entirely relevant. Furthermore, adherence to systematic review techniques like the PRISMA standards ensured an exhaustive, transparent review process (Moher et al. 2009). The involvement of multiple researchers and subject matter experts at this stage underscored the variety of perspectives, improving the ventilatory and thoroughness of our inferences. Following the review, we developed a set of distinct indicators that align with Jordan's urban transport system. We subjected these indicators to a series of validation tests to ascertain their reliability and accuracy. To supplement these indicators, we conducted surveys and interviews with stakeholders, gleaning valuable data and insights about Jordan's urban transport landscape. Analyzing data gleaned from the literature review, validation tests, and stakeholder consultations entailed the use of various statistical and analytical techniques. Statistical software such as SPSS and Excel facilitated this analysis, generating comprehensible visual representations of data streams (Field 2013). The ATSSI method, the intensive literature review process, and the advanced statistical and analytical techniques ensured the reliability of the study's results, which are contextual to Jordan's urban transport system. Moreover, the detailed account of the approach adopted in this study in this section facilitates the replication of the study in other contexts or locales if required.

3 Results

3.1 Accessibility Indicators

The study reveals significant accessibility challenges in Amman's public transportation, with disparities noted across neighborhoods and affordability issues for marginalized groups. Key solutions include increasing the frequency of public transport lines, establishing clear affordability policies, and diversifying transportation modes for reduced private car dependency. Although certain indicators received lower importance, improvement in all areas is needed for a comprehensive, efficient, and sustainable transport network in Amman. Increasing reliance on sustainable practices and prioritizing environmentally friendly transportation options are deemed critical for the future (Fig. 1).

3.2 Safety Indicators

Amman's transport safety faces significant concerns, including traffic accidents, air, and noise pollution. Low public transportation usage and rising vehicle numbers cause congestion, long commutes, and pollution. Experts undervalue noise and air pollution (3% each), yet these issues need addressing in Jordan's urban areas. They promote public transport, regulate emissions, and enhance pedestrian/cycling infrastructure. Safety ranks fourth in importance, posing challenges with accidents, personal security, and low public transport use. Accessibility, particularly active transport track proximity, is crucial (30% importance), but only 41% of Amman is served, exacerbating the problem (Fig. 2).

3.3 Livability Indicators

The study highlights several challenges in Amman's livability: inequity in exposure to environmental impacts, limited public participation, inadequate public transport, security concerns, and neglected pedestrian/cycling infrastructure. Noise and air pollution are undervalued but important, requiring the promotion of public transport, active modes, and emissions regulations. While safety ranks fourth, it's vital, with traffic accidents, low public transport usage, and private vehicle dominance. The proximity of active transport tracks is crucial (41% served), as is public participation. Accessibility, quality, and connectivity indicators are vital for equitable public transport. Continuous monitoring and public involvement are essential for sustainable urban development (Fig. 3).

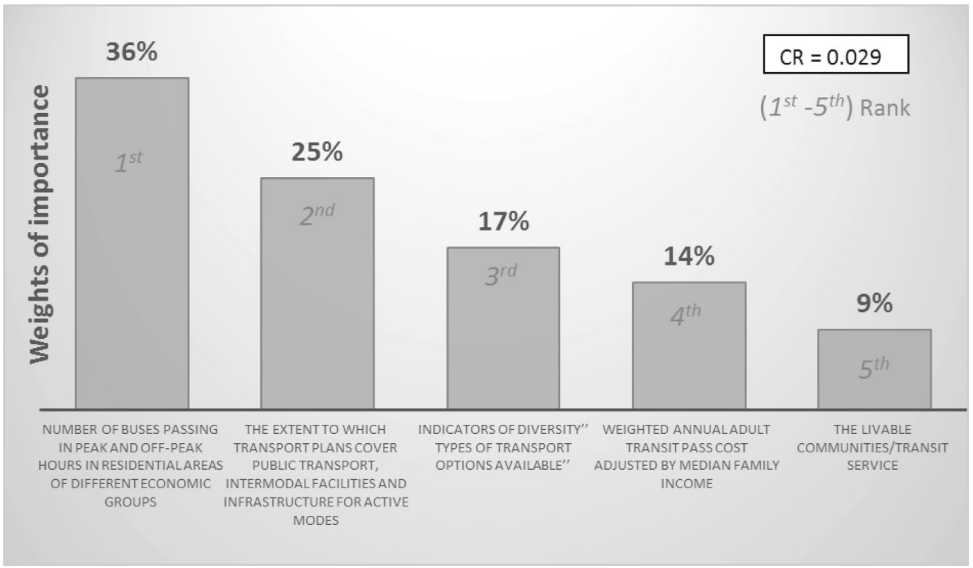


Fig. 1 Weights assigned to accessibility indicators by experts with consistency ratio. *Source* Mohammad Thaher

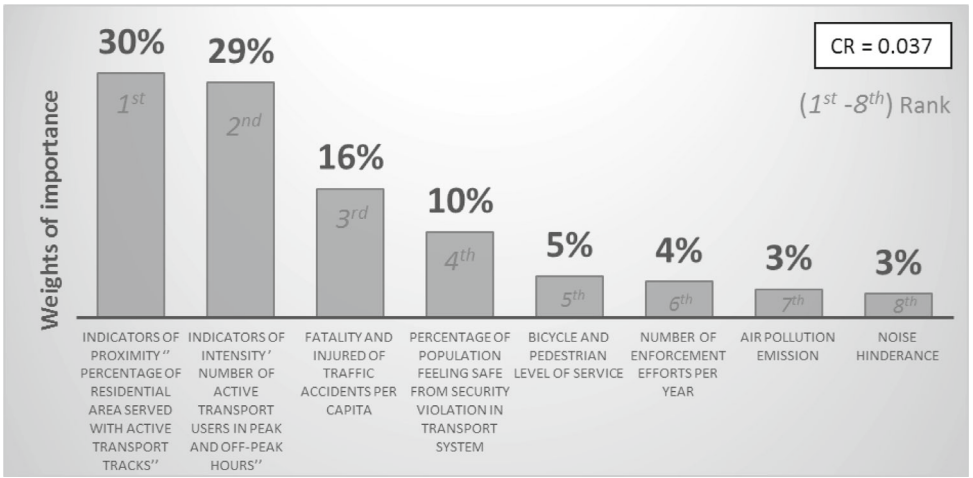


Fig. 2 Weights assigned to safety indicators by experts with consistency ratio. *Source* Mohammad Thaher

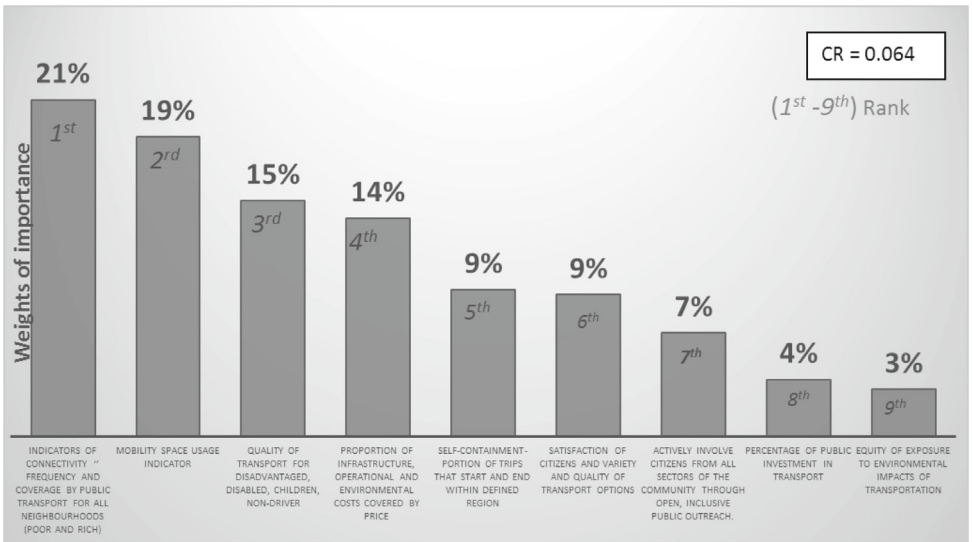


Fig. 3 Weights assigned to livability indicators by experts with consistency ratio. *Source* Mohammad Thaher

4 Discussion and Conclusions

In light of the findings and limitations identified during the study, several recommendations are proposed to enhance the application of the ATSSI method and address potential challenges. Firstly, efforts should be made to enhance the accessibility of expert insights by leveraging technological tools for effective communication and remote collaboration, thereby overcoming geographical barriers and broadening the range of perspectives. Secondly, to mitigate cultural biases in indicator selection and measurement methods, it is vital to involve stakeholders from diverse backgrounds in the development and testing of the ATSSI method. Their input can ensure the relevance and applicability of indicators across different cultural and socioeconomic contexts. To improve the quality and accessibility of data, investment in data collection and management systems is essential. Collaboration with relevant organizations can help establish data-sharing networks and enhance the overall caliber of data used in the ATSSI method. Exploring alternative data sources and innovative methodologies like crowdsourcing and remote sensing should also be considered to supplement traditional data collection approaches. To simplify the implementation of the ATSSI method, comprehensive guidelines should be developed, providing step-by-step instructions, examples, and case studies to support a wider range of users. Additionally, training programs and capacity-building initiatives can equip individuals and organizations with the necessary knowledge and skills for effective application. In conclusion, the ATSSI method presents a valuable approach for the development of site-specific social sustainability indicators in urban transport, with the potential to enhance safety, livability, and accessibility. By addressing identified limitations and adopting recommended strategies, researchers and practitioners can fully harness the ATSSI method's potential, contributing to the promotion of sustainable urban transport systems that prioritize the well-being of residents in diverse contexts.

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Does Energy Transition Play a Key Role in the Regional Policy in Poland? Comparative Analysis of Strategic Documents

Brygida Klemens and Marzena Szewczuk-Stępień

Abstract

Environmental threats and progressive climate change have become a reality. Awareness of the changes that must be implemented is being discussed at various levels of management. The absence of a structured and long-term policy to support the energy transition will become costs, including social and economic costs, to be borne by people living in various regions. The aim of the conducted study was to carry out a desk research analysis of the existing development strategies of all 16 voivodeships (regions) in Poland together with an analysis of the existence of sectoral documents dedicated to energy transition and, in particular, support for renewable energy. The local government of each region has a strong influence on policy-making in this regard, despite the constraints coming from the national level. The analysed documents were obtained from the official websites of the Marshal Offices of specific voivodeships. Research shows that energy issues, including issues on renewable energy, are reflected in strategic documents, mainly in terms of strengthening the energy infrastructure and counteracting negative climate change. In accordance with the Ministry of the Environment's guidelines, all regions have Environmental Protection Programmes, which also raise energy transition issues. However, only a few voivodeships have a sectoral strategy as a policy to support the region's energy transition, which means that there is no recognition of the importance of this issue beyond the required scope. The remaining challenge is to change the approach to supporting energy transition as a phenomenon constituting a good alternative solution for counteracting negative climate change and raising the topic in key strategic documents, which is a basis for the expenditure of public funds.

B. Klemens (✉) · M. Szewczuk-Stępień
Opole University of Technology, Opole, Poland
e-mail: b.klemens@po.edu.pl

Keywords

Regional development · Regional development strategies · Energy transition

1 Introduction

Environmental sustainability refers to using resources in such a way that they are preserved for future generations and do not harm the ecosystem. Measures aimed at achieving environmental sustainability include reducing greenhouse gas and pollutant emissions, as well as protecting biodiversity. In terms of the negative effects of climate change, policy makers are faced with an attempt to balance economic growth and environmental protection in a broad context (Wang 2023). Negative environmental changes affect people's quality of life, both directly and indirectly, depending on access to broadly understood resources, their socio-economic status, and place of residence (Rohling 2019). The pursuit of appropriate policies to address the negative effects of climate change is becoming a key issue and requires coordinated action at different levels of governance.

As of January 1, 1999, Poland has been administratively divided into 16 voivodeships. These regions differ in many variables, including area, population, economic specialisations, wealth, etc. Despite the many differences in terms of development opportunities and challenges, certain issues, due to their scale and importance, affect the entire country (Zygmunt 2017). One such concern is the imperative for an energy transition prompted by factors such as the adverse impacts of climate change and legal obligations, including those stipulated by the EU (Gatto 2022; Renewable Energy Directive II (RED II) 2018; Zecca et al. 2023).

The absence of a structured and long-term policy to support the energy transition will result in costs, including social and economic implication, borne by residents across different

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regions. The alarming global climate change and its negative effects are already being experienced by ordinary citizens influencing a wide range of decisions, including their consumer decisions, the cost of using basic utilities (e.g. water, electricity) or holiday plans and, in extreme cases, even migration decisions related, for example, to changes in the labour market or loss of assets due to natural disasters (e.g. floods, fires, hurricanes). For this reason, policymakers and regional leaders should recognise such a significant issue and take extensive measures to prevent and mitigate it, thereby improving the quality of life and sense of security of residents. A primary step is to identify these risks and propose strategies for counteracting the negative effects of climate change in strategic documents, as these guide action and provide opportunities for financing them over several years. Despite the fact that energy transition is generally the domain of policy at the national level, the local governments of individual regions also wield some influence on the energy policy development in their respective area.

Hence, the main objective of the study was to address the question of whether energy transition plays an important role in planning the development of regions in Poland. The following research hypothesis was formulated: energy transition is in the sphere of interest of regional authorities in Poland. The verification of the research hypothesis involved a desk research analysis of the existing development strategies of all 16 voivodeships (regions) in Poland together with an analysis of the existence of sectoral documents dedicated to energy transition and, in particular, support for renewable energy.

2 Materials and Methods

The present paper focuses on the analysis of strategic and sectoral documents in all 16 regions (voivodeships) of Poland in terms of the energy transition. Regional development strategies, but also sectoral strategies, are the most important development documents at regional level, meaning that they address pressing development issues (Szewczuk-Stępień and Klemens 2019). They should also include documents co-developed with a wide range of stakeholders, as this ensures that the general interest is taken care of and that different aspects of the phenomenon are recognised (Beck 2023).

The aforementioned study's objective was achieved through desk research analysis, conducted between 15 July and 8 August 2023. The analysed documents were obtained from the official websites of the Marshal's Offices of the individual voivodeships, under the assumption that significant matters should be accessible to the general public.

Following an analysis of Energy Policy of Poland until 2040 (MK 2021), a pivotal strategic document, in terms of energy, keywords pertaining to the energy transition within the context of broader regional development were identified. Subsequently, regional development strategies were examined by querying these keywords (see Table 1). The next step was to identify and analyse in each region the sectoral documents dedicated to energy, including renewable energy.

Table 1 Factors analysed in regional development strategies in Poland (16 = 100%)

Issue	Number of strategies
Environmental/natural/air/soil/water protection	16
Counteracting climate change	16
Sustainable development	16
Bio-economy/biodiversity	7
Energy transition	13
Green energy/RES	16
Energy infrastructure	16
Smart/innovative power/energy systems/ grids	10
Collective transport/low or zero emission/ electro-mobility/smart transport systems	15
Energy efficiency improvement	15
District heating and co-generation development	13
Energy poverty reduction	5

3 Results

The data presented in Table 1 indicates that matters pertaining to energy transition in the broadest sense of the term have been addressed in the development strategies of all regions (although not all strategies use this phrase strictly). Regional authorities recognise the need to protect the environment, implement green energy, make changes in the energy infrastructure, improve energy efficiency, etc. (see Table 1).

All regions have developed Environmental Protection Programmes according in adherence to the guidelines set by the Ministry of the Environment. Within the documents, one of the intervention categories was climate and air quality protection, under which broad objectives were defined, including those related to energy transition (Table 2).

Table 2 Regional strategy documents on, inter alia, energy transition issues

Regional development strategy	Regional environmental protection programme	Territorial just transformation plan	Energy policy/ programme/ strategy
16	16	6	3

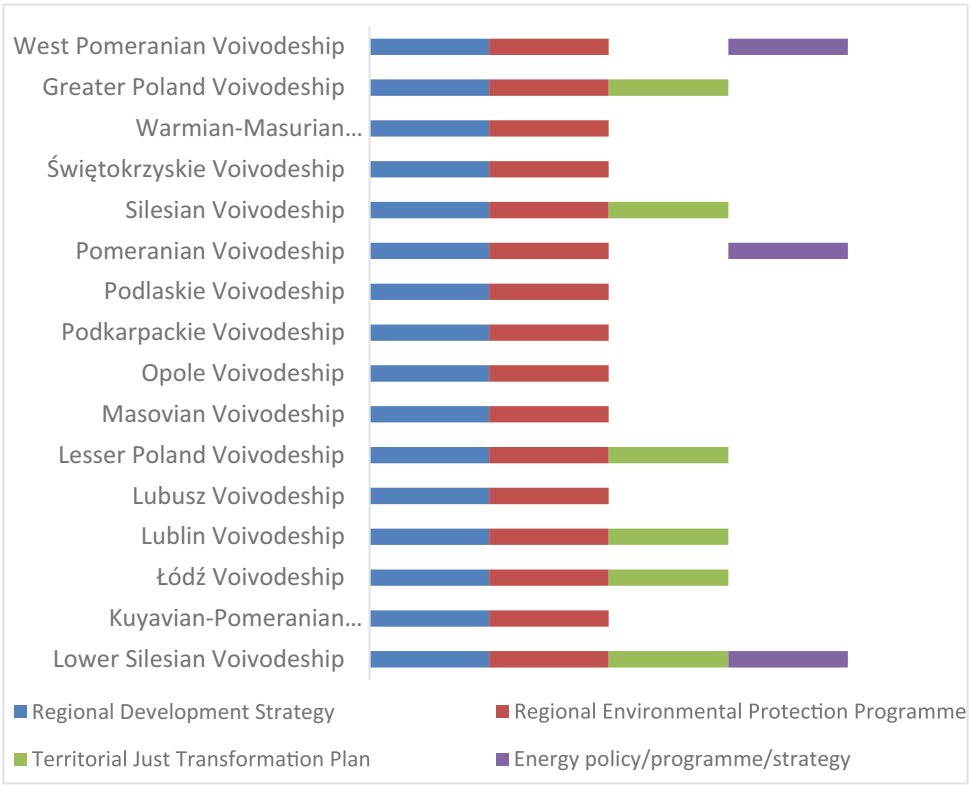


Fig. 1 Regional strategy documents on, inter alia, energy transition issues in the Polish Voivodeships

Regions with environmentally damaging activities such as mining and energy have developed Territorial Just Transformation Plans (by 2030). These plans delineate a trajectory towards a climate-neutral economy with an indication of the social, economic and environmental challenges.

Three regions in Poland can be identified as leaders in strategic planning in the context of the energy transition: Dolnośląskie, Śląskie and Pomorskie Voivodeship, which have made an effort to develop sectoral documents on the subject (Fig. 1).

4 Discussion

Equally important is the awareness of limitations in the conducted study. There is no unified methodology for developing local development strategies; therefore, each voivodeship office has been creating a strategy according to its own needs. The lack of standardization in methods for measuring progress in energy transformation across different regions can lead to difficulties in comparing the effectiveness of adopted strategies. The rapid technological development in the energy sector may result in provisions becoming inadequate to existing needs even during their formulation. Additionally, the absence of uniform criteria for evaluating the success of energy transformation could impact the process of comparative analysis and drawing clear conclusions regarding the effectiveness of strategies.

Counteracting the negative effects of climate change is a strategic challenge and is implemented through a range of tools. The issue is not a lack of measures taken at different levels of governance, as these are being implemented (Szewczyk and Szeliga-Duchnowska 2022), e.g. the "My Electricity" Programme (Kuźmiński et al. 2023; https://mojprad.gov.pl/), implemented at the national level, through which it is possible to obtain funding for renewable energy sources, such as photovoltaic system or heat pumps. Among a number of issues in terms of the energy transition, it is possible to point out, for example, the lack of appropriate infrastructure for the transmission of renewable energy generated, which significantly hampers the development of green energy in Poland. One evident consequence is the imposition of restrictions on the grid of energy produced by prosumers if too many and too capacious micro-installations operate in an area supplied from a single sub-station (Halama and Majorek 2022). One of the main energy operators in Poland, Energa, already issues a refusal decision in 95% of applications for the connection of larger RES installations to the Polish grid system (https://globenergia.pl/). These measures are not implemented at the regional level and pose a real risk in terms of achieving the country's greenhouse gas reduction and energy transition targets. Thus, comprehending the energy transition policies of distinct regions requires genuine

engagement at the national level for any initiatives to prove effective.

5 Conclusions

Research indicates that energy issues, including issues on renewable energy, are reflected in strategic documents, mainly in terms of strengthening the energy infrastructure and counteracting negative climate change. All regions have developed Environmental Protection Programmes, and those regions with environmentally damaging activities have also developed Territorial Just Transformation Plans. However, only 3 voivodeships have a strictly sectoral strategy as a policy to support the region's energy transition. At a time of increasing negative effects of climate change, such a situation seems concerning. Regional authorities seem to focus on reactive measures in response to some phenomena, but with delay or even failing to raise pressing issues. Energy transition appears to be an important issue being addressed by regional authorities, but it is not given the same priority by all. The remaining regional challenge involves shifting the approach to supporting energy transition as a phenomenon constituting a good alternative solution for counteracting negative climate change and raising the topic in key strategic documents, which is a basis for the expenditure of public funds. It also seems that changing the reactive approach to taking proactive action in terms of energy transition in the regions will be a big challenge.

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Risk Perception Differences between Two States in the Cross-Border Silesian Basin

Hana Šlachtová, Hana Tomášková, Renata Zlotkowska, Markéta Stanovská, Agnieszka Mateja, and Rastislav Mačar

Abstract

Understanding public health risks perception by different people in different places is crucial for dissemination of policies and programs to be most effective. The aim of the presented study was to find out the perception differences between the Czech and Poland people living in the border areas of the Silesian black-coal basin. The questionnaire based Czech data originated from the randomly selected sub-sample of the HAIE project in Ostrava, the Polish sample was collected in Sosnowiec and Katowice. Risk perception of the general and environmental health problems was surveyed using the means of 5-point Likert scale. The analyses were performed using Pearson chi-square test, Mann-Whitney test and logistic regression. A total of 471 respondents aged 18–78 years participated in the survey, 243 from the Czech Republic (CR) and 228 from Poland (PL). No statistical differences between countries were found by sex, age and marital status. Mostly people with high school education participated in CR (42.4%) and university education in PL (59.2%). Among the general problems, one's own health (Likert scale score = 4.1), drug addiction (score = 3.9) and AIDS (score = 3.7) were considered of the most concern in CR, while in PL, health (score = 4.8), quality of housing (score = 4.7) and quality of health care (score = 4.3) were set on the top and the concern was significantly more serious for all three problems comparing with the CR ($p < 0.001$). As for environmental problems, air pollution in the place of residence (score = 2.9), car traffic (score = 2.9), and cleanliness of public spaces (score = 2.7) dominated in CR. In PL, odour (score = 4.4), pollution (score = 4.3) and night noise around the residence (score = 4.3) prevailed. Environmental information is significantly more followed by people in PL ($p < 0.001$), their share is 57.7%, while in CR only 32.5%. The interest in air pollution information increases with age. General and environmental problems are perceived significantly more serious in Poland.

Keywords

Risk perception · General and environmental problems · Silesian basin

1 Introduction

Understanding how environmental health risks are perceived by different people, in different places, and at different times is critical to their management (Cardwell and Elliott 2019). Environmental health risk perceptions often diverge from those of agencies and the knowledge of specific kinds may help overcome the gap between agency conclusions regarding environmental health risk and the perceptions of community members (Nagisetty et al. 2022).

The aim of the presented study was to find out the perception differences between the Czech and Poland people living in the border areas of the Silesian black-coal basin.

2 Materials and Methods

The questionnaire based Czech data originated from the randomly selected sub-sample of the ERDF/ESF supported HAIE project (Healthy Aging in Industrial Environment—

H. Šlachtová (✉) · H. Tomášková · M. Stanovská · R. Mačar
Department of Epidemiology and Public Health, Faculty of Medicine, University of Ostrava, Ostrava, Czech Republic
e-mail: hana.slachtova@osu.cz

H. Tomášková
Public Health Institute Ostrava, Ostrava, Czech Republic

R. Zlotkowska
Humanitas University in Sosnowiec, Sosnowiec, Poland

A. Mateja
University of Silesia in Katowice, Katowice, Poland

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CZ.02.1.01/0.0/0.0/16_019/0000798), that was a large longitudinal study. The respondents were recruited in vaccination centres in Ostrava and Karvina during the COVID-19 pandemic. The Polish sample was collected from the students, their parents and health care workers of the Humanitas University in Sosnowiec and University of Silesia in Katowice.

Risk perception of the general and environmental health problems was surveyed using the means of 5-point Likert scale. The participants were asked to indicate a level of concern about a number of topics (general, environmental—worldwide, national, local). The questions were formulated as follows: "To what extent are the items mentioned below of concern to you?, *Please circle the number indicating your level of concern for each item (1-no concern at all, 5-extremely concern)*". The respondents indicated the level of concern for the listed 13 general problems and 9 environmental problems. They also answered the question on the trend (*1-better, 5-worse*) of air pollution during the past 5 years from different sources. Also responsible institutions that could advocate for improvement of the air pollution (*1-do not trust at all, 5-trust fully*) were determined by the respondents. The respondents were asked for indicating the most important source of their information by selection from the list of 10 items (*1-not important at all, 5-the most important*) and in another question for indicating the most credible source of their information from the same list of items (*1-not credible at all, 5-the most credible*).

Differences between countries were analyzed using the Pearson chi-square test, Mann-Whitney test and logistic regression. SW STATA v.17 was employed in the analyses.

3 Results

3.1 Description of the Study Sample

A total of 471 respondents aged 18–78 years participated in the survey, 243 from the Czech Republic (CR) and 228 from Poland (PL), with a higher proportion of women (59.3% and 67.5%, respectively). No statistical differences were found by sex, age and marital status between countries. The highest proportion of people with a high school education participated in CR (42.4%), whereas in PL participants with university education prevailed (59.2%).

3.2 Perception of General Problems

Among the general problems, one's own health (Likert scale score = 4.1), drug addiction (score = 3.9) and AIDS (score = 3.7) were considered to be of significant concern in CR. In PL, health (score = 4.8), quality of housing (score = 4.7) and quality of health care (score = 4.3) were set on the top and the concern was significantly more serious for all the three problems compared with the CR ($p < 0.001$) (Fig. 1).

3.3 Perception of Environmental Problems

As for environmental problems, air pollution in the place of residence (score = 2.9), car traffic (score = 2.9), and cleanliness of public spaces (score = 2.7) dominated in CR. In PL, odour (score = 4.4), pollution (score = 4.3) and night noise around the residence (score = 4.3) prevailed. When assessing

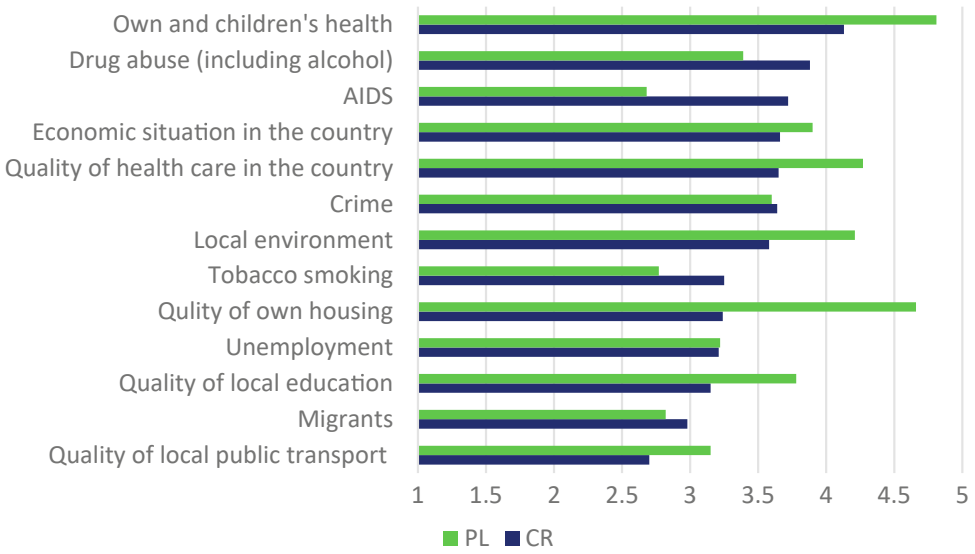


Fig. 1 Scores of the Likert-scale perceptions regarding general problems and comparison between Czech and Polish population

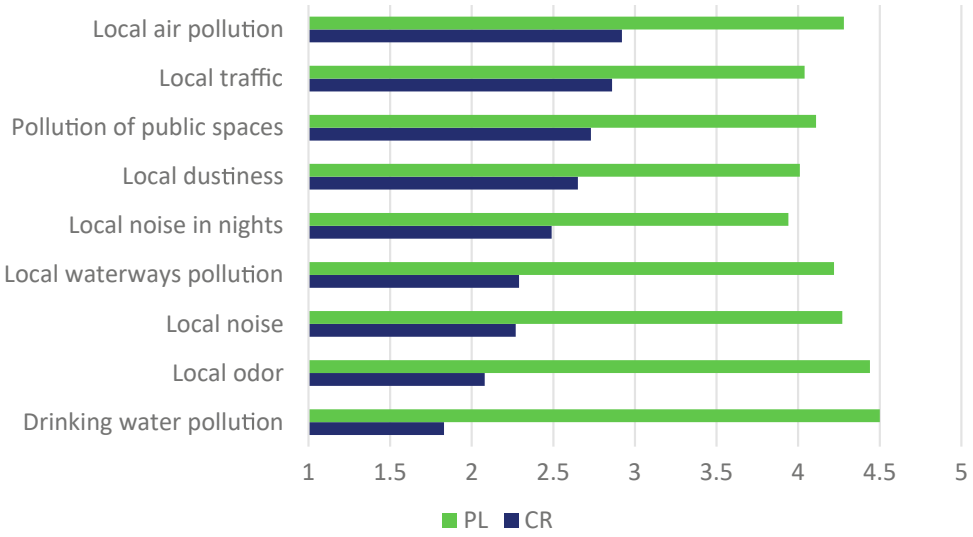


Fig. 2 Perception differences of environmental problems

the trend of air pollution over the last 5 years from different sources, people in CR considered the worsening of pollution from transport to be the greatest; the same was observed in respondents in PL ($p = 0.193$).

Respondents expected local councils would solve the environmental problems in CR, as in PL, but in Poland it was perceived more urgently ($p < 0.001$). The most important sources of information about environmental pollution in CR were physicians (score = 3.6), internet and media (score = 3.3), and family and friends (score = 3.1). In PL, information was obtained from NGOs (score = 3.9), the internet and media (score = 3.5), doctors (score = 3.5), the national experts and scientific literature (score = 3.5).

Comparing with CR, people in PL are significantly more interested ($p < 0.001$) about the information on the state of air pollution, their share was 57.7%, while in CR only 32.5%. The proportion of people following air pollution information increased with age, the oldest age group monitored those information 6 times more often than the youngest age group (OR = 6.63; 95%CI: 3.23–13.59).

General and environmental problems were perceived significantly more seriously in PL ($p < 0.001$) (Fig. 2).

4 Discussion

The most significant environmental problems were found in Poland compared with the population of Czech Republic. This finding might have been affected by the educational difference in the two study samples. The study of Shin et al. (Shin et al. 2019) confirmed that people with a college or higher education were more likely to be concerned about how the environment affects their health. The survey of Orru et al. (2018) brought evidence that perceived exposure influences symptoms and prediction of environmentally induced symptoms and diseases at relatively low levels of air pollution.

The surprising finding was the concern to quality of housing in Poland (set on the second place). According to the Czech Statistical Office, in the Czech Republic the area of the apartments was larger, significantly more flats were connected to the water supply and gas network, which might explain the different perception of this problem (Czech Statistical Office 2024).

In spite of mandatory implementation of the same EU Environmental Directives, their adherence was not as rigorously required in PL as in CR in the recent past. This fact might explain the perception differences of environmental problems between the two countries. Explanation of environmental health patterns are key in managing environmental health and in developing successful prevention, mitigation and communication strategies as stated by Noël et al. (2021). Only in the fall of 2023, the declaration between Czech and Polish ministers of the environment was signed to improve the air quality on both sides of the common borders. In addition to improving air quality, this could contribute to a similar perception of environmental issues in both countries.

5 Conclusions

People in Poland were more concerned by environmental problems comparing with the population in the Czech Republic. Another important finding of the study was identification of a possible communication channel of environmental health issues; in Poland, mostly NGOs, experts in the field, and local government were these channels, while in the Czech Republic physicians played this role. Finding the most reliable source of information will serve to address these sources when

communicating environmental issues. The possible way, how to disseminate the study results is to make them available to the Regional Council for the next contacts with the partner institutions in Poland.

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Healthy Soil Challenges and the Influence of EU Policies: Examining the Italian Case

Anita De Franco, Israa Mahmoud, Eugenio Morello, Silvia Ronchi, and Andrea Arcidiacono

Abstract

The concept of "healthy soil" is particularly debated in public and academic discussions. The European Union (EU) has recently included the Mission "A Soil Deal for Europe" as the core of the European Green Deal. In this context, this research article will analyze: first, the main objectives related to the EU Soil Mission (i.e. desertification, organic carbon stocks, soil sealing and re-use, pollution, erosion, biodiversity, global footprint, literacy in society); second, the various strategies proposed, both at the policy level (e.g. Soil Health Law in 2023) and at the practical level (e.g. the establishment of 100 Living Labs and lighthouses); third, the main challenges at stake, with particular reference to Italy and the national debates on soil issues. To do so, and from a methodological point of view, the analysis is based on (i) a narrative analysis, based on the talks of selected key actors invited to the Italian event of the EU Soil Mission; (ii) a gap analysis matrix, based on the data collected from the participants to the national event. Reflecting on the "quadruple helix model", this research article depicts how academia, industry, civil society and governments play a role in the EU Soil Mission. The overall impression is that much of sustainable food production and agriculture, biodiversity and climate resilience, carbon sequestration, water purification, technological innovation, local livability and societal prosperity will depend on our idea of, and means to achieve, "healthy soils".

Keywords

Healthy soils · European policies · biodiversity · land use · Italy

1 Introduction

Life on Earth depends on healthy soils (Harris et al. 2022; Bouma 2022). Healthy soils have a primary role in ensuring biodiversity increment, providing numerous ecosystem services, and supporting human activities in general (linked to urbanization, industrialization, naturalization and agriculture processes) (Ferrarini et al. 2018; Ronchi et al. 2019). Institutions are increasingly aware of the great diversity in the structure and quality of local soils; the European Union (EU) is actively interested in monitoring "soil health" states across its territory (consider e.g., *EU Soil Observatory*). Based on the latest estimations (EUSO, 2023), around 61% of European soils are affected by "degradation" resulting from overlapping and converging among different indicators (accounting levels of biodiversity, carbon stock, compaction, erosion, pollutants, nutrients). On this basis, "A Soil Deal for Europe" has entered in the EU *Green Deal* and Horizon Europe strategic programmes (Panagos et al. 2022), breaking down "healthy soils" issues into eight operative objectives (see Table 1). In the await for the official framework of EU Soil Strategy for 2030, this paper aims to illustrate the state of the debate on the issue of "healthy soils" and main challenges at stake, with particular reference to Italy.

A. De Franco (✉) · I. Mahmoud · E. Morello · S. Ronchi · A. Arcidiacono
Department of Architecture and Urban Studies, Polytechnic University of Milan, MI, Italy
e-mail: anita.defranco@polimi.it

I. Mahmoud
e-mail: israa.mahmoud@polimi.it

E. Morello
e-mail: eugenio.morello@polimi.it

S. Ronchi
e-mail: silvia.ronchi@polimi.it

A. Arcidiacono
e-mail: andrea.arcidiacono@polimi.it

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Table 1 Gap-analysis matrix relating EU soil mission (i.e., 8 objectives) to and four soil types

EU soil mission objectives	Urban soils	Industrial soils	Agricultural soils	Forestry/natural soils
1. Reduce desertification	X		X	
2. Conserve soil organic carbon stocks			X	
3. Stop soil sealing and increase re-use of urban soils	X	X		
4. Reduce soil pollution and enhance restoration	X		X	
5. Prevent erosion	X	X	X	
6. Improve soil structure to enhance soil biodiversity			X	X
7. Reduce the EU global footprint on soils				
8. Improve soil literacy in society	X	X		

2 Research Methods and Materials

In this paper, the analysis is based on two main methods. First, a narrative analysis accounting the main sociological interpretations of "healthy soils" in Italy, based on the talks of selected key actors invited to the Italian event of the EU Soil Mission (i.e. Evento nazionale sulla Missione Suolo dell'Unione Europea—verso l'istituzione di 100 living labs e lighthouses). Second, a gap analysis matrix, based on the data collected from the participants to the national event. The information presented here has been collected in the Italian event, where more than 130 registered participants (55 onsite, 81 online) and around 20 keynote speakers (mainly based in Italy), had the occasion to discuss the main soil issues they face in their area of expertise (professional and/or academic). The topics of the discussion related to various issues concerning soil types and activities considered relevant to achieving "healthy soils" in various contexts (Rodríguez-Rojas and Grindlay Moreno 2022; Suzic et al. 2022). The results highlight how different stakeholders relate certain "healthy soils" to different thematic issues, concerning soil types (i.e. urban, industrial, agricultural, natural) and EU Soil Mission objectives. In order to assess possible innovation frameworks among stakeholder types, a "quadruple helix model" (Suzic et al. 2022) has been used to divide the different audiences whether they are representatives of academia, industry, civil society and governments. It is assumed that these social categories play a relevant role in the EU Soil Mission, and that certain challenges are better understood, and propelled, in a multi-actor perspective (Gouvea et al. 2013).

3 Results

This section illustrates the main results from the first round of national events organized in the context of the H2020 project NATI00NS (Grant agreement ID: 101090738) in 44 countries (across the EU and associated countries). This project aims at improving the European soils health status reaching out relevant stakeholders and potential actors and preparing them to apply and implement soil health Living Labs (LLs). The ambition of the EU mission is to establish 100 regional LLs and Lighthouses, to collaboratively create and test land management practices and solutions. The national engagement events are organized in 43 countries (all EU Member States and Horizon Europe Associated Countries). The Italian event has been organized on March 2023, attracting more than 120 registered participants. Among the speakers there were representatives from academia (e.g. the universities of Padoa, Siena, Turin and Trento, also with Polytechnic University of Milan, as host of the event and participant), industry and civil society (among which the national association of municipalities: ANCI; environmental associations: *Legambiente*; and national institutes and trade associations of agricultural confederations: *CIA*; building constructors: ANCE; urban planners: INU), governmental and international agencies (among which *APRE, CREA, ISPRA*, and representatives of the EU Joint Research Center: *JRC*). The keynote speakers were invited to present and react to the various discussions around the main challenges, themes and projects around soil issues in Italy.

3.1 How Different Stakeholders Relate "Healthy Soils" Issues for Land Use Types

Considering the total number of participants in the national event (Fig. 1), the majority comes from the world of academia (52% i.e. universities, research centers), followed by representatives of civil society organized as NGOs or groups of citizens (20% i.e. consumers, cultural associations, thematic organizations, property/fund owners), industry (15% i.e. agronomists, architects, building contractors, consultants, manufacturers, spatial planners, small-medium enterprises, start-ups, trade societies), and government representatives (9% i.e. national, local, regional authorities). The category of "Other" (4%) relates to those who were directly involved in the EU soil mission as LLs (Bouma 2022; Panagos et al. 2022) or local organizers. Concerning the main "healthy soils"

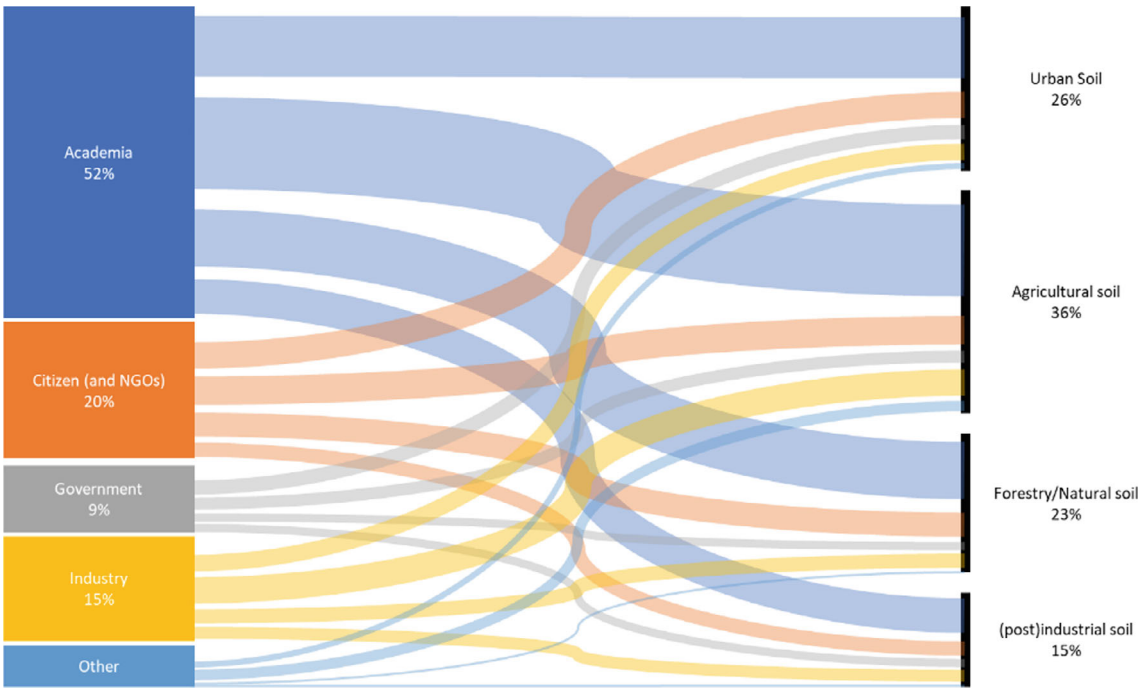


Fig. 1 Relationship between stakeholder types ("quadruple helix model") and land use types

themes (Harris et al. 2022; Ferrarini et al. 2018; Ronchi et al. 2019; Pickett and Cadenasso 2009; Rodríguez-Rojas and Grindlay Moreno 2022) and land-use types, the participants were mostly interested or working on themes concerning agricultural soil (36%), followed urban soils (26%), forestry/natural soils (23%) and (post) industrial soils (15%).

3.2 Narratives Surrounding "Healthy Soils" Objectives

Considering the talks delivered by the keynote speakers in the national event, it was clear that "healthy soils" challenges were particularly pressing in a country like Italy where, especially in its northern regions is particularly affected by anthropic pressures.

Most of the interest was on the "health state" of agricultural soils in relation to the loss of organic matter and desertification problems (objectives 1 and 2), but also in relation to pollution, erosion and biodiversity problems (objectives 4, 5, 6). The state of health of urban soils was more discussed in relation to desertification, soil sealing, pollution and erosion. In many cases, soil sealing problems (objective 3) is framed as the replacement of agricultural land with other types of uses. In Italy this perception of "wasteful" activities typically arises on demographics and productivity arguments (e.g. stagnation of the population, best uses of fertile lands). Moreover, the perceived difficulty to reclaim "urban voids" (e.g. unused spaces), typically former industrial sites is seen as an impediment to comply with other objectives to reduce pollution, erosion and desertification of local soils (objectives 1, 5, 6). Forestry/natural land uses were only mentioned in relation to biodiversity (objective 6), and in connection to water use practices and agricultural activities. Notably, there were no direct connections or mentions on the need to reduce the "footprint" of EU soils (objective 7). While it was particularly discussed the issue to improve soil literacy, especially for urban and industrial soils. On this aspect, many speakers pointed out how the importance of having clean water and air is perceived by all, much less obvious is the importance of having clean and functioning soils.

4 Discussions and Concluding Remarks

Albeit limited to the Italian territorial case, the results address how the concept of "healthy soils" is depicted in public discourses.

Considering the results here collected for the Italian case, it was expected to have mainly academic stakeholders (due also to the keynote panel selection), although the presence of various representatives of citizens groups (e.g. NGOs) was particularly relevant considering the issues at stake as the civil society becomes more aware of how "healthy soils" relate to the ability to produce food, biomass, water filtering, etc., there is a good chance of meeting the EU Commission aims of connecting and monitoring LLs and "lighthouses" (Harris et al. 2022; Panagos et al. 2022), conceived as vehicles for

bottom-up processes on-site, in a logic of co-management, co-decision and co-implementation of resources with various stakeholders.

Considering the objectives, it was expected to have more mentions (or direct relations) on soil health issues related to forestry/natural soil types and on the EU global footprint (that could, although, be taken as implicit or more general to the Mission). Our analysis showed how communication and dissemination of good practices through soil mission's objectives can be perceived in various ways by key actors and stakeholders.

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Thermal Regulation in Silvicultural Arrangements in the Eastern Amazon, Pará, Brazil

Daniela Pauletto and Lucieta Guerreiro Martonaro

Abstract

The application of thermography in the infrared spectrum represents a valuable tool for assessing thermal conditions both in the environmental and animal realms, providing precise and versatile data. Thus, the purpose of this study was to employ thermograms to evaluate thermal regulation indicators in agroforestry systems cultivated in the Eastern Amazon. The analysis comprised 19 thermographic images captured in the infrared range in July 2021, taken during a period of intense solar thermal load. From each color pattern present in the images, samples were extracted, totaling 558 analysis points. The results revealed a considerable thermal amplitude among the evaluated elements, with the minimum temperature variation registering at 28.1 °C in the canopy of the species *Schizolobium amazonicum*, while the maximum value of 57.6 °C was identified in an area of soil completely exposed to the sun. The median temperature reached 35.0 °C, with the mean situated at 36.4 ± 5.35 °C. Elevated average temperatures (45.8 °C ± 7.4 °C) were observed on the surface of the soil covered by plant residues, indicating higher thermal loads compared to the average values obtained in the canopy of forest plantations (29.5 °C ± 1.2 °C). In contrast, areas with soil fully exposed to the sun without cultivation showed an average temperature of 52.9 °C ± 1.3 °C, generating a thermal amplitude of approximately 20 °C when compared to shaded areas covered by vegetation. The predominant influence of the tree component on thermal regulation became evident, especially for the species *Tectona grandis* and *Khaya grandifoliola*, which led to temperature reductions of 9.1–10.8 °C when comparing values recorded in the canopy and in shaded soil, in relation to measurements taken in the soil in areas near the edges of the crops directly exposed to solar radiation. The species *Handroanthus serratifolius* and *Carapa guianensis* also stood out, showing an average thermal reduction between 7.3 °C and 7.5 °C due to the beneficial shading effect provided by their canopies. Furthermore, the use of infrared thermography proved to be valuable for quantifying the thermal benefits provided by tree canopies in different agroforestry arrangements.

Keywords

Agroforestry system · Climatic parameters · Infrared radiation

1 Introduction

In the field of agricultural sciences, research related to infrared thermography has experienced significant growth. Research using infrared thermography has been increasing in the field of agricultural sciences over the past 20 years (Fouda et al. 2023; Hu et al. 2011; Ishimwe et al. 2014; Manickavasagan et al. 2005; Zhang et al. 2020). Infrared thermography has been applied for several purposes, such as to assess thermal comfort levels in agroforestry systems and to determine the onset of thermal stress in animals under certain environmental conditions (Ferreira et al. 2011; Gregory 2010; Karvatte et al. 2021).

Analyses using thermographic monitoring have been conducted in different environments for multiple purposes, including assessments of landscape patterns such as degrading pastures (Pilato et al. 2018; dos Santos et al. 2016), evaluation of irrigation systems (Carlos et al. 2021) and productivity indices with native bees (Pires et al. 2017), and non-

D. Pauletto (✉)
Rede Bionorte—Programa de Pós-Graduação em Biodiversidade e Biotecnologia e Universidade Federal do Oeste do Pará, Santarém, Pará, Brazil

L. G. Martonaro
Embrapa Amazônia Oriental, Programa de Pós-Graduação em Biodiversidade e Biotecnologia Santarém, Santarém, Pará, Brazil

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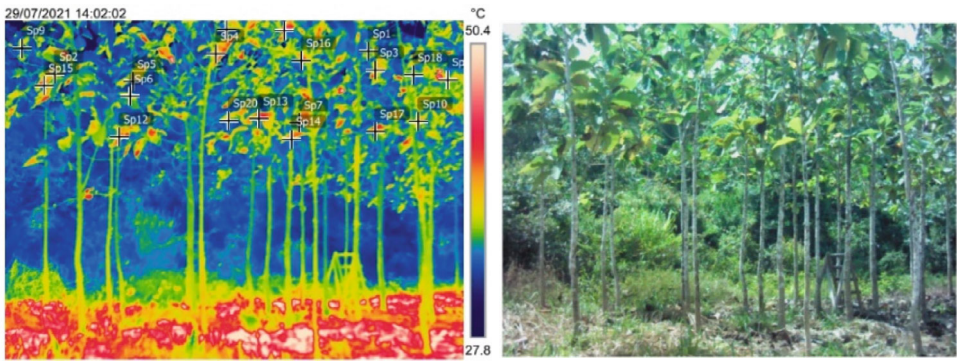


Fig. 1 Thermographic patterns imaged at infrared and visible wavelengths in agroforestry systems, Santarém/Pará, Brazil

invasive investigations in animal science (Barros et al. 2016). The aforementioned technique has been employed due to its effectiveness in detecting the heat radiated by objects, which is linked to climatic conditions. Infrared thermography is considered a valuable tool for evaluating microclimates in agroforestry systems (Junior et al. 2020). These cultivation systems aim to combine species with different purposes, promoting interactions in mixed arrangements. Due to the distinct morphological characteristics of perennial species, their responses to thermal variations in the environment can vary considerably.

In this context, guided by inquiries about which tree species have a greater influence on modulating heat in the soil through their canopies, and what the thermal variation is between the aboveground parts of the trees and the soil, the present study was conducted. The purpose was to apply thermograms to analyze indicators related to thermal regulation in agroforestry systems (AFS) established in an experimental unit located in the Eastern Amazon region.

2 Materials and Methods

The study was conducted in agroforestry systems (AFS) established at the Experimental Farm of the Western University of Pará (− 2.68856 S, − 54.53170 W), in Santarém, Pará, Brazil. The research area initially comprised secondary vegetation resulting from a fallow period after being used for livestock activities. Between the years of 2016 and 2017, several AFS were implemented.

The first system (AFS 1) involved planting forest species (*Handroanthus serratifolius*, *Schizolobium amazonicum*, *Carapa guianensis*) with a spacing of 8 × 8 m. Occasionally, short-cycle food species were cultivated between the rows of trees. In preparing this area, the secondary vegetation was partially removed without the use of fire or heavy machinery, while leaving residues on the soil. In the second area (AFS 2), the same aforementioned species were cultivated with the same spacing. However, the preparation and management of this space included complete vegetation removal using heavy machinery. In the third area (AFS 3), species intended for green manure (*Inga heteraphylla* and *Gliricidia sepium*) were cultivated with a spacing of 6 × 2 m, intercropped with short-cycle species. The fourth system (AFS 4) was established by cutting and burning the secondary vegetation, incorporating the planting of tree species (*Tectona grandis* and *Khaya grandifoliola*) with a spacing of 3 × 2 m, occasionally intercropped with short-cycle species for food purposes.

Thermographic diagnoses were performed on 29/07/2021, during the period of high solar thermal load from 12:00 PM to 2:00 PM. A Flir T650C thermal imaging camera was used, with an infrared resolution of 640 × 480 pixels. Thermal samples were extracted from each color pattern, totaling 558 points analyzed in 19 images, processed in the Flir software program Tools (6.3v), as exemplified in Fig. 1. The images cover spectra in the range of 0.7–100 μm, with an optical resolution of 640 × 480 pixels and emissivity of 0.95. Statistical inferences and graphs were prepared using SAS software.

3 Results

The data revealed a wide range of temperature conditions across the various areas evaluated in the environments, with a coefficient of variation (CV) of 14.7%. The amplitude of thermal variation recorded a minimum temperature of 28.1 °C in the canopy of the species *S. amazonicum*, and a maximum temperature of 57.6 °C observed in an area of exposed soil under direct sunlight, devoid of vegetation cover. These extremes demonstrated a thermal range of 29.5 °C. The median temperature stood at 35.0 °C, while the average temperature was calculated at 36.4 ± 5.3 °C.

In AFS 1 (Fig. 2), it was noted that among the monitored targets, the highest temperatures were depicted in the soil exposed directly to the sun (Sso) and in the leaf litter cover (Sse). These two groups differentiated themselves, forming a cluster as per the hierarchical cluster analysis with a dendrogram. The tree canopies exhibited greater thermal stability with a variation of 1.6 °C among species. More-

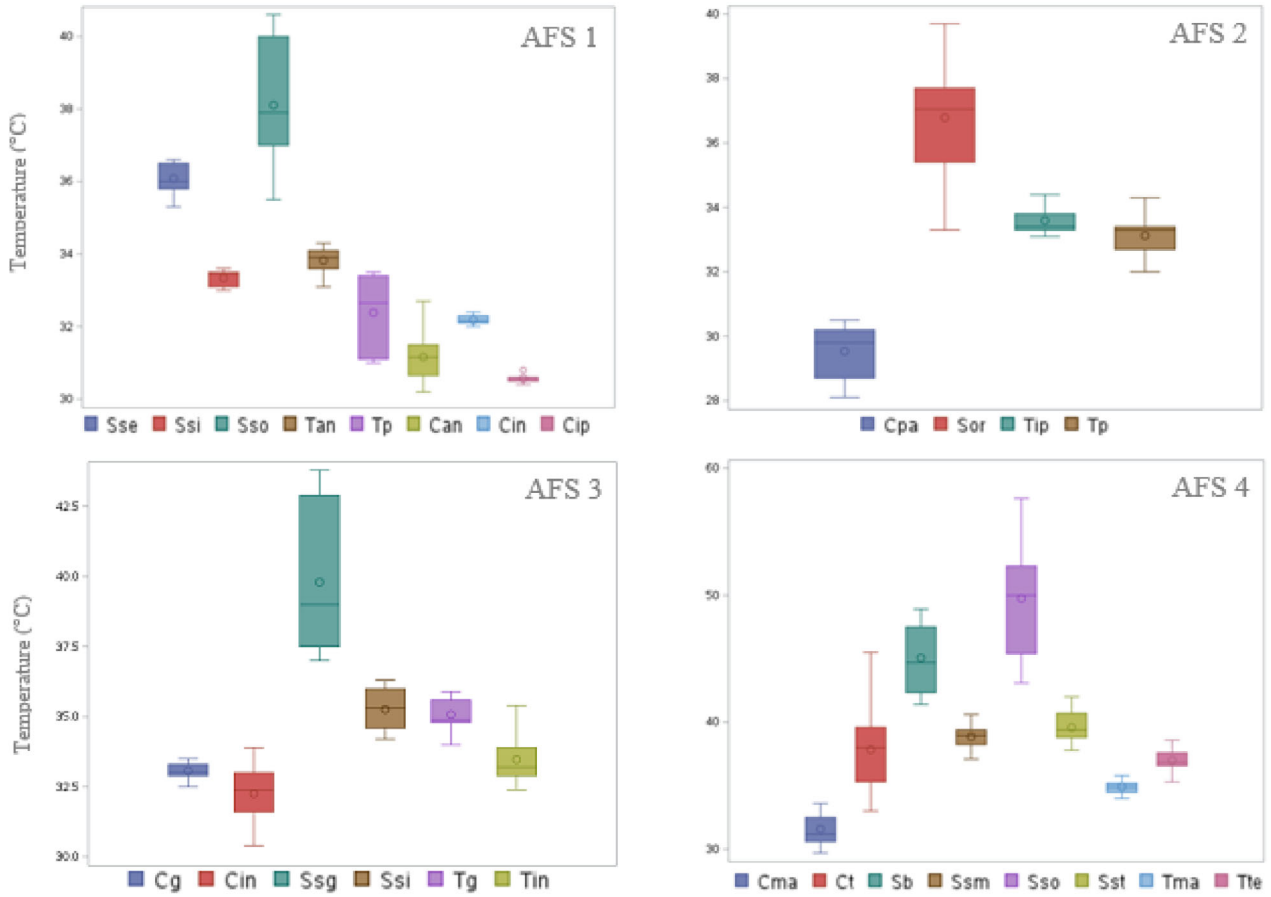


Fig. 2 Temperature distribution (°C) on different targets in four agroforestry systems (AFS) in Santarém, Pará, Brazil. Caption: Can—canopy of *C. guianensis*; Cg—canopy of *G. sepium*; Cin—cup of *I. heterophylla*; Cip—Cup of *H. serratifolius*; Cma—crown of *K. grandifoliola*; Cpa—canopy of *S. amazonicum*; Ct—crown of *T. grandis*; Sb—soil planting edges; Sor—soil with plant residues from clearing; Sse—litter; Ssg—soil shaded by *G. sepium*; Ssi—soil shaded by *I. heteraphylla*, Ssm—soil shaded by *K. grandifoliola*; Sso—soil exposed to the sun; Sst—soil shaded by *T. grandis*; Tan—stem of *C. guianensis*; Tg—stem of *G. sepium*; Tin—stem of *I. heterophylla*; Tip—stem of *H. serratifolius*; Tma—stem of *K. grandifoliola*; Tp—stem of *S. amazonicum*; Tte—stem of *T. grandis*

over, they demonstrated the ability to attenuate heat in the soil, registering an average temperature reduction of around 4.8 °C.

In AFS 2 (Fig. 2), the temperature obtained from the leaves of *S. amazonicum* tree canopies stands out with an average of 29.5 ± 0.8 °C. This measurement revealed a difference of up to 6.4 °C compared to the adjacent soil temperature, resulting in a distinct clustering in the dendrogram, standing out in comparison to the other three categories evaluated in this planting. In AFS 3 (Fig. 2), the highest temperature was highlighted in the soil under the shade of *G. sepium* with an average of 39.8 ± 2.6 °C, isolated in a cluster compared to the others in this planting. On the other hand, the soil under the canopy of the I. heterophylla species showed an 11.3% reduction in soil temperature.

Lastly, in AFS 4, it was also evident that in regions with wider canopy openings, such as at the planting edges, the highest average soil temperatures were recorded, ranging from 45.1 to 49.7 °C. However, under the same thermal load conditions, the soil under the shade of *T. grandis* and *K. grandifoliola* leaves maintained temperatures between 38.9 and 39.6 °C (Fig. 2), providing temperature reductions between 9.1 °C and 10.8 °C. Areas with soil fully exposed to the sun, without cultivation, presented an average temperature of 52.9 °C ± 1.3 °C, resulting in a thermal range of approximately 20 °C when compared to areas shaded by vegetation.

4 Discussion

The higher temperatures identified in the condition of soil directly exposed to the sun and covered with leaf litter revealed distinct effects compared to shaded soil, highlighting

the influence of thermal regulation resulting from the shading provided by tree canopies in AFSs. Currently, temperatures have exceeded the tolerance limits of several plant species, causing thermal stress and consequently crop yield losses (Pörtner et al. 2022). The association of trees with other crops has the potential to mitigate climate change through thermal regulation, reducing thermal variation, which in turn can benefit biodiversity and agricultural productivity. In environments with high solar radiation, stomatal opening may be reduced, negatively impacting water use efficiency (Matthews and Vialet-Chabrand 2017). Thermal variation can affect plant growth, as elevated temperatures, reaching 38 °C, combined with high irradiance, play a crucial role in the severity of photosynthesis photoinhibition (Dias and Marenco 2007). Intense solar radiation can potentially lead to an excess energy production during photosynthesis, resulting in stress and damage to the photosynthetic apparatus (Tian et al. 2016).

The heat reduction identified in this study, attributed to the presence of trees, can generate various benefits for the management and decisions involved in conducting AFSs. The existence of trees provides a more favorable environment in terms of thermal comfort, as systems with less available shading tend to accumulate more heat (Junior et al. 2021). Considering that the presence of trees in agroforestry systems accounts for most of environmental microclimate conditions (Gagliardi et al. 2021), the results of the present study are in accordance with the Brazilian National Policy for Payment for Environmental Services (Brasil 2021).

The decrease in thermal load also creates more suitable conditions for workers involved in cleaning and managing the plantations. Leaf infrared radiation has the capacity to influence agroforestry microclimates (Junior et al. 2020), and the temperature reduction caused by canopy shading can open up possibilities for intercropping with perennial plantations. Furthermore, canopy density also proved to be a determining factor in the temperature reflected in the soil. In the case of AFS 3, the species I. heterophylla, which has a denser canopy, proved to be more effective in attenuating heat compared to *G. sepium*, which allows greater light penetration. In AFS 4, the shade of leaves from the perennial species demonstrated the heat-reducing effect, resulting in a reduction of up to 22% in soil temperature. This factor becomes particularly relevant, especially in extreme climatic periods such as El Niño.

5 Conclusions

The thermal patterns in the soil are distinct from each other and higher than the temperature conditions in the leaves and stems of the species analyzed. Infrared thermography analysis has proven to be an efficient tool to highlight this environmental benefit. The presence of perennial species in cultivation indicates potential for payment for environmental services due to the heat attenuation and thermal regulation. Future research involving sampling at various times of the year could expand upon the findings, exploring the long-term impact of these thermal patterns on soil and plant growth.

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Organised Hypocrisy, Organisational Façades, Temporalties of Hypocrisy and CSR Reporting: The Case of Two Mining Corporations in Ghana.

Osman Issah and Tânia Menezes Montenegro

Abstract

Context/Purpose This paper explores how tax-evading mining corporations in Ghana attempt to used CSR reporting, through means of organised hypocrisy, organisational façades, and the temporalities of hypocrisy, in order to mitigate reputational damage arising from tax avoidance and other unethical behaviour. *Methods* A case study design with summative and deductive content analysis was developed on CSR reports of two tax-evading mining entities in Ghana, and juxtaposed against analysis of the firms' actual behaviour. *Results* We find significant gaps between CSR disclosure and real actions of the two Ghanaian companies. By juxtaposing the real context and the CSR reporting of the companies, the results show that organised hypocrisy, organisational façades, and the temporalities of hypocrisy were used to support CSR disclosures. *Interpretation* Company A, used a hypocrisy, with a reactive communication strategy, thereby making CSR disclosures during and after unethical behaviours, as well as progressive façades and an aspirational/deferment mode of temporal hypocrisy, by projecting the impression, through CSR reporting, that several actions are/will be taken. Re-narration seems to be used when the company selects incidents from the past to support current and future practices. Reputation façades and the evasion mode of temporal hypocrisy are also used, to strengthen the firm's image during/following observed unethical actions. Company B engaged in a reactive communication scheme, and used reputational façades and the evasion mode of temporal hypocrisy, to protect the firm's reputation during/following observed unethical actions. *Conclusion* Reactive communications strategies, reputation and progressive façades, as well as aspiration, deferment, re-narration and evasion temporal modes of hypocrisy are found in CSR reporting behaviour of two tax-evading mining entities in Ghana.

Keywords

CSR · Tax avoidance · Hypocrisy · Façades · Ghana

1 Introduction

This paper explores how how tax-evading mining corporations in Ghana attempt to used CSR reporting, through means of organised hypocrisy, organisational façades, and the temporalities of hypocrisy, in order to mitigate reputational damage arising from tax avoidance and other unethical behaviour.

Similar to other sin industries, while mining companies have legal licenses to operate, their activity is generally perceived as environmentally hazardous, potentially harmful for human rights and local economies, and are considered as largely deviating from social, ethical and environmental standards (Andrews 2016; Dhandhania and Higgins 2022; Lauwo et al. 2020). In adition, mining industry in developing countries is one of the larger generators of illicit financial flows (African Centre for Energy Policy 2015).

In sin industries, CSR is often used by firms to demonstrate their contribution to the community, to enhance their legitimacy, to forestall perceptions of undesirable externalities, to sustain legitimacy in the face of long-standing legitimacy gaps, and often to counter the accusations on unethical and harmful activities (Dhandhania and Higgins 2022; Kuruppu et al. 2019; Leung and Snell 2021). In the context of Ghanian mining entities, Essah and Andrews

O. Issah
University for Development Studies, Tamale, Ghana

O. Issah · T. M. Montenegro (✉)
School of Economics, Management and Political Science, iBMS—Centre for Research in Business, Markets & Society, University of Minho, Braga, Portugal
e-mail: taniab@eeg.uminho.pt

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(2016) suggest that there is a discrepancy between CSR discourse and their real actions, and that CSR disclosures are primarily used in a symbolic level. These gaps between promises of responsible and ethical conduct and the real corporate actions highlight the inconsistencies of organisational words and action which are aligned with the concepts of organised hypocrisy and organisational façades (Cho et al. 2015). While the link between the unethical corporate actions and CSR reporting has been widely explored in the literature, little research is found in developing countries (e.g., Patnaik et al. 2018), particularly in Ghana (Issah and Rodrigues 2021; Patnaik et al. 2018). Also, according to Lauwo et al. (2020), there is a need to problematise CSR practices in the mining industry and a call by CSR scholars for further studies in sin industries in different jurisdictions (e.g., Acuti et al. 2024; Dhandhania and Higgins 2022; Leung and Snell 2021). This study explores this research gap, by exploring how mining corporations accused of tax evasion in Ghana attempt to used CSR reporting to mitigate reputational damage arising from misconduct in terms of tax compliance and other unethical activities.

2 Method

A case study design, with summative and deductive content analysis performed on data from CSR reports of two alleged tax-evading mining entities (Company A and Company B) in Ghana, is used in this study. For Company A, data consists of annual stand-alone CSR reports for the years ending 2014, 2015, 2016 and 2017. For Company B data were available only for only a stand-alone CSR report issued in 2021. Content analysis is applied to decode the companies' CSR statements and juxtapose them against analysis of the actual behaviour of the companies (extracted from media coverage of these entities). The organised hypocrisy and organisational façades concepts integrated with the temporal dynamics of hypocrisy are used as a theoretical lens.

3 Results

Comparing the real behaviour obtained through media coverage and CSR disclosures of Company A reveals that most of concrete actions do not appear in CSR reports. The results indicate that, under the concepts of organised hypocrisy and organisational façades, a reactive communication strategy and reputation façades deeply pervade the efforts of Company A to restore/maintain its image and reputation through CSR reporting. CSR disclosures highlight positive impacts and omit negative information (such as poor working conditions, tax evasion practices, fraudulent business practices and severe environmental damages), this way keeping unethical and hazardous behaviours out of the stakeholders' view (Murcia 2021). Overall, CSR disclosures are largely used in a symbolic level. In the social dimension, Company A, perhaps pressured by Mining Regulations to create social benefits to host communities, also engages in progressive façades, as the company projects through CSR disclosures the impression that several actions are/will be taken, when, in fact, little is done (Cho et al. 2015).

The four temporal modes of hypocrisy are also found in CSR reporting of Company A. The aspiration and deferment temporal modes of hypocrisy are found in CSR disclosures describing several projects not yet started, and in the unchanged commitment with other projects that occurred in the past (Christensen et al. 2013, 2020). Re-narration is found when Company A picks incidents from the past (traffic accidents related to the bauxite haulage) to support current and future practices (reduce traffic accidents and protect user safety) (Christensen et al. 2020). Disclosures in the environmental area highlight the evasion temporal mode of hypocrisy, by revealing positive aspects and omitting (ignoring) negative information about hazardous actions in the past (e.g., allow the local community citizens access to the company's health facility and monitoring the water quality, beyond a contribution to the host community health, it is also a way to handle with the public health and safety risks caused by the company's mining activity) (Christensen et al. 2020).

For Company B, severe inconsistencies are also found between real behaviour and CSR reporting on the social, economic and environmental dimensions. Under the concepts of corporate hypocrisy and organisational façades, Company B uses a reactive communication strategy and reputation façades, expressly declaring to be something it is not (Wagner et al. 2009). This type of behaviour is described by Gribnau and Jallai (2017) as minimalist or zero compliance approach to CSR.

Moreover, in terms of temporal modes of hypocrisy, Company B's CSR report for 2021 falls into the evasion temporal mode. Company B explicitly ignores past dangerous and unethical behaviours, a "dark shadow" that can undermine its reputation in the public eye (Christensen et al. 2020). The Company B's 2021 CSR report is used to keep years of unethical and hazardous practices out of public's view: workers' deaths; poor working conditions; an abusive mode of acquisition and use of land; barriers to development and livelihood of host communities; fraudulent business practices and management actions (including tax evasion); as well as damages caused to the natural biodiversity and health of workers and local community.

4 Discussion

By juxtaposing the CSR reporting and the real context of the two Ghanaian mining corporations under study, we find evidence that, overall, CSR disclosures are used to protect the companies' reputation from unethical behaviours. Both companies have excluded negativity from their CSR reports, and portray a positive CSR stance. We contend that this behaviour reflects the overall context of Ghana, and, in particular, that of the large-scale mining industry, where multinational companies, beyond the huge damages caused to natural resources and local communites, reveal an excessive dependence (and even an abuse), of tax benefits granted by the State, without making real efforts to add value to the livelihood of the local communities and to the country's economy (Ansu-Mensah et al. 2021; Mineral Commission of Ghana 2014). Additionally, large-scale mining corporations have to deal with contradictory pressures from regulators, investors, employees, host community's representatives, governmental agencies and Non-Governmental Organisations (NGOs) (Ansu-Mensah et al. 2021). This complexity of the institutional elements of Ghana is brought into the analysis of CSR reporting through the lens of the organised hypocrisy, organisational façades and temporalities of hypocrisy. We provide evidence that organised hypocrisy and organisational façades pervades the large-scale mining industry in Ghana, namely through reactive communication strategies, reputational façades and the evasion temporal mode of hypocrisy. Yet, perhaps driven by Mining Regulations and NGOs demands, large-scale mining firms also engage in the aspiration, the deferment and the re-narration temporal modes of hypocrisy, to sustain inconsistencies between words and actions, (re)assert acceptable linkages between the past, present and future and, perhaps, encourage more sustainable business practices (Christensen and Cornelissen 2013).

5 Conclusions

This study examines how two mining corporations accused of tax evasion in Ghana attempt to used CSR reporting to mitigate reputational damage arising from unethical activities. The research focuses on the interaction of the concepts of organised hypocrisy, organisational façades and temporal dynamics of hypocrisy with CSR reporting.

Major findings reveal that the two mining corporations under study used CSR reporting in a symbolic way to protect their reputation from unethical behaviours. We conclude that organised hypocrisy and organisational façades pervade the large-scale mining industry in Ghana, particularly via reactive communication strategies, reputational façades and the evasion temporal mode of hypocrisy. Perhaps driven by Mining Regulations and NGOs demands, large-scale mining corporations also engage in the aspiration, the deferment and the re-narration temporal modes of hypocrisy, to support inconsistencies between words and actions and (re)assert acceptable linkages between the past, present and future. These insights provide guidelines for Ghanaian authorities to build a monitoring system and draw attention to the need for constant scrutiny of the large-scale mining industry.

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Physiologically Equivalent Temperature as a Method to Assess the Impact of Thermal Environment on Human Health: A Systematic Review

Katerina Pantavou, Lunzheng Li, Adrien Fillon, Zacharias Maniadis, and Georgios Nikolopoulos

Abstract

The consequences of climate change on public health increase the demand for employing integrated methods to monitor the association between thermal environment and human health. The Physiologically Equivalent Temperature (PET, °C), one of the most widely used indices in the biometeorological research, is an integrated method for assessing how people experience the surrounding thermal environment. PET is derived from human energy balance and incorporates several meteorological variables including air temperature, relative humidity, wind speed, and radiation as well as physiological variables, such as age, sex, height, and weight. This paper aims to summarize the published evidence on the association between PET and human health. PubMed, Scopus, and Web of Science (Science Citation Index Expanded, Social Sciences Citation Index, Emerging Sources Citation Index) databases were systematically searched from inception to May 15th, 2023. Studies examining the association between PET and any health outcome were identified. We included studies focusing on the outdoor thermal environment. A total of 6586 records were screened of which 33 studies were sought for retrieval. Of these, 32 articles were included in the systematic review. Studies examining the association between PET and health outcomes were published after 2006. The health outcomes included mainly morbidity from cardiovascular and respiratory diseases (64.9%). Twenty-two studies examined all—and specific-cause morbidity and ten examined mortality. Three studies were focused on milder heat-related symptoms, such as dizziness, headache, exhaustion, cramps and medical stress. Summarizing the published evidence is expected to popularize PET and attract the interest of clinicians, epidemiologists, public health experts, and policy makers. The application of PET simplifies the study of heat-related health effects by integrating the number of variables considered into one parameter while ensuring comparability of the obtained results.

Keywords

PET · Health effects · Thermal conditions · Mortality · Morbidity

1 Introduction

The biometeorological indices assess how people experience their surrounding thermal environment. They combine meteorological and, in some cases, physiological variables to create a comprehensive assessment. One such index is the Physiologically Equivalent Temperature (PET, °C) (Mayer and Höppe 1987; Höppe 1999). PET is universal, applied in all climates and in both warm and cold conditions. It is derived from human energy balance based on the Munich Energy-balance Model for Individuals (MEMI). PET represents the air temperature at which, in a typical indoor setting (without wind and solar radiation), the heat budget of the human body is balanced with the same core and skin temperature as under the complex outdoor conditions to be assessed (Höppe 1999).

The aim of this paper is to summarize the published evidence on the association between PET and human health. This is expected to popularize PET among medical scientists and policy makers.

K. Pantavou · L. Li · A. Fillon · Z. Maniadis · G. Nikolopoulos (✉)
University of Cyprus, Nicosia, Cyprus
e-mail: nikolopoulos.georgios@ucy.ac.cy

Z. Maniadis
University of Southampton, Southampton, UK

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2 Methods

This paper focuses on PET and it is part of a systematic review (PROSPERO CRD42023412470) encompassing all thermal indices for the assessment of outdoor thermal environment effects on human health.

PubMed, Scopus, and Web of Science (Science Citation Index Expanded, Social Sciences Citation Index, Emerging Sources Citation Index) were systematically searched to identify studies examining the association between thermal indices and any health outcome. The keywords included the terms: heat, warm, cold, cool, thermal environment and condition, weather, climate, equivalent temperature, PET, mortality, death, morbidity, hospital, emergency, health, exposure, exhaustion, illness, and disease. The search was conducted from inception to May 15th, 2023 and was limited to original articles in English language, and related to humans and outdoor environments. The reference lists of the identified articles were screened for additional eligible publications. Duplicates were removed in Mendeley reference management software. The titles and abstracts were screened in Rayyan software (Ouzzani et al. 2016) by two authors (KP and LL). The conflicts were resolved by discussion with a third team member (AF).

From the retrieved publications, we focused on those related to PET. Data extraction was conducted using a template in Excel. Three authors (KP, LL and AF) extracted the data. The extracted information included information of first author, year and journal of publication, continent, climate, and health outcome. The health outcomes were classified according to the International Statistical Classification of Diseases and Related Health Problems tenth Revision (ICD-10).

3 Results

A total of 6586 records were retrieved from PubMed (n = 884), Scopus (n = 1590), and Web of Science (n = 4112). Among these 1785 articles were removed as duplicates and 4801 records were screened for title and abstract. Thirty-three studies examined the effect of PET on health outcomes, and 32 (Dastoorpoor et al. 2021; Shiue et al. 2016a; Shiue et al. 2016b; Shiue et al. 2016c; Dastoorpoor et al. 2022a; da Silva and Ribeiro 2012; Borsi et al. 2022; Shiue et al. 2016d; Hartz et al. 2013; Pantavou et al. 2020; Schroeder et al. 2023; Vasconcelos et al. 2013; Shiue et al. 2015; Zaninović and Matzarakis 2014; Ruuhela et al. 2017; Thach et al. 2015; Matzarakis et al. 2010; Urban et al. 2019; Muthers et al. 2010a; Muthers et al. 2010b; Sharafkhani et al. 2018; Shartova et al. 2018; Nastos and Matzarakis 2006; Dastoorpoor et al. 2022b; Çağlak and Matzarakis 2023; Ferrari et al. 2015; Lim et al. 2017; et al. 2021; Çağlak 2022; Roshan et al. 2022; Halabian and Moghbel 2022; Romaszko et al. 2022) met the eligibility criteria for inclusion in this systematic review. The eligible studies were published between 2006 and 2023 in 20 scientific journals. Most of the studies (n = 5, 15.6%) were published in the *Environmental Science and Pollution Research*. The studies were primarily conducted in Europe (n = 17, 53.1%), approximately 34.4% (n = 11) were conducted in Asia, and 12.5% (n = 4) in America. The climates considered were arid (BSk, BWh; 26.3%), temperate (Cfa, Cfb, Csa, Csb, Cwa; 44,7%), and continental (Dfa, Dfb, Dfc; 28.9%).

Most of the studies (68.8%, n = 22) focused on morbidity while 31.3% (n = 10) focused on mortality. Overall, 30 health outcomes were considered. The mortality-related health outcomes included all-cause mortality (Zaninović and Matzarakis 2014; Ruuhela et al. 2017; Thach et al. 2015; Matzarakis et al. 2010; Urban et al. 2019; Muthers et al. 2010a; Muthers et al. 2010b; Sharafkhani et al. 2018; Dastoorpoor et al. 2022b) and mortality attributed to diseases of the circulatory (Thach et al. 2015; Sharafkhani et al. 2018; Shartova et al. 2018; Dastoorpoor et al. 2022b) and respiratory system (Muthers et al. 2010b). The morbidity-related outcomes encompassed all-cause morbidity (Pantavou et al. 2021), and morbidity linked to diseases of the circulatory (Shiue et al. 2016a; Shiue et al. 2016b; Shiue et al. 2016c; Dastoorpoor et al. 2022a; Vasconcelos et al. 2013; Ferrari et al. 2015; Lim et al. 2017; et al. 2021; Çağlak 2022; Roshan et al. 2022; Halabian and Moghbel 2022) and respiratory system (Borsi et al. 2022; Nastos and Matzarakis 2006; Çağlak and Matzarakis 2023), certain conditions originating in the perinatal period (i.e., low birth weight) (Dastoorpoor et al. 2021), factors influencing health status and contact with health services (i.e, stillbirth) (Dastoorpoor et al. 2021), mental and behavioral disorders (Shiue et al. 2016d), neoplasms (Shiue et al. 2015), pregnancy, childbirth and the puerperium (i.e., preterm labor, spontaneous abortion, pre-eclampsia, gestational hypertension) (Dastoorpoor et al. 2021), mild heat-related symptoms (Hartz et al. 2013; Pantavou et al. 2020), and medical stress (Schroeder et al. 2023).

Twenty-five studies presented results of 55 assessments of the impact of warm conditions on health. Twenty-six (47.3%) of these assessments suggested an increased risk of adverse health outcomes when PET increases while 24 (43.6%) assessments were non-significant. Twenty-two studies reported findings from 47 assessments examining the effect of cool conditions on health. The number of assessments suggesting an increased risk of negative health outcomes when PET decreases and the non-significant assessments were equal, i.e., 21 (44.7%).

4 Discussion

This systematic review described the weather-related health outcomes examined by means of PET. There has been an increase in the number of related studies and the examined health outcomes over the years. This indicates a growing scientific interest in PET, similar to the findings for the Universal Thermal Climate Index (Romaszko et al. 2022). Nevertheless, the variety of health outcomes, the methods followed as well as the information presented in the studies demonstrated significant heterogeneity that creates difficulties in conducting a meta-analysis.

5 Conclusions

Implementing integrated and universal methods to monitor the association between thermal environments and health, such as biometeorological indices, could be valuable tools in shaping effective policies. PET can potentially serve as an integrated method for modeling the heat/cold-related impact on human health.

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Rural Workers' Occupational Perception of Pesticides in the Amazonian Agricultural Frontier

Ilze Caroline Gois Braga Pedroso, Antônia Irisley da Silva Blandes, Kely Prissila Saraiva Cordovil, Paulo Sérgio Taube Junior, Maxwell Barbosa de Santana, Rodolfo Maduro Almeida, Flávia Garcez da Silva, Ruy Bessa Lopes, and Luís Reginaldo Ribeiro Rodrigues

Abstract

The main goal is to collect data to support the implementation of health promotion measures for rural workers in the agricultural frontier near the municipality of Santarém, Pará, Amazônia, Brazil, based on the workers' perceptions. The research will contribute to public awareness and support decision-making by the competent authorities. This is a field, descriptive, and cross-sectional study with a quantitative approach. The research was developed in rural communities located on the agricultural border of PA-370. The instrument for data collection was a survey containing specific questions about the use of pesticides by rural workers and possible symptoms associated with acute or chronic poisoning. The research was approved by the ethics committee. The data were organized and analyzed using descriptive statistics, focusing on frequency distributions and percentagens to characterize the study population. Of the 76 participants in the survey, 76.3% of rural workers reported using pesticides during planting, 28.9% reported using monthly, 67.2% reported not to use personal protective equipment (PPE), in addition, about 11.8% reported to ingest food and water during pesticide application. When asked about the manifestation of clinical symptoms after handling and applying pesticides, the participants listed 22 symptoms, of which 20.3% were headache, 9.8% eye irritation and another 9% reported dyspnea. Handling pesticides requires technical knowledge due to their health implications, and therefore the correct use of PPE is essential. The consumption of food, tobacco, or liquid, while pesticides are being applied, is reproachable due to the high risk of intoxication by accidental ingestion of these compounds, which can cause serious health problems such as those listed. Actions must be taken to raise awareness among these rural workers to the conscious use of PPE. Furthermore, these results shed light on general debates related to the expansion of agricultural frontiers and the risk of occupational exposure, both of which have scarce data in the Amazonian context.

Keywords

Brazil · Public health · Clinical manifestations · Agrochemicals · Personal protective equipment

I. C. G. B. Pedroso (✉) · K. P. S. Cordovil · P. S. T. Junior · L. R. R. Rodrigues
Programa de Pós-Graduação em Sociedade, Natureza e Desenvolvimento (PPGSND), Instituto de Biodiversidade e Florestas (IBEF), Universidade Federal do Oeste do Pará (UFOPA), Santarém, Brazil

I. C. G. B. Pedroso · L. R. R. Rodrigues
Laboratório de Genética e Biodiversidade (LGBio), Instituto de Ciências da Educação (ICED), Universidade Federal do Oeste do Pará (UFOPA), Santarém, Brazil

A. I. da Silva Blandes · L. R. R. Rodrigues
Programa de Pós-Graduação em Biodiversidade e Biotecnologia (REDE BIONORTE), Instituto de Saúde Coletiva (ISCO), Universidade Federal do Oeste do Pará (UFOPA), Santarém, Brazil

M. B. de Santana · R. B. Lopes
Instituto de Ciências e Tecnologia das Águas (ICTA), Universidade Federal do Oeste do Pará (UFOPA), Santarém, Brazil

R. M. Almeida
Instituto de Ciências da Educação (ICED), Universidade Federal do Oeste do Pará (UFOPA), Santarém, Brazil

F. G. da Silva
Instituto de Saúde Coletiva (ISCO), Universidade Federal do Oeste do Pará (UFOPA), Santarém, Brazil

1 Introduction

In terms of market value, Brazil is one of the world's largest exporters of grains, such as soybeans (FAOSTAT n.d.), and, since 2008, has been the world leader in pesticide consumption (Homepage 2020; Khan et al. 2023). The developmental pressure on the Brazilian Amazon in recent decades, coupled

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with Brazil's ranking in the consumption of these compounds, is especially related to the expansion of temporary agriculture into the region (Steward 2007). With the Brazilian agricultural expansion frontier towards the north, specifically soybean and corn grain production, adverse effects on the environment and health are potential (Pimentel 2005). Among them, the widespread use of pesticides is of urgent concern (Rani et al. 2021).

The main routes of human exposure to pesticides are inhalation, oral, and dermal, and can be classified by forms of environmental exposure (dispersion through the atmosphere, for example), food (contaminated ingestion), and occupational (during handling) (Oga et al. 2014). In the interior of the state of Pará, three large regions constitute an area of agricultural frontier expansion. The production areas together correspond to 75.2% of soybean cultivation in the state. One of them is in western Pará and is led by the municipality of Santarém and other adjacent areas, which have an expansion frontier around highways such as BR-163 and PA-370 (Costa et al. 2017; Pedroso and Junior 2018).

Within the context of the Amazonian agricultural frontier, rural workers are the main ones to suffer impacts from the expansion frontier, in what can also be considered a public health problem. The situation makes them increasingly susceptible to the potential deleterious effects of the widespread use of pesticides in their surroundings and their work activity (Lopes and De Albuquerque 2018; Santana et al. 2022). Through the survey about health clinical manifestations and the use of personal protective equipment (PPE) by rural workers, the study aims to collect essential data to support the implementation of health promotion measures of occupational health in the agricultural frontier of rural areas in western Pará, Amazon, Brazil.

2 Methods

The study was approved by the research ethics committee of the State University of Western Paraná, under the certificate of submission for ethical appraisal (CAAE) number 82220117.0.0000.0107. Participants read and signed the Informed Consent Form. This is a field, descriptive, and cross-sectional study with a quantitative approach, conducted in March and April 2019, in a period of strong convective activity in the Amazon, in which large producers focus on the soybean harvest.

The research was conducted with rural workers who live and work in communities around the PA-370 highway, an area of agricultural frontier expansion in the municipality of Santarém, in the Amazon (17.898 km^2, located 697.24 km from Belém, capital of Pará). The study employed a non-probabilistic convenience sampling method, through a systematic recruitment process, by contacting regional leaders. All participants were aged 18 years or older. All rural workers handled pesticides in some way, either in the preparation of the solution or in the application of the product. The data collection instrument was a previously validated survey applied by a trained professional.

In all, 76 rural workers participated in the study. The survey consisted of 30 objectives questions (dichotomous yes/no or multiple choice) on sociodemographic profile, housing aspects, perception of chemical risk, and clinical manifestations felt after handling pesticides (associated with acute and chronic intoxication). This extended abstract addresses the frequency and pesticides use, the PPE use, habits, and clinical manifestations experienced. Data were organized and analyzed using IBM SPSS Statistics software (version 24, 2016). Descriptive statistics, including absolute frequencies (N) and percentages (%), were applied.

3 Results

Of the 76 participants, 76.3% of rural workers reported using pesticides during planting, 28.9% reported using monthly, 67.2% reported not to use PPE, in addition, about 11.8% reported to ingest food and water during pesticide application. When asked about the manifestation of clinical symptoms after handling and applying pesticides, the participants listed 22 symptoms, of which 20.3% were headache, 9.8% eye irritation and another 9% reported dyspnea (Table 1).

4 Discussion

The use of pesticides has been an important resource for the maintenance of agricultural production; therefore, it is essential to emphasize the necessary precautions regarding their application and correct handling (Pasiani et al. 2012). One of the requirements for the prevention of occupational exposure is maintaining an aproppriate spraying or application cycle of pesticides. In the present study, a monthly application frequency was observed, which does not strictly follow the recommendations of health organizations (Ndayambaje et al. 2019).

The results are consistent with findings from a study in the south of Brazil that, when inquiring about the use of PPE during the application of pesticides on the farm, only 25.6% stated that they used it completely (Sasso et al. 2021). Further research also highlights this debate about the importance of the use of PPE by workers, considering the numerous impacts on the health of rural workers, when inhaling and being exposed to the effects of pesticides (Ndayambaje et al. 2019). Regarding the ingestion of food and beverages in the application environment, our data reflect a concerning trend also reported in a survey conducted in southeastern Brazil,

Table 1 Frequency and use of pesticides, use of PPE, habits, and clinical manifestations of rural workers on the agricultural frontier of PA-370, Santarém, Amazon

Pesticides use	N	Fr (%)
Yes	58	76.3
Not	18	23.7
Pesticides application frequency		
Annually	12	15.8
Daily	3	3.9
Monthly	22	28.9
None	18	23.7
Weekly	12	15.8
Biannually	9	11.8
PPE use		
Yes	25	32.8
Not	51	67.2
Ingestion of food and water during handling of pesticides		
Yes	9	11.8
Not	67	88.2
Total	76	100
Clinical manifestations	**N**	**Fr (%)**
Headache	27	20.3
Eye irritation	13	9.8
Dyspnea	12	9.0
Cough	10	7.5
Nausea	9	6.8
Abdominal pain	9	6.8
Epiphora	6	3.8
Blurred vision	6	4.5
Vomiting	5	3.8
Allergy	5	3.8
Others 12 symptoms <5 citations	31	23.9
Total	133	100.00

where 91% of the interviewed workers reported this practice, including on pesticide application days (Buralli et al. 2021).

Regarding symptoms of acute and chronic poisoning after application, the reported frequencies in this study allign with the findings of a survey in Nigeria, which found similar clinical manifestations such as headache at 56.1%, eye irritation at 40.7%, and sialorrhea at 44.2%, in addition to other symptoms such as skin irritation (Moda et al. 2022). A similar pattern was also observed in a study in the southeastern region of Brazil, which found that 81% of rural workers presented headaches after pesticide application (Buralli et al. 2020).

5 Conclusions

The study indicates that many rural workers do not consistently use PPE, even if they handle pesticides periodically/routinely. A high prevalence of adverse clinical manifestations related to acute and/or chronic intoxication was observed following pesticide handling. Given these symptoms, actions must be taken to raise awareness among rural workers about the use of PPE and the potentially dangerous health effects caused by exposure to pesticides. These results provide insights into broader debates regarding the expansion of agricultural frontiers and the risk of occupational exposure, both of which suffer from scarce data in the Amazon context. The research may serve to inform public awareness and as a basis for decision-making by competent governmental entities. However, it is essencial to deepen the understanding of this region through further epidemiological research and use of biomarkers.

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DNA Damage in Buccal and Urine Epithelial Cells of Habitual Tobacco Users

Mohd Dawood Khan, Bani Bandana Ganguly, and Nitin N. Kadam

Abstract

Context/Purpose Tobacco consumption destabilizes DNA leading to genetic instability and onset of cancer, which is further aggravated by the environmental/occupational exposures. However, interaction of the geographical climate and life-style factors would not be a straightforward study. In the present study, DNA damage was assessed in exfoliated cells of oral cavity and urinary excretion in habitual smokers and chewers. The study has highlighted the extent of damage in tobacco-exposed cells passed through respiratory and/or digestive system and excreted in urine. *Methods* Ethical approval and participants' informed consent were obtained. Occupationally, chewing and control population was working and living in a tailoring factory, while smokers were engaged in computer work from home. Thus, the former group was additionally exposed to cloth-fiber particles, while smokers inhaled more smoke in the closed internal environment. However, they were not much exposed to external environment in their daily life. Buccal (by scrapping) and urine exfoliates were obtained from the same individuals from chewing (10), smoking (10) and control (10) population. Cells were processed for short hypotonic and fixative treatment, collected onto glass slides and stained in Giemsa. For each subject, 1000 cells were studied for estimation of micronucleus (MN), and analyzed by one-way ANOVA and Tukey post-hoc tests. *Results* Frequency of MN was significantly higher in buccal cells of the chewers (1.1 ± 0.99) compared to smokers (0.25 ± 0.07) and controls (0.06 ± 0.07). The difference of micronuclei was insignificant in the oral epithelium of smokers and controls, though incidence was higher in smokers. The frequency was similar in urine samples of smokers (0.52 ± 0.35) and chewers (0.52 ± 0.09), but significantly higher than controls (0.14 ± 0.10). Collectively, DNA damage was higher in the oral cells of chewers than their urine counterpart, and urine cells of smokers and controls relative to their respective oral cells. *Interpretation* Long-term exposure of tobacco-chew could affect the basal layer of the epithelium in the oral and digestive system. Uniform damage in urine epithelia of tobacco consumers indicates similar excretion. Smoking could directly damage the lung cells but appeared less harmful to oral epithelium. Conclusion: Tobacco chewing causes more DNA damage than smoking. However, work and living environmental/epigenetic factors/inherent immune status might confound the ultimate tobacco effect.

Keywords

DNA damage · Micronucleus assay · Oral epithelium · Tobacco consumption · Urine epithelial cells

1 Introduction

Tobacco consumption has catastrophic impact on individuals and society, contributing to major public health problems worldwide. The destructive effects of tobacco are due to the combination of chemical compounds present or produced during tobacco consumption (Hoffmann and Hoffmann 1998). These substances have been categorically linked to a wide range of unfavorable health consequences, including cancer, heart disease, respiratory issues, and other health conditions. The impact of tobacco is further worsened by environmental and occupational factors. Understanding the effects of tobacco is challenging due to the interac-

M. D. Khan · B. B. Ganguly · N. N. Kadam
MGM Center for Genetic Research and Diagnosis, MGM New Bombay Hospital, Navi Mumbai, India

B. B. Ganguly (✉) · N. N. Kadam
MGM Institute of Health Sciences, Navi Mumbai, India
e-mail: bani.b.ganguly@mgmhospitalvashi.net

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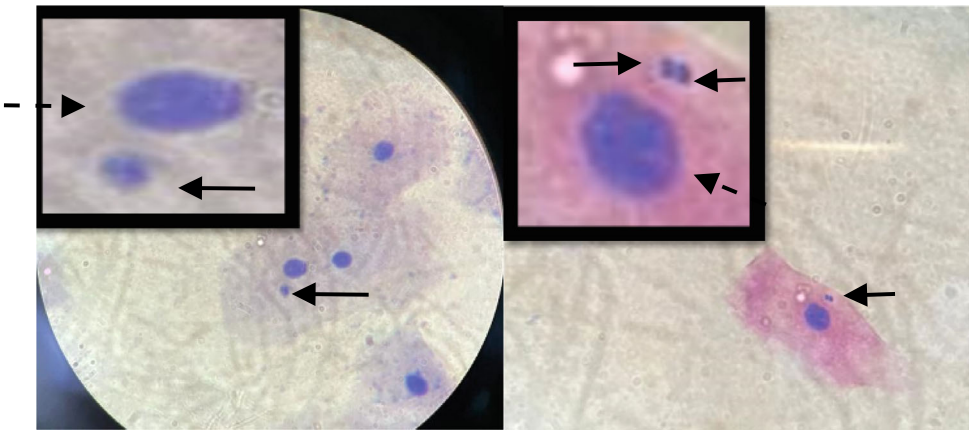


Fig. 1 Microscopy images of micronuclei (MN) in buccal epithelial cells (right) and urine epithelial cells (left) captured under oil immersion lens. The dark arrow points to the MN, while arrows with separate lines point to the nucleus

tions among geographical climate, lifestyle choices, and the biological mechanisms involved in tobacco-induced genetic instability (Ganguly 1994).

In this present study, our aim was to assess DNA damage in exfoliated cells from the oral cavity and urine cells of habitual smokers and chewers. The study has highlighted the extent of damage in tobacco-exposed cells passed through respiratory and/or digestive system and excreted in urine. The epithelial cells of the oral cavity are a primary site of exposure for both smoking and chewing. On the other hand, while the epithelial cells of the urinary tract do not directly interact with tobacco products, they can still be affected by tobacco-related damage. By analyzing micronuclei in these different biological compartments, we aimed to gain a comprehensive understanding of the extent and patterns of tobacco-induced genetic instability.

2 Materials and Methods

The study received ethical approval from the Institutional Ethics Committee of MGM's New Bombay Hospital in Navi Mumbai, India. Participants were fully informed about the purpose, objectives, and potential outcomes of the research. Participants' consent was obtained before initiation of sampling. The study collected buccal samples from chewing participants in a factory setting and smoking participants in a home setting. Participants rinsed their mouths and provided buccal scrapings using a toothbrush. Samples were transferred to glass slides, air-dried, and immersed in a KCl solution followed by Canoy's fixative. A Giemsa stain was applied, and one thousand cells were analyzed for each case. Participants provided morning urine samples in labelled containers, which were processed in the laboratory. The urine was centrifuged, and the resulting pellet was resuspended in KCl solution. After further centrifugation, the pellet was resuspended in Carnoy's fixative. Washing steps with Carnoy's fixative were repeated until the pellets appeared snowy white. The slides were examined under a binocular bright field microscope at 100X magnifications in a zigzag pattern. One thousand cells were examined for each case and analyzed by one-way ANOVA, Tukey post-hoc tests and independent '*t*' test.

3 Results

Micronuclei were observed in intact cells in all the specimens studied (Fig. 1).

Frequency of MN was significantly higher in buccal cells of the chewers (1.1 ± 0.99) compared to smokers (0.25 ± 0.07) and controls (0.06 ± 0.07). The difference of MN was insignificant in oral epithelial of smokers and controls, though incidence was higher in smokers (Sharma et al. 2018). The frequency of MN was similar in urine samples of smokers (0.52 ± 0.35) and chewers (0.52 ± 0.09), but significantly higher than the control group (0.14 ± 0.10) (Fig. 2).

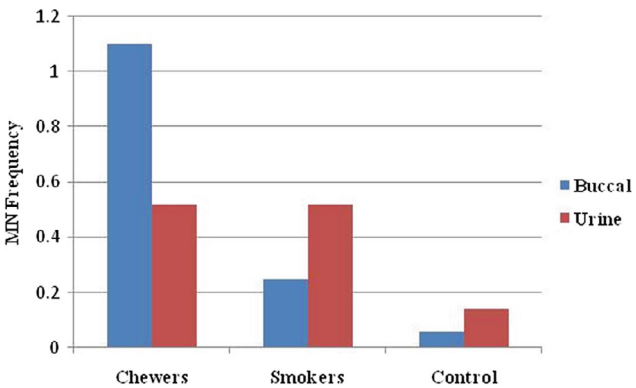


Fig. 2 Comparative means analysis of micronuclei (MN) frequency in 1. tobacco chewers, 2. smokers and 3. control population in buccal and urine epithelial cells

However, both smoking and smokeless tobacco consumption showed a similar and significant increase in the frequency of micronuclei in urine samples when compared to the control group, indicating that both forms of tobacco use can have harmful effects on the urinary tract.

4 Discussion

Chewers have a higher number of MN in their buccal epithelial cells compared to smokers, suggesting a greater risk of DNA damage. Both chewers and smokers exhibit similar frequencies of MN in their urine, indicating potential genetic instability caused by tobacco use. The frequencies of MN in urine and buccal epithelial cells among chewers are high. Hence, chewers have a higher likelihood of developing head, neck, and urinary tract cancers (Blaszczyk and Mielzynska-Svach 2014; International Agency for Research on Cancer: IARC monograph on the evaluation of the carcinogenic risk of chemicals to humans, 37. Lyon, 1985. https://monographs.iarc.who.int/wpcontent/uploads/2018/06/mono99.pdf, n.d.). In contrast, smokers display a significant difference in MN frequency in buccal epithelial cells, indicating a relatively lower health risk compared to chewers. Smokers are more prone to developing urinary tract cancer rather than cancer in the mouth, buccal region, head, or neck. Tobacco-chewing was associated with significantly higher MN frequency in the MIC-affected population compared to non-chewers (Ganguly et al. 2019).

5 Conclusions

This study emphasizes the genotoxic effects of tobacco chewing compared to smoking. However, additional factors like lifestyle, work environment, epigenetics, and immune status can influence the overall impact of tobacco. By considering lifestyle factors and exploring the mechanisms, we can advance our understanding of the long-term consequences and implement effective strategies to minimize the health risks associated with tobacco consumption.

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Urban Parks and COVID-19: A Simulative Infection Assessment to Aid Crowd Management

Shahana Usman Abdulla, Baka Lakshmi Narasimha Sai, and Bimal Puthuvayi

Abstract

Context/Purpose It is becoming increasingly evident that the management of public spaces is crucial as infectious diseases like COVID-19 continue to alter lives worldwide. With the prolonged lockdowns, the necessity of public outdoor recreational space has become more apparent in urban areas. So the way forward requires us to maintain the accessibility of these public spaces with minimum risk of infection. This paper attempts to simulate the disease spread potential of different activities in an urban park. *Methods* The hybrid model used the data of user statistics, activities, and timings of an Urban Park in India to simulate disease transmission in indoor, outdoor, and social distancing scenarios by varying the level of compliance. The study executed the simulation by coupling the agent-based model with the system dynamics model using AnyLogic software. The agent-based model (ABM) gave the contact rate required, based on which the system dynamics model calculated the number of infected and exposed. The results of the simulations helped us formulate guidelines for crowd management in urban parks. *Results* The results show that staggered slots for recreational spaces with 75% compliance with the precautions yield the best results. The simulation proves that the transmission is deficient outdoors compared to indoors, especially if the time is within 1 hour. *Interpretation* Reopening outdoor parks and open spaces before reopening indoor spaces could be permitted, prioritizing parks with larger areas and minimum contact surfaces over indoor spaces while easing restrictions. The authorities can fix opening timings for the park in a staggered manner based on the probable proportion of infected and susceptible populations. *Conclusion* Similar simulations for public spaces can help form more defined and transpicuous measures for containment with minimal impacts on daily lives.

Keywords

Simulation · COVID-19 · Public spaces · Urban parks · AnyLogic · Agent-based modeling · System dynamics

1 Introduction

Globally, as of July 26 2023, there have been 768,560,727 confirmed cases of COVID-19, including 6,952,522 deaths, reported to the World Health Organisation (WHO Coronavirus (COVID-19) Dashboard n.d.). Despite efforts of management from around the world, the spread of the disease has not ceased, bringing our focus to effectively managing such outbreaks. Outbreaks have been reported where people have gathered, often in crowded settings where they talk loudly, shout, breathe heavily, or sing (Advice for the public: Coronavirus disease (COVID-19) 2023). Such a public space with crowding and interaction is an urban park being investigated in this study to measure the risk of COVID-19 infection. Calculating the possible risk of the disease posed by an urban park helps regulate the movements while lowering the disease spread.

2 Methods

To demonstrate the determination of the risk of infection posed by an urban park, the Chitturi memorial ground, located in Tanuku, Andhra Pradesh, India, was selected for the study. A primary observational survey conducted for a day during the lockdown gave the necessary input data for the simulation model, including user statistics, activities, and timings. The study used a literature review and

S. U. Abdulla (✉) · B. L. N. Sai · B. Puthuvayi
National Institute of Technology Calicut, Calicut, Kerala, India
e-mail: shahana.usab@gmail.com

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primary data to assess the probability of transmission of the identified activities for the different user groups of the park. The hybrid model used these data to run indoor, outdoor, and social distance scenario simulations to check the disease spread in these scenarios. The scenario with minimal spread of the disease is selected for containment strategy formulation. The study executed the simulation using AnyLogic software as a mix of agent-based and system dynamics models. The agent-based model gave the contact rate required based on which the system dynamics model calculated the number of infected and exposed.

3 Results

Simulations run for various scenarios represented indoor, outdoor, and social distancing conditions with different parameters. The agent-based model gave values of contact rates for each scenario. Table 1 shows the parameters used for each scenario. The results for each scenario are shown in Figs. 1, 2, 3, 4, 5 and 6.

Table 1 Conditions used for scenarios

Parameters	Sc-1	Sc-2	Sc-3	Sc-4	Sc-5	Sc-6
Total population	200	200	200	400	200	200
Infectivity (%)	10	1	0.5	1	0.5	0.5
Contact rate (ppl/hr)	75	75	75	126	30	12
Average incubation (hr)	144					
Density (person/m^2)	0.04					



Fig. 1 Simulation results of scenario—1

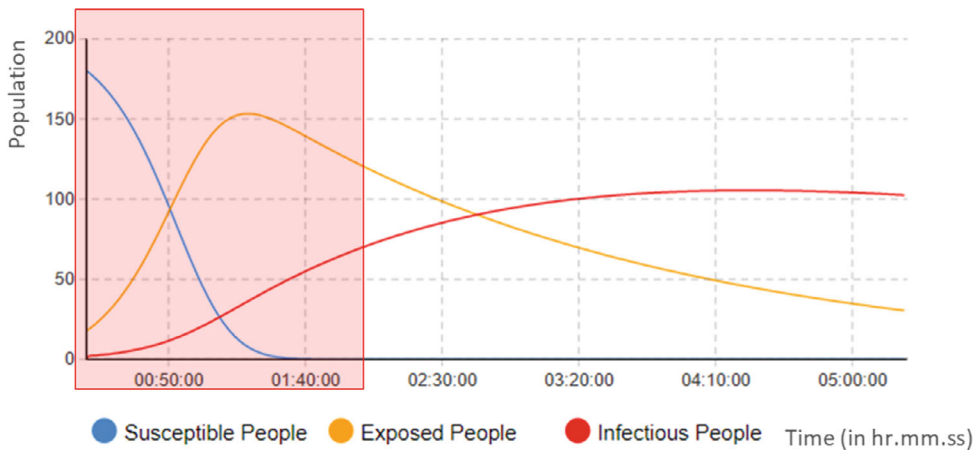


Fig. 2 Simulation results of scenario—2



Fig. 3 Simulation results of scenario—3

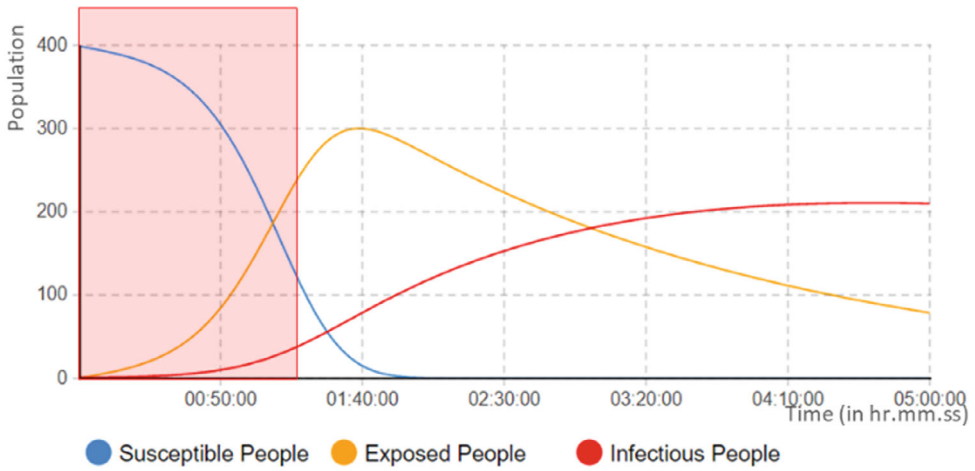


Fig. 4 Simulation results of scenario—4



Fig. 5 Simulation results of scenario5

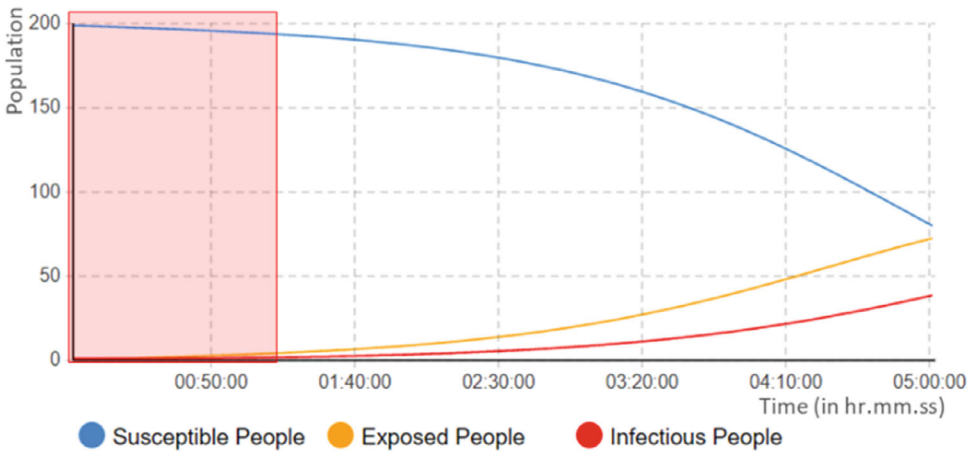


Fig. 6 Simulation results of scenario—5

4 Discussion

The simulation proves that the transmission is deficient outdoors compared to indoors, especially if the time is within 1 hour. Adopting strict measures to monitor social distancing measures reduces the infection rate drastically. The opening timings for the park can be decided based on the infection rate (proportion of infected people). Three scenarios of simulation where the initial infections are varied (0.5, 5, and 10%) show different results. As we analyze the results of the scenarios by varying the initial infected population, the number of infections stabilizes at around 100. The time to reach this saturation point varies inversely to the number of initial infections. After simulating the scenarios with compliance to social distancing measures, results show drastic changes in the peak exposed and infectivity rate. We can see that the peaks of each state shift towards the right. These show that with staggered timings, the infection rate decreases at a higher rate, leading to increased daily opening. Reopening outdoor parks and open spaces before reopening indoor spaces allows for physical distancing, especially in parks with minimum contact surfaces. We can propose staggered timings based on the probable rate of infection posed by the particular area. Moving physical activity and enrichment programs indoors to outdoors can also control the spread.

5 Conclusions

Identifying public areas and related activities leading to a higher risk of infection helps formulate containment strategies. The risk assessment of these spaces requires a detailed study of activities that risks the health of the people involved since it is a disease. That is when we can take the aid of simulation, where we can model the actual activities and predict the probabilities of infection. Such a spatial risk assessment could form a solid foundation for decisions on areas to prioritize for lockdown, the number of people allowed, the activities permitted, and so on.

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Environmental Drivers of Natural Focal Diseases' Spatio-Temporal Distribution in the Russian Far East

Svetlana Malkhazova, Fedor Korennoy, Dmitry Orlov, Natalia Shartova, Galina Surkova, and Igor Vladimirov

Abstract

Natural focal infections present a permanent threat to human health in the forestry areas of the Russian Far East along the Sino-Russian border. The incidence of diseases and its pathogens' range may vary due to changes of climate, land cover and anthropogenic activity. The objective of this study is to model and analyze the distribution of select environment-related diseases' incidence with regard to various climatic, landscape and socio-demographic factors. The following tick-borne and rodent-borne diseases were considered: tick-borne encephalitis, tick-borne borrelioses (Lyme disease), tick-borne rickettsiosis and Hantavirus hemorrhagic fever with renal syndrome (HFRS). The study region includes four entities of the Russian Federation bordering China (namely Amur region, Zabaikalsky and Khabarovsk krais and Jewish autonomous oblast). Disease incidence data at the municipality level, as well as exact locations of pathogens' registration for the period 2004–2020 were obtained from official sources. For revealing the disease incidence change patterns, mathematical-geographical techniques of Forest Based Classification and Regression, and Ecological Niche modeling were applied. The special climatic indicators calculated according to the data of Russian Research Institute of Hydrometeorological Information—World Data Center (RIHMI-WDC), as well as ERA-Interim atmospheric reanalysis data were used among the other environmental factors. The modeling results demonstrated a stronger effect of landscape and socio-economic indicators on the observed distribution of the study diseases' incidence than of climatic factors. In particular, the relationship between the diversity of land cover, the level of socio-economic development of municipalities and the level of incidence of modeled diseases was revealed. For HFRS, an increased favorability of the southern study area coincides with grass and crop classification types of land cover. This could indicate the conditions for rodent habitat and reproduction including the connection with food sources.

Keywords

Climate factors · Far East · Natural focal diseases · Ecological niche · Landscape factors

1 Introduction

Natural focal diseases circulate in nature independently of human presence and are caused by agents linked to specific landscapes, presenting a permanent threat to population in forestry areas of Russian Far East along Sino-Russian border (Busani et al. 2016; Malkhazova et al. 2014). The region is characterized by a pronounced heterogeneity of socio-economic, landscape and climatic conditions, as well as population density.

Despite the average annual incidence of focal tick borne infections in humans does not exceed 10 cases per 100,000 population, a trend of its increase is obvious. Hantavirus hemorrhagic fever with renal syndrome demonstrates similar incidence rates, but results in up to 20% lethality rates due to high virulence in the study region.

Various environmental and socio-economic factors play an important role in shaping the disease agents' range as well in providing conditions for human-agent interface (Zhang et al. 2023; Kjær et al. 2023). In this study, we focused on revealing potential relationships between the

S. Malkhazova (✉) · D. Orlov · N. Shartova · G. Surkova · I. Vladimirov
Lomonosov Moscow State University, Moscow, Russia

F. Korennoy
Federal Center for Animal Health (FGBI ARRIAH), Vladimir, Russia

N. Shartova
HSE University, Moscow, Russia

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epidemic indicators of some tick-borne and rodent-borne human diseases and a set of potential predictors within the study area.

2 Material and Methods

The diseases under study were: Tick-Borne Encephalitis (TBE), Tick-Borne Borrelioses or Lyme Disease (LD), Tick-Borne Rickettsiosis (TBR) and Hantavirus Hemorrhagic Fever with Renal Syndrome (HFRS).

For TBE, LD and TBR, the study area comprises four entities of the Russian Far East, namely: Amur oblast, Zabaikalsky and Khabarovsk Krais and Jewish autonomous oblast (Fig. 1A). Disease incidence data as averaged number of cases per 100,000 population (2016–2020) were connected to the second-level administrative divisions (districts or 'raions'), which were the study units in our analysis ($n = 83$). For HFRS, we focused on the Jewish autonomous oblast (JAO, Fig. 1b), for which the exact locations of human infection and virus isolation in the environment for 2004–2020 were known ($n = 156$). Disease incidence data as well as the virus isolation locations were obtained from the official records of Rospotrebnadzor—The Federal Service for Surveillance on Consumer Rights Protection and Human Wellbeing (Federal Service for Surveillance on Consumer Rights Protection and Human Wellbeing Rospotrebnadzor n.d.).

To reveal relationships between the average incidence of TBE, LD, TBR and a set of potential explanatory factors, we applied a Forest-based Classification and Regression model. This is a supervised machine learning method that builds a set of decision trees using the observed values and explanatory variables in order to create a regression (Breiman 2001). The method is less sensitive to input data multicollinearity or overdispersion (Grömping 2009).

To study HFRS spatial distribution in JAO, we performed ecological niche modelling with the random forest (RF) algorithm implemented in Google Earth Engine (GEE) (Crego et al. 2022) using the HFRS detection locations as presence points (Evans et al. 2011).

As potential explanatory factors, we used a set of landscape, climatic and socio-economic variables, which may influence both tick/rodents abundance (by shaping suitable conditions for tick/rodents survival), and probability of peoples' contact with ticks/rodents (by explaining living conditions and professional proximity to open areas). During pre-processing, those variables were excluded from modeling with Variance Inflation Factor (VIF) > 10.

3 Results

3.1 TBE, LD and TBR Modeling

Modeling by Forest based Classification and Regression method demonstrated satisfactory model fit with near-random spatial distribution of residuals. The most influencing variables for TBE were Share of Close Forest and Share of Population Employed in Manufacturing, followed by Precipitation in July, Forest Height Loss, Share of Population Employed in Mining, Air Temperature for July and Precipitation in January. For LD, Share of Close Forest and Precipitation in July were the most contributing factors, followed by Precipitation in January and Share of Open Forest. For TBE, the stronger influence of LST (Land Surface Temperature) and NDVI for May, Precipitation and Air temperature for January was revealed.

Distribution of observed and modeled incidence rates is visualized by maps (Fig. 2 is provided as an example for TBR).

3.2 HFRS Modeling

The mean AUC-ROC (0.87, SD ± 0.10) and the mean AUC-PR (0.75 ± 0.10) indicated good model performance with the mean sensitivity of 0.85 ± 0.10, and the mean specificity of 0.81 ± 0.09. The greatest suitability for HFRS distribution can

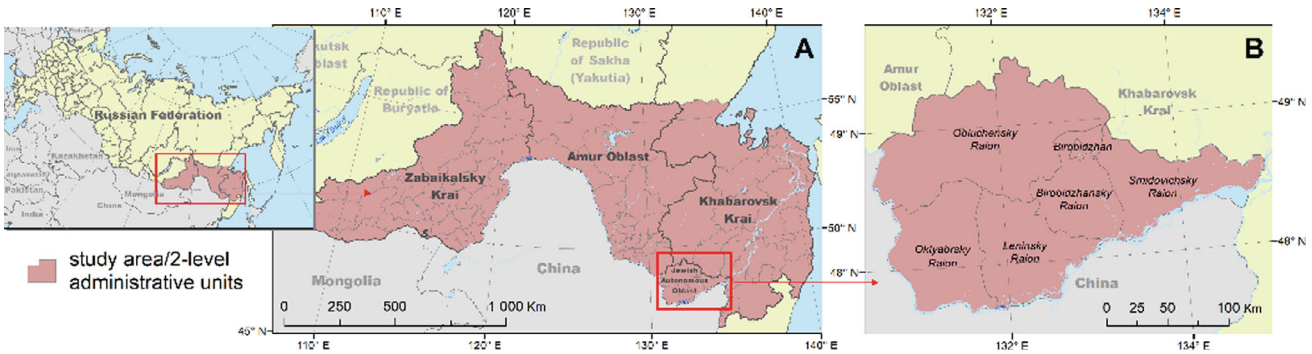


Fig. 1 **a** Study area for TBE, LD and TBR: Zabaikalsky Krai, Amur oblast, Khabarovsk Krai and Jewish autonomous oblast; **b** Study area for HFRS: Jewish autonomous oblast

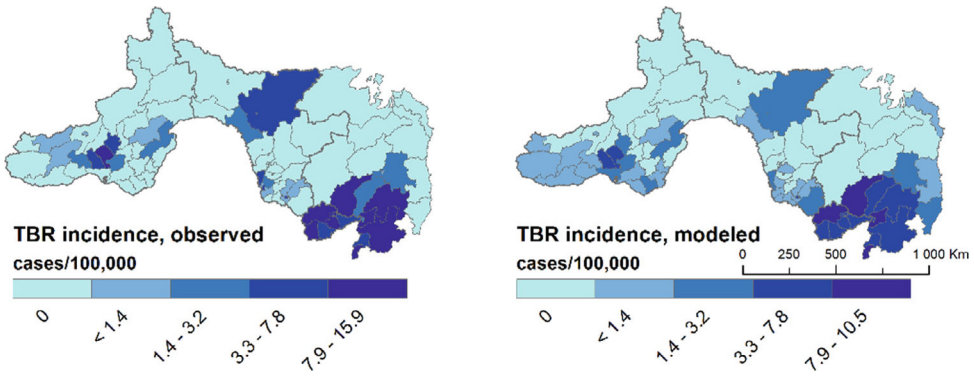


Fig. 2 Maps of observed (left) and modeled (right) Tick borne rickettsiosis incidence in the Far East of Russia

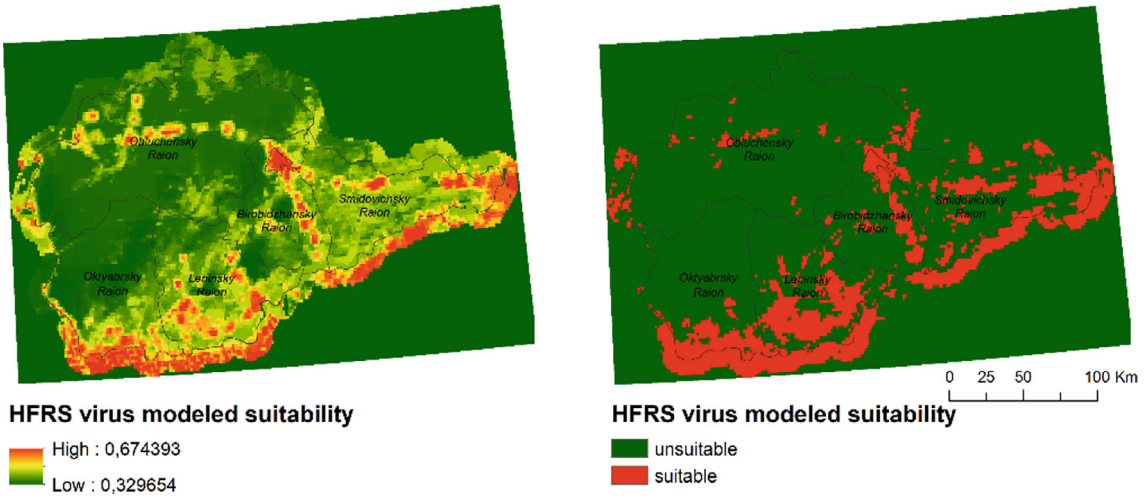


Fig. 3 Continuous (left) and binary (right) distribution of suitability of the Jewish Autonomous oblast to HFRS as per results of ecological niche modeling results

be found along rivers (Fig. 3). High suitability was apparent on the Chinese-Russian border, as well as on the border area with the Amur Oblast. Additionally, the area of Birobidzhan City was found to be highly suitable. The favorable territory also corresponds to the buffer zone beyond the administrative boundaries of the JAO (the territory of China beyond the Amur River).

4 Discussion and Conclusions

The results of three tick-borne diseases modeling suggest a weaker dependence of the observed distribution of disease incidence on climatic factors, but a more pronounced relation to landscape and socio-economic predictors. LD and TBE were found to be stronger influenced by the share of population employed in manufacturing and mining that assumes wider peoples' exposure to the environment, and thus stipulates potential contacts with ticks.

The distribution of TBR was strongly influenced by climate and landscape factors (such as LST and Precipitation), which may shape the favorable conditions for *Ixodes persulcatus*.

HFRS modeling results suggest that the most favorable territory in the south of the study area coincides with grass and crop types of land cover. This area has the highest LST values (around 25 °C) and lowest NDVI values (around 0.6). LST may has more direct influence on the abundance and distribution of rodents than air temperature. The correlation between the NDVI and HFRS distribution has been proven in many studies at different areas of China (Zhang et al. 2010; Xiao et al. 2013; Luo et al. 2022; He et al. 2019). We expect that our results will allow local healthcare authorities to develop targeted region-specific preventive measures. They will contribute to the current knowledge of natural focal diseases environmental drivers and provide a conceptual basis of solving global healthcare problems and prevention of potential expansion of disease ranges.

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Special Session: Social and Environmental Impacts of Land Use Changes in the Amazon

Enterprises in the Amazon: Sustainable Forest Management, Environmental Impacts and Social Interaction

Kely Prissila Saraiva Cordovil, Ilze Caroline Gois Braga Pedroso, Biane Silva Pontes, Lucas Vaz Peres, Janaina Vieira da Rocha, and Luciana Gonçalves de Carvalho

Abstract

This study addresses the interaction between employees-projects-communities and environment from the perspectives of two professionals from a company that works in forest management projects near traditional communities in the Amazon. This is a qualitative research with an ethnographic approach. Data collection was carried out by means of a semi-structured questionnaire in interviews with the professionals involved. During the period of the study, the company was carrying out the initial stage of a forest management project, as well as providing environmental consulting and technical assistance to this enterprise implemented around Cachoeira do Aruã, a riverside community located in the region of the Arapiuns River, 100 km from the municipality of Santarém, in western Pará. The interviews with the professionals, a forest engineer and a wood cuber (mateiro), were carried out between the months of July and December 2022. The main analysis of the interviews shows two distinct points of view: for the forest engineer, the installation of the company benefits the local community by generating jobs; for the wood cuber, the number of trees felled per project is high. The inspection and monitoring, on the part of the executing agencies of the environmental policy at the state and federal level, seek only to evaluate the amount of wood that is being exploited and the veracity of the species that are being extracted. Even with the availability of data that provides information about the Amazon, this base is little used in the search for a broad understanding that contemplates the historical process of integration of this environment, which implies in the transformations of the space and the way of life of the traditional peoples and communities that exist around these enterprises. In general, this study addresses that sustainable development is only possible when it is socially just. In the case of forest management projects and the interaction with traditional peoples and communities in the Amazon, there is a need to contemplate the ways of life so that the interpretations result in the implementation of public policies, aiming to respect the right of these populations to remain in their territories with sociocultural autonomy.

Keywords

Amazon · Conflicts · Ethnography · Traditional populations · Wood extraction

K. P. S. Cordovil (✉) · I. C. G. B. Pedroso
Doctoral Graduate Program in Society, Nature and Development, Federal University of Western Pará, Santarém, Brazil
e-mail: kely20125026@gmail.com

B. S. Pontes
Chico Mendes Institute for Biodiversity Conservation, Brasília, Brazil

L. V. Peres
Engineering and Geosciences Institute, Federal University of Western Pará, Santarém, Brazil

J. V. da Rocha
Master's Degree Program in Sustainable Development, University of Brasília, Brasília, Brazil

L. G. de Carvalho
Social Sciencies Institute, Federal University of Western Pará, Santarém, Brazil

1 Introduction

Historically, the development of the Amazon Region was linked to the expansion of productive activities, increasing forest deforestation, threatening biodiversity and changes in the structure and way of life of local populations (Prates and Bacha 2011). Sustainable forest management emerged to reduce the impacts caused by the disorderly exploitation of forest resources and also as a way to ensure that the local population had legal access to these resources (Do

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Nascimento et al. 2023). However, deforestation still persists at alarming rates, with livestock, agriculture and predatory exploitation of timber being some of the main causes of this problem (Higuchi et al. 2012).

Since the last decades of the twentieth century, a pattern of occupation in the Amazon region has been outlined that seeks economic development through the exploitation of natural resources and urbanization, often ignoring the environmental, social and cultural impacts caused by this approach. Groups such as riverine people, indigenous people, rubber tappers, quilombola populations and others who have ancestral practices of relating to nature are harmed by this occupation process, since their territories are invaded, their livelihoods are threatened and their cultures and identities are devalued (Ferreira De Souza 2023).

Given the above, this work aims to describe the functioning of sustainable forest management plans in the Lower Amazon region and the interaction between employees-projects-community and the environment from the perspective of the professional Forestry Engineer and woodsman.

2 Methods

The research area of this study are enterprises located around Cachoeira do Aruã, a riverside community located in the region of the Arapiuns river, 100 km from the municipality of Santarém, western of Pará. This is a study with an ethnographic approach. Data collection have been done through semi-structured interviews, using a voice recorder, carried out with a technician in Forestry Engineering and a woodsman employee, a wood cutter.

The interviews were carried out between June and December 2022, following the start and end schedule of the field work, obeying the closed period (art. 31 of Federal Law nº 12.651, of May 25, 2012, and art. 11 of Normative Instruction No. 05, of December 11, 2006) of the Ministry of the Environment. General and specific questions were elaborated involving the workplace and period worked, social interactions and possible environmental and social impacts caused by the implementation of projects in the region.

3 Results

3.1 Sustainable Forest Management Plan: Case Study

The company addressed in this study operates in approximately 20 regular projects, licensed as sustainable forest management with a cutting cycle of an average of 30 years and suppression for alternative land use. The work carried out in these areas demands for specific professionals to perform each function, from pre-exploratory activities (delimitation of work units, forest inventory, etc.) to exploratory activities (construction of infrastructure (roads and patios), felling, dragging, etc.).

Table 1 Positive and negative points of the activities developed in the sustainable forest management plans, according to the interviewees

Positive points	Negative points
Good remuneration	Isolation (Projects are very far from urban centers, cerca de 160 km dentro das florestas)
Possibility of growth in the company	Long time in the bush working (10 days off and 90 days on work)
Has licensed and not clandestine employment	Estrangement from the family (they complain that they miss important dates, such as their children's birthdays, for example)

The bushmen are workers who generally do not have a high level of education, and see in forest management plans alternatives to obtain income and family support. The work carried out in the enterprises is described by the interviewees as dangerous, therefore, it requires specialized technical assistance. In addition to felling and dragging trees, another point that requires attention is the storage yard, mainly due to the movement of heavy machinery and high piles of logs. Both list positive and negative points of the job (Table 1).

3.2 Social Interaction: Culture and Knowledge

The existing social interactions between the local populations and the enterprises installed in the region are, for the most part, labor related. Because they are from the region, these people are able to recognize and identify the forest species that occur in the Amazon rainforest. The reliability of the information contained in the forest inventory is important and is subject to audit by the inspection entities and/or entities responsible for licensing the enterprise.

According to the forestry engineer, the identification for checking the inventory continues to be done by project employees, which may give rise to deliberately inadequate identifications. Allied to this, the identification of the species during the inventory is done by the same person who will verify the veracity of the same during the inspection. Ideally, there would be a specialized professional during the action with the bodies responsible for licensing, making sure of the correct identification, comparing the inventory information with the species indicated on site. In this case, the ineffectiveness and lack of adequate inspection are evident,

which can contribute and/or facilitate the illegal extraction of wood.

Regarding the use of forest resources (business vs. traditional community), it was observed that where the timber industry only sees wood, traditional peoples make multiple uses of the resource (collection of food products, natural remedies, handicraft etc.). Examples of timber species used for other purposes by traditional populations are: Maçaranduba (*Manilkara* spp., Sapotaceae), which has part of its bark used for intestinal problems, andiroba (*Carapa guianensis* Aubl.) and copaiba (*Copaifera* sp.) whose oils are extracted for use in traditional medicine, and the pequiá (*Caryocar brasiliense*) whose fruit is used as food.

3.3 Environmental and Social Impacts

According to Eng. Forestry, the projects are prepared following all the guidelines and conditions required by the licensing body and that the regeneration of the area is satisfactory in terms of forest management to reduce the impact, but it is necessary to have commitment and social and environmental responsibility on the part of companies. Woodsman says that the amount of forest cut down per project is very extensive, and that he thinks deforestation is large: the feeling is according to the release, there is a project that has 3 thousand trees for felling, some 7 thousand and another 10 thousand trees for felling, all according to demand.

According to data from Terra Brasilis, of the National Institute for Space Research (INPE and TERRABRASILIS 2023), the increase in deforestation accumulated in the years 2019–2022 in the State of Pará was 18,689.51 km^2, being the state with the highest deforestation rate in the Amazon region, totaling 40.87% of the area deforested in the last 4 years.

As reported, the implementation of projects changes the way of life of people and traditional communities, because, before the installation of the projects, these people lived basically from hunting, fishing, small-scale agriculture, flour production and extraction of non-timber forest products such as copaiba, andiroba and other forestry products, and after the implementation of the projects, a new form of work and income emerges.

4 Discussion

According to information from the Brazilian Institute for the Environment and Renewable Natural Resources (Ibama), in 1999, the agency had registered around 658 forest management plan projects in the Amazon, covering an area of 17,642 km^2 (Garrido Filha 2002). The States with the highest number of projects were: Pará, with 252 (38%), in an area of 9415 km^2 (53%), and Mato Grosso, with 187 (28%), in an area of 2460 km^2 (14%). Although the number of projects is expressive, these are also the federal units that have the highest deforestation rates and the highest production of industrialized wood.

The history of occupation in the Amazon is complex and marked by different periods and strategies. Initially, a region was explored for the heritage of forest products, such as wood, medicinal plants, oils, among others. During the promising periods of gold exploration and rubber production, there was an important boost in the country's economy and in the region's development, but these moments also brought their challenges and social and environmental impacts (Ferreira De Souza 2023).

Unfortunately, the government's public actions, especially during the military government, did not take into account the environmental and social dimensions, generating a series of conflicts, mainly with the local populations (river people, indigenous people, among others). These are often considered as "archaic peoples" and "obstacles" to the development model, as they live in other historical temporalities and have ways of life influenced from productive and environmental rationales different from capitalist rationality (Do Carmo Cruz 2006).

5 Conclusions

It is understood that ecologically viable development is only possible when socially fair. In the case of traditional communities that live in the Amazon, there is a need to expand studies that favor the search for knowledge about the way of doing and living of these people and that the interpretations can result in the implementation of public policies aimed at socio-environmental sustainability, respecting the right of these populations to remain in their territories with sociocultural and political autonomy. Even the engineer of the company under study assumes that communication with people from communities surrounding forest management projects is almost non-existent and that a more sensitive look at these traditional peoples is lacking.

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The Installation of Ports as an Instrument of Business Territorialization in Santarém/PA, Brazil and Potential Impact on Fishing Resources

Wandicleia Lopes de Sousa, Elizabete de Matos Serrão, Diego Maia Zacardi, Sérgio Melo, Antônia do Socorro Pena da Gama, and Thiago Almeida Vieira

Abstract

Santarém city is considered one of the main fishing production centers in Pará state due to its diversity and natural potential. In recent years, the city has received strong pressure from the private sector through projects to implement highways/ports, hydroelectric plants and mining as an option to promote economic progress and "development" in the region, which has been causing changes in the way of life of populations and the Amazonian ecosystem. In this context, this study presents the results of several studies on fishing resources and artisanal fishing, carried out in the region where ATEM Distribuidoras de Petróleo S/A is located and around the port located on the shores of Maicá lake, and the possible impacts on artisanal fishing and fishing resources, which supported the preparation of a technical note sent to the Public Ministry. This document is the result of the materialization of reflections, concerns and actions developed in research carried out on the banks of the Amazon River, Maicá lake and Ituqui River, as well as experiences lived as facilitators and researchers with fishermen in the Lower Amazon, situations that allowed the collection of data for study, as well as contributing to the process of resistance, defense of the territory and guarantee of the rights of fishermen in the face of the State. Thus, it was found that the interaction of community members and users with the aquatic ecosystem is reflected in the process of exploring ichthyofaunistic resources, making it possible to identify seasonal patterns in their use, in the exploration of environments and in the choice of capture equipment. Thus, fishing depends on biological productivity and maintenance of the diversity of flooded areas, functioning as an indicator of the well-being of these ecosystems. In this sense, understanding this dynamic and its particularities is decisive to generate guiding strategies and actions that act in the management of fish stocks, in the conservation of exploitable resources and in the sustainability of local fisheries.

Keywords

Artisanal fishing · Fisheries resources · Impacts on fisheries · Fisheries sustainability

1 Introduction

In a scenario where the capitalist system and commercial globalization hold positions of dominant power, social and labor organizations have been coming together and resisting the changes imposed by savage capitalism on the way of life of populations and on the Amazonian ecosystem. Faced with this new reality, artisanal fishermen and fisherwomen, quilombola communities, farmers, indigenous groups, and other peoples have been forming institutional partnerships with civil society, non-governmental organizations, legal and research institutions, as well as universities in order to develop technical documents that assist them in crafting legal instruments to ensure the respect for their rights against the power of capital (Cherem and Azevedo 2016).

This document is the outcome of the embodiment of reflections, concerns, and actions carried out in the research conducted along the banks of the Amazon River, Maicá lake,

W. L. de Sousa (✉) · E. de Matos Serrão · S. Melo · T. A. Vieira
Programa de Pós-Graduação em Sociedade, Natureza e Desenvolvimento, Universidade Federal do Oeste do Pará, Santarém, Brazil
e-mail: wandicleia@hotmail.com

D. M. Zacardi
Laboratório de Ecologia do Ictioplâncton e Pesca em Águas Interiores, Instituto de Ciências e Tecnologia das Águas, Universidade Federal do Oeste do Pará, Santarém, Brazil

A. do Socorro Pena da Gama
Instituto de Ciências da Sociedade, Universidade Federal do Oeste do Pará, Santarém, Brazil

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and Ituqui River. Additionally, it draws from experiences lived as facilitators and researchers alongside fishermen and fisherwomen in the Lower Amazon. These situations have enabled us to gather data for study, as well as to contribute to the process of resistance, territorial defense, and the assurance of fishermen's rights vis-à-vis the State. These data have contributed to the empowerment of fishermen and fisherwomen in defending their territories. In fact, a portion of this material has supported the creation of a technical note for community discussions with the Public Ministry of Pará State.

In this way, this study aims to present the outcomes of several academic research endeavors concerning fishing resources and artisanal fishing activities conducted in the vicinity of implementation and around the port of ATEM'S Distribuidoras de Petróleo S/A.

2 Methodology

The study's methodology encompassed bibliographic research, incorporating various studies related to fishing resources and artisanal fishing activities conducted in the vicinity of implementation and around the port of ATEM'S Distribuidoras de Petróleo S/A. The advantage of bibliographic research lies precisely in enabling the researcher to encompass a wide range of phenomena in a much broader manner (Gil 1990).

3 Results and Discussion

3.1 Fishing Dynamics in the Installation Area of Atem's Port

Santarém city is considered one of the main hubs of fishing production in the state due to its existing diversity and natural potential. It encompasses an extensive floodplain region and has its primary trade connections with the capitals Manaus and Belém (Isaac 2008). In recent years, the municipality has faced significant pressure from the private sector through projects for the installation of Roads/Ports, Hydroelectric Plants, and Mining, all aimed at promoting economic progress and "development" in the region.

Among the proposals is the establishment of a Grain Port on the shores of Maicá lake, planned by the agribusiness group to facilitate the production and circulation of soybeans and corn from the Brazilian Midwest to the foreign trade (Silva 2014). This proposal was conceived without conducting an Environmental Impact Assessment and with an Environmental Impact Report that omits the presence of traditional communities (fishermen, quilombolas, and indigenous people) within the territory encompassing Maicá lake. As a result, a legal process is currently underway in federal court.

The geographic area where ATEM'S Port is located encompasses the vicinity of Maicá lake and the various territories historically inhabited by quilombola communities, indigenous peoples, and artisanal fishermen (Fig. 1). Approximately 1.7–8.2 km from the construction site of the enterprise, there are the quilombola communities Pérola do Maicá, Arapemã, and Saracura, as well as Maria Valentina and Bom Jardim, situated approximately 12.2 km and 14.4 km away from the mentioned construction. Within this area, there is also the Munduruku indigenous people of Planalto Santareno. Additionally, throughout the entire territory, there are fishermen and fisherwomen, particularly those involved in shrimp and aviú fishing, whose way of life is deeply connected to the environment they inhabit. These distances did not adhere to the guidelines stipulated in Interministerial Ordinance No. 60/2015, which provides guidance on the presumed impacts of port projects.

The regional shrimp, also known as Amazon River shrimp, *Macrobrachium amazonicum*, (Palaemonidae), and the aviú or avium, *Acetes paraguayensis* (Sergestidae) are the two most exploited species of freshwater shrimp year-round in the region. They are highly favored by the population and are sold in local markets and fairs (Coelho et al. 2020; Lima and Montagner 2014). The specific fishing for these organisms is artisanal and small-scale, characterized by family labor. It takes place along the entire marginal zone of the Amazon River and adjacent floodplain areas (channels and lakes). Fishing spots are located along the Uruará neighborhood waterfront (urban area of Santarém), extending to the Paraná do Ituqui, areas subject to periodic flooding from the Amazon River. The fishing is carried out using a device called "matapi," which is a semi-fixed trap handmade by the fishermen themselves and does not have a standard size (Lima and Montagner 2014).

Fishermen already mention that the shrimp fishing situation has been deteriorating over the years, mainly due to increased competition, resulting in lost job opportunities and signs of declining natural stocks caused by the growing fishing effort and environmental changes observed in the region (Lima and Montagner 2014). Consequently, the surrounding communities and fishermen are among the primary stakeholders potentially affected by the port development.

The commercialization of these products mainly takes place at a market known as "Porto dos Milagres," in front of their own homes, and along the streets of the Uruará neighborhood. However, several mentioned that they also supply their products to specialized stores such as "Casa do Camarão," as well as to communities and head-

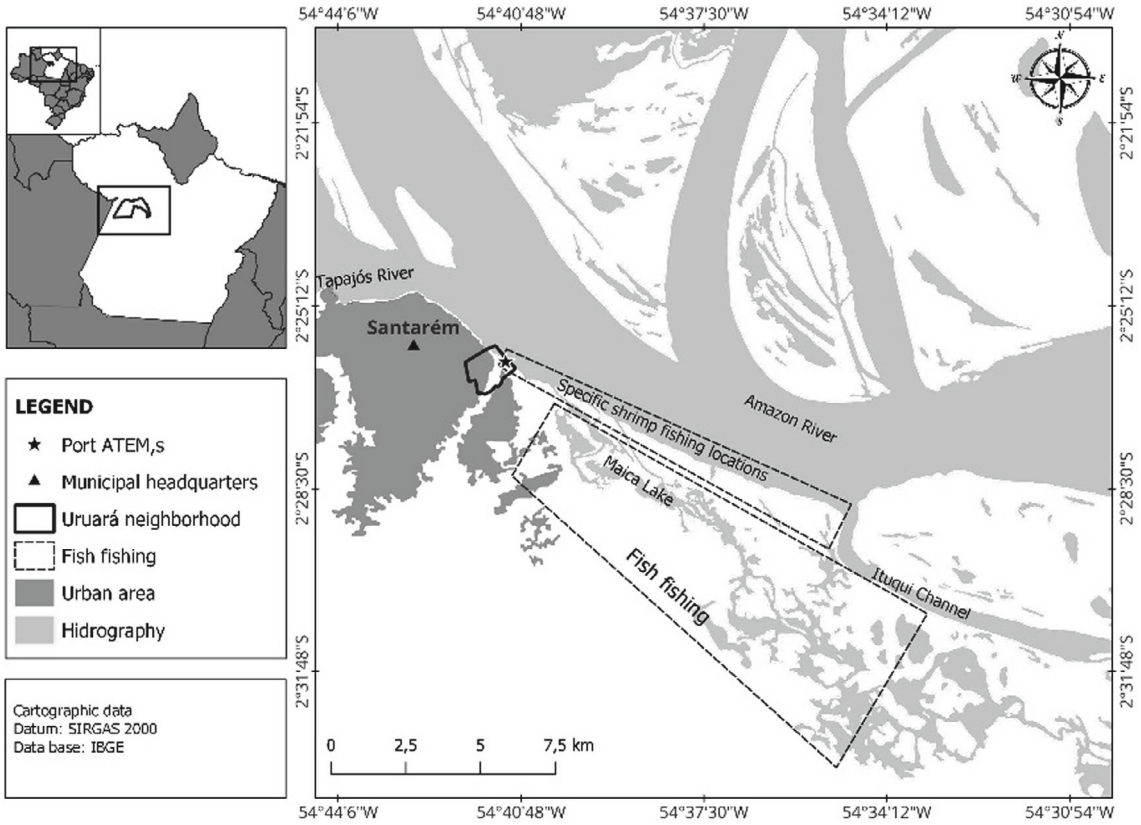


Fig. 1 Location of Santarém city (PA), ATEM'S port facility, with emphasis on the specific areas for shrimp and fish fishing around the port

quarters of other municipalities in the region (Lima and Montagner 2014). Consequently, any alteration or impact on this activity could affect not only the fishermen and consumers within the locality but also have repercussions throughout the Lower Amazon region.

In general, artisanal fishing in the Lower Amazon (PA) is characterized by its familial nature, conducted on a small and medium scale, shared and lived on a daily basis. It encompasses knowledge, wisdom, and cultural codes that are passed down from generation to generation. It's worth noting that fishing contributes to the social and economic development of fishermen (Nascimento and Guerra 2016; Feitosa et al. 2018), serving as a significant income and subsistence source for numerous families. Additionally, it, along with other Amazonian products, ensures a rich, nutritious, and high-quality diet, playing a pivotal role in the diet of artisanal fishermen and riverside communities.

The interaction of community members and users with the aquatic ecosystem is reflected in the process of exploiting ichthyofaunal resources. It's possible to identify seasonal patterns in their use, the exploration of environments, and the selection of capture devices. Fishing relies on biological productivity and the maintenance of diversity in flooded areas, serving as an indicator of the well-being of these ecosystems.

4 Considerations

Artisanal fishing conducted in the Santarém region is complex, involving multiple species, various fishing tools, and seasonal patterns. It targets dozens of species, much like in other regions of the Amazon. It serves as one of the primary sources of employment, food, and income, highlighting the significant role of fishing in the regional economy. This economic activity is directly linked to the dynamics of the environment and the way of life of traditional human populations living along various urban and peri-urban water bodies. In this regard, comprehending this dynamic and its intricacies is crucial for devising guiding strategies and actions that contribute to the management of fish stocks, the preservation of exploitable resources, and the sustainability of local fishing.

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Supporting the Formalization of Informal Microenterprises in Their Entrepreneurial Ecosystem

El hassania Rahou, Mouna Hajjaj, and Ahmed Taqi

Abstract

Context/Purpose: Informality is prevalent in developing countries, particularly among microenterprises. However, this informality can yield detrimental effects on economic growth, job creation, and access to formal financial services for these microenterprises. The aim of this article is to investigate the challenges related to the formalization of informal microenterprises and to propose an approach to streamline this process within their entrepreneurial ecosystem. *Methods*: The article takes a quantitative approach, focusing on 500 informal microentrepreneurs in northern Morocco, selected carefully through purposive and convenience sampling. Using a logistic regression model, the study examines how different forms of support impact the registration of these microentrepreneurs, aiming to uncover meaningful connections. Data is gathered in person from the participants and analyzed using the open-source tool R. *Results*: The study discovers that informal microenterprises are more likely to formalize when exposed to different types of support. Additionally, leveraging various forms of entrepreneurial aid allows entrepreneurs to not only aid environmental conservation but also establish sustainable and successful business models. *Interpretation*: The results indicate that offering diverse support and accompanying structures is crucial in motivating informal microenterprises to transition towards formalization. This emphasizes the importance of stakeholders such as governments, financial institutions, and civil society organizations in facilitating the formalization process. *Conclusion*: The findings highlight the essential role of stakeholder collaboration in aiding the formalization of informal microenterprises. This collaboration could have a positive effect on economic growth and job generation in developing nations. To achieve this, policies should address both internal business factors and external environmental influences.

Keywords

Informal microenterprises · Formalization · Entrepreneurial ecosystem · Forms and structures of support · Stakeholders

1 Introduction

In many corners of the world, informal microenterprises constitute the backbone of the economy, making a significant contribution to job creation and income generation. However, despite their vital role, these microenterprises often exist on the fringes of the formal system, lacking access to the benefits and opportunities provided by regulated structures and services. According to McKenzie (2015) and Philippart (2017), support through appropriate guidance conditions the formalization of informal activities and alleviates the fears or concerns of informal microentrepreneurs regarding administrative processes. For these authors, guidance materializes through awareness campaigns and information dissemination about the advantages of formalization and the benefits of statuses (taxation and financing), along with overseeing the formalization procedures. Manifesting in various forms or practices such as counseling, coaching, sponsoring, mentoring, tutoring, advising, or consultancy, guidance is a comprehensive concept that emerges at the intersection of diverse logics: educating, teaching, aiding, advising, and even governing (Siegel 2006).

E. Rahou (✉) · M. Hajjaj
LRMD, Faculty of Economics and Management, Hassan First University of Settat, Settat, Morocco
e-mail: elhassania.rahou@uhp.ac.ma

A. Taqi
Faculty of Legal, Economic and Social Sciences of Tetouan, Abdelmalek Essaâdi University, Tétouan, Morocco

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Indeed, receiving guidance enables informal entrepreneurs to overcome the obstacles impeding their formalization, as both dedicated and non-dedicated support structures provide them with tangible resources and relational assets (Chabaud 2006; Sammut 2008). Consequently, the practices of guidance prove indispensable, as accompanied enterprises appear to outperform their unaccompanied counterparts (Chrisman and McMullan 2004). The challenge of formalizing these informal microenterprises resides at the core of economic and societal concerns, as it encompasses not only reinforcing their growth and viability but also expanding the foundations of a sustainable and balanced economy. Hence, by harnessing diverse forms of entrepreneurial support, businesses and entrepreneurs can significantly contribute to environmental preservation while developing models of enduring and prosperous business. In this article, we explore the challenges inherent in this intricate process and outline innovative approaches to steer these microenterprises towards formality within their ecosystem.

2 Methods

2.1 Context and Design

Limited research on guidance confirms a positive connection between guidance and business sustainability (Nkakleu et al. 2013; Sammut 2008), along with a beneficial impact of entrepreneurial guidance on the formalization of informal businesses. This article adopts a quantitative approach to gain valuable insights into how a particular entrepreneurial environment affects the formalization of informal microenterprises.

2.2 Settings and Participants

The study includes 500 informal microentrepreneurs located in northern Morocco. The use of both purposive and convenience sampling techniques aids in accurately selecting sample elements and adhering to research criteria, such as homogeneity. To further investigate how different support structures motivate informal microentrepreneurs to register, the study employs a logistic regression model. The objective is to uncover meaningful relationships and identify significant associations in this context.

2.3 Data Collection and Analysis

For our study, we conducted a survey involving 500 informal microentrepreneurs. We personally distributed the questionnaires to the surveyed entrepreneurs and collected them individually once completed. The survey spanned approximately 6 months.

In addition to the data obtained through the questionnaires, we also established contacts and conducted interviews with representatives from public and/or private organizations such as ANAPEC, the Chamber of Commerce and Industry, the Regional Investment Center and microcredit associations.

By utilizing the Open source R tool, we were able to implement the binomial logistic regression model, estimate the model parameters, and conduct statistical tests to assess the significance of the independent variables. Furthermore, we generated tables that aided in presenting the results in a precise and easily interpretable manner.

3 Results

3.1 Empirical Findings

We employed the Open source tool R to analyze the impact of guidance practices on the transition of informal microenterprises to formal entrepreneurial status. The findings are summarized in Table 1, showing coefficient values in the third column associated with each explanatory variable category, referred to as "Estimate." The sign of these coefficients signifies whether the explanatory variable positively or negatively affects the phenomenon. To validate the individual significance of each coefficient, we assessed the related probabilities (P-value) at a 5% significance level.

The statistical model shows that all variables have a highly significant influence (P-value < 0.05). Consequently, from the role of variable S4Q101 (Undergoing guidance actions) in the model, it can be deduced that microentrepreneurs who have received guidance are the most inclined to transition towards formal entrepreneurship.

Considering variable S4Q102 (Type of guidance: non-dedicated structures), the model effectively assesses the impact of guidance forms that actively contribute to microenterprise formalization. These forms are ranked by positive Estimates: Activity Monitoring, Networking, Advice, Registration Assistance, Financing Assistance, Information, and Trainings.

Table 1 Values and significance for the "guidance practices" variable

Variables	Modality	Estimate (coefficient)	Std. error	*z*-value	*P*-value
S4Q101	Accompanying action	7.704e + 14	1.405e + 07	54,840,095	< 2e − 16
S4Q102_1	Advice	5.840e + 15	8.371e + 07	69,769,309	< 2e − 16
S4Q102_2	Informations	5.524e + 15	8.438e + 07	65,463,103	< 2e − 16
S4Q102_3	Trainings	5.107e + 15	8.412e + 07	60,714,392	< 2e −1 6
S4Q102_4	Making contact	6.023e + 15	8.661e + 07	69,540,813	< 2e − 16
S4Q102_5	Registration assistance	5.840e + 15	8.495e + 07	68,744,935	< 2e − 16
S4Q102_6	Financing assistance	5.709e + 15	7.926e + 07	72,032,960	< 2e − 16
S4Q102_7	Activity monitoring	7.031e + 15	1.007e + 08	69,831,856	< 2e − 16
S4Q103_1	Family/Friends	5.120e + 15	7.355e + 07	69,608,419	< 2e − 16
S4Q103_2	Credit institution	5.733e + 15	7.250e + 07	79,071,187	< 2e − 16
S4Q103_3	Incubator/Nursery	4.066e + 15	7.332e + 07	55,457,562	< 2e − 16
S4Q103_4	State	7.174e + 15	7.404e + 07	96,895,658	< 2e − 16
S4Q103_5	Associations	7.150e + 15	7.630e + 07	93,701,748	< 2e − 16

Source Authors' compilation based on Open Source R

In terms of variable S4Q103 (Guidance structure: dedicated structures), the model evaluates the effectiveness of guidance systems that play an active role in microenterprise formalization. These structures are ranked based on positive Estimates: Government, Associations, Credit Institutions, Family/Friends, and Incubator/Nursery.

4 Discussion

In conclusion, guidance practices and specialized structures play a positive role in influencing microentrepreneurs' willingness to formalize their operations. Notably, guidance from dedicated entities like ANAPEC, the Chamber of Commerce, financial institutions, incubators, and Regional Investment Centers has a substantial impact, effectively aiding the shift from the informal to formal sectors.

The assistance provided by these entities aids operators in improving project management and broadening their social connections. This corresponds to the viewpoint of Mckenzie et al. (2016), which advocates for supportive guidance encompassing entrepreneurial training, activity oversight, financing aid, and more. Likewise, our estimations highlight the substantial significance of guidance from family and associations, categorized as "non-dedicated structures." This analysis underscores the crucial role of internal social networks' social capital in influencing informal microentrepreneurs' inclination to transition to the formal sector.

To address issues of management or compliance with regulations, informal entrepreneurs heavily rely on their entrepreneurial skills and draw closer to their professional circles as well as family, especially in the domains of marketing, human resource management, registration assistance, and sales forecasting. We conclude that both types of guidance structures contribute nearly equally to incentivizing formalization.

Our study further confirms that microentrepreneurs who have received activity monitoring or networking support (especially from influential individuals) are more likely to formalize. The obtained estimates indicate that the link between these two variables and the dependent variable presents coefficients with values that can be considered satisfactory (7.031e + 15; 6.023e + 15 and $p < 0.05$); the regression coefficients are significant at the 5% level. This aligns with the work of Mouko (2015), suggesting that entrepreneurs make formalization choices considering the influence of societal signals emanating from various social or business networks they are embedded in. Hence, it would be important for each informal entrepreneur to expand their relational network, particularly by connecting with individuals of high socio-economic status.

5 Conclusions

The results obtained in this study have led to policy recommendations aimed at reducing obstacles to simplify entrepreneurship in the informal sector. Different policies should be formulated while considering both internal factors of the enterprise and factors related to its external environment. Thus, entrepreneurial support in the environmental domain plays a pivotal role in fostering sustainable, innovative, and environmentally-respectful initiatives. This can be achieved through the establishment of incubators and accelerators, access to green financing, expert mentoring in the field, etc.

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The Entrepreneurial Ecosystem and the Blended Value Creation: A Configurational View in Knowledge-Intensive Entrepreneurship

Nágela Bianca do Prado,
Gustavo Hermínio Salati Marcondes de Moraes,
and Bruno Brandão Fischer

Abstract

The article aims to unravel how the entrepreneurial ecosystem's elements can be configured to generate high levels of blended value creation in knowledge-intensive entrepreneurial (KIE) firms. Our empirical scenario involves 284 firms that had projects approved between 2020 and 2023 for the Innovative Research in Small Businesses (PIPE) Program in Brazil. This initiative is managed by the São Paulo Research Foundation, and emulates the Small Business Innovation Research program in the United States. Ecosystem indicators were obtained from the Entrepreneurial Cities Index, a dataset made available by the Brazilian government in partnership with Endeavor, a global NGO. Data comprehends indicators of the regulatory environment, infrastructure, market, financial resources, human capital, culture, and innovation. We used longitudinal data to consistently assess the ecosystem's dynamics, thus considering the four-year indicators' averages (2020–2023). The blended value creation indicators were generated from the available detailed description of the PIPE projects. Four researchers specializing in the subject evaluated the projects and gave a score for the economic, social, and environmental dimensions. The center of area defuzzification method was used to group the scores and form the blended value creation score. The analysis used the fuzzy-set Qualitative Comparative Analysis, considering the blended value creation as the outcome and the ecosystem indicators as causal conditions. The configurational approach presented six paths with adequate solution consistency and coverage. Results highlighted the market and innovation as core causal conditions in most paths. Surprisingly, the absence of the regulatory environment and human capital also appeared as core causal contribution conditions. Analyses indicate that the creation of social and environmental value, as well as economic value, are only loosely attached to several of the main pillars of entrepreneurial ecosystems. This evidence suggests that thriving ecosystems may be more oriented towards fomenting new businesses that generate market impacts without much concern for social and environmental value. Hence, our contribution brings forward a potential mismatch between the dominant logic of entrepreneurial ecosystems and the challenges associated with Sustainable Development Goals. Findings contribute to policymaking processes that seek to further connect the promotion of KIE with environmentally sustainable transitions in entrepreneurial ecosystems.

Keywords

Entrepreneurial ecosystem · Value creation · Knowledge-intensive entrepreneurship · Sustainability · Sustainable Development Goals

1 Introduction

The spatial distribution of the Entrepreneurial Ecosystem (EE) engenders path-dependent trajectories, wherein proximity facilitates the exchange of knowledge, ideas, and capabilities. Consequently, Knowledge-Intensive Entrepreneurship (KIE) emerges within this context. KIE is an entrepreneurial modality in which knowledge is used, transformed, and generated to create innovation within a venture (Malerba and McKelvey 2020). Indeed, knowledge-intensive entrepreneurs are considered central actors in solving the

N. B. do Prado · G. H. S. M. de Moraes (✉) · B. B. Fischer
School of Applied Sciences, University of Campinas, Limeira, Brazil
e-mail: salati@unicamp.br

G. H. S. M. de Moraes · B. B. Fischer
National Research University Higher School of Economics, Moscow, Russia

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grand challenges the world faces. They have focused on Blended Value Creation (BVC), where businesses aim to combine both social, environmental, and commercial missions to enhance competitive behavior and efficiency (Kummitha 2022). The BVC concept is aligned with Sustainable Development Goals (SDGs).

Scholars point out that BVC requires research, especially regarding definition and theory. At the same time, sustainability issues in EE remain understudied (Bischoff 2021). Similarly, KIE literature has grown without explicitly focusing on sustainability (Alves et al. 2021). Relating to BVC, it is a complex phenomenon in which ventures need to experience both internal and external challenges in order to lead to hybrid missions (Kummitha 2022). Gaining a strategic understanding of the distinct interplay, characteristics, and trajectories of key drivers within entrepreneurial ecosystems has become a crucial aspect of the ongoing discourse.

Studying ecosystem themes can bring several practical contributions. Ecosystem services can offer significant insights into spatial planning practices, as empirically demonstrated by Longato et al. (2021). In the same way, it can base decisions regarding land at risk of degradation, as argued by Hernández and Camerin (2023), in which research provided a method for public policies to enable guidelines and regulations for more ecosystem-based decisions for spatial planning tools. Thus, we build on the proposition that different ecosystem configurations lead to a higher density of knowledge-intensive entrepreneurs dedicated to BVC.

2 Methods

This article used fuzzy-set Qualitative Comparative Analysis (fsQCA). The empirical scenario involves 317 firms that had projects approved between 2020 and 2023 for the Innovative Research in Small Businesses (PIPE) Program in Brazil. Ecosystem indicators were obtained from the Entrepreneurial Cities Index, a dataset made available by the Brazilian government in partnership with Endeavor, a global NGO. Data comprehends indicators of the regulatory environment, infrastructure, market, financial resources, human capital, culture, and innovation. We used longitudinal data (2020–2023) to consistently assess the ecosystem's dynamics.

BVC indicators were generated from the available detailed description of the PIPE projects. Four researchers specializing in the subject evaluated the projects and gave a score for the economic, social, and environmental dimensions. The Center of Area (CoA) defuzzification method was used to group the scores and form the BVC score. In the CoA defuzzification method, to estimate the spreads of fuzzy numbers, we use information about the mean deviation of a fuzzy number.

Finally, we used the BVC score generated for each of the 317 firms and calculated the average BVC for each city in the sample so that the unit of analysis would be the same. Thus, we used BVC as an outcome and the EE indicators as causal conditions.

3 Results

To use fsQCA, the original data encompassing the conditions and outcomes were transformed to obtain fuzzy membership scores. To perform the calibration, we used the percentile method. As the data are asymmetric, we used values of 80%, 50%, and 20% as thresholds for full membership, crossover point, and non-membership, respectively.

Subsequently, the necessary conditions were tested for the sample before analyzing the sufficient conditions. Findings indicate that no condition can be considered necessary for achieving high levels of BVC. A truth table algorithm based on the calibrated fuzzy scores was employed to organize the sufficient configurations for the outcome and eliminate the remaining configurations. A minimum consistency cut-off point of 0.8 was followed, and cases that do not meet the criteria were excluded (Fiss 2011).

Table 1 displays the intermediate solution, identifying the central and contributing causal conditions for each path. The categorization of conditions as central or contributing was determined through a counterfactual analysis facilitated by the three different solutions generated (complex, parsimonious, and intermediate solutions) (Fiss 2011). Conditions present in the parsimonious solution were designated as central conditions, while those appearing exclusively in the intermediate solution were contributing conditions.

The configurational approach presented six paths with adequate solution consistency and coverage. The first path presents absent core or contributing conditions for all ecosystem elements except the market. The second path has the presence of market, innovation, and culture. The third path has the presence of financial resources and culture. The fourth path has the presence of infrastructure, market, and financial resources. The fifth path has the presence of all elements, with the absence of only the regulatory environment and culture. Finally, the sixth path has the presence of all elements, with the absence of only human capital and the absence of infrastructure.

After creating the truth table algorithm to test for robustness, we changed the minimum consistency cutoff to 0.60 from 0.80 and removed cases that did not qualify for the

Table 1 Configurational paths for high levels of BVC

Condition	Path1	Path2	Path 3	Path4	Path5	Path6
REG	○	○	○	○	○	●
INF	○		○	●	●	●
MKT		●	○	●	●	●
FIN	○	○	●	●	●	●
IN	○	●	○	○	●	●
HC	○	○	○	○	●	○
CUL	○	●	●	○	○	●
Raw coverage	0.188	0.181	0.115	0.081	0.120	0.161
Unique coverage	0.124	0.115	0.060	0.023	0.071	0.123
Consistency	0.815	0.869	0.882	0.958	0.918	0.786
Solution coverage	0.620					
Solution consistency	0.833					

REG regulatory environment, *INF* infrastructure, *MKT*: market, *FIN* financial resources, *IN* innovation, *HC* human capital, *CUL* culture

● = core causal contributing condition (present); ○ = core causal contributing condition (absent); ● = contributing causal conditions (present); ○ = contributing causal conditions (absent)

configurations (Fiss 2011). We then compute a standard analysis, and the results show no difference from the original one, demonstrating robustness in the obtained configurations.

4 Discussion

According to the results of the configurational approach of EE's elements, six paths with adequate solution consistency and coverage emerge. Results showed no indicator as a necessary condition but highlighted the market in four paths, being a core condition in three of them, and innovation as a core causal condition in three paths. Financial resources appear in four paths but as a contribution condition.

The market is responsible for creating demands, especially social and environmental demands, to be attended by entrepreneurs (Zhao et al. 2023). Innovation appeared as a driving force in the EE for BVC. Our results confirm that innovation is a relevant resource for the KIE (Fischer et al. 2018). Results indicate that financial resources are crucial in encouraging KIE to generate BVC by providing the necessary capital.

Surprisingly, the absence of the regulatory environment and human capital also appeared as a core condition in four paths. These results bring some novel elements to the debate on the association between EE, KIE and BVC. Likewise, human capital could be a better determinant for BVC, as it just appeared in one path. It is contrary to the literature that considers human capital as a key element to entrepreneurial success, as it implies high levels of individual knowledge (Zhao et al. 2023). This result was not expected in the context of KIE firms, where knowledge is at the core of a business strategy (Fischer et al. 2018).

Finally, like previous studies, EEs oriented to the BVC are context-specific (Bischoff 2021). It means that heterogeneous combinations of elements can create thriving environments for BVC (Alves et al. 2021). The results point to a substantial limitation in the association between EE and the generation of BVC by entrepreneurs. There are many conditions whose absence is associated with BVC, which is contrary to the literature that indicated EEs as a catalyst for entrepreneurial activity and, subsequently, regional economic development (Bischoff 2021).

5 Conclusions

Drawing on city-level data from the State of São Paulo, we could offer an understanding of configurations that lead to higher levels of BVC within the relatively unexplored context. Our study addresses theoretical, practical, and social implications. Theoretically, we contribute to the discussion involving EE and BVC in KIE in a developing economy. We advanced in a gap in the literature on how knowledge-intensive entrepreneurs create BVC with their ventures. Analyses with an asymmetric technique (fsQCA) allowed a more nuanced view on how KIE can use different combinations of ecosystem elements to generate BVC, and also on what are the main elements of the EE that cut across the configurations and represent the main pillars for the BVC.

Regarding managerial contributions, what is intriguing is the possibility that KIEs can result in BVC without the need

for various elements of the EE, especially in the absence of a regulatory environment and human capital. Concerning the regulatory framework, while it may not be imperative for BVC, managers can capitalize on governmental initiatives, programs, and projects that favor small enterprises with environmental and social significance, a trend that has recently gained momentum. Socially, understanding different EE configurations that influence the development of local entrepreneurship, which generates social and environmental value, becomes essential to learn how public policymakers can encourage the growth of EEs and stimulate the creation and success of new companies, resulting in economic growth and job creation, but also the creation of social and environmental value.

The results also demonstrate the clear disconnection of some EE pillars in generating BVC (e.g., regulatory environment, human capital, and culture). Such conditions highlight the inadequacy of traditional EE structures to foster BVC in KIE firms, as per our sample. This calls for attention from policymakers and other EE orchestrators in order to steer configurations toward sustainable transitions.

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Environmental Issues Addressed by Knowledge-Intensive Ecological Business: A Critical Analysis in a Developing Country

Nágela Bianca do Prado
and Gustavo Hermínio Salati Marcondes de Moraes

Abstract

Green entrepreneurship, also known as eco entrepreneurship or sustainable entrepreneurship, has emerged as a significant driver of sustainable change in economic systems. By integrating environmental sustainability into their entrepreneurial activities, green entrepreneurs take on the responsibility of assessing the social, environmental, and economic implications of their business decisions while ensuring the satisfaction of their current needs without jeopardizing the living conditions of future generations. This approach recognizes entrepreneurship as a viable means of mitigating contemporary socio-environmental problems and contributing to Sustainable Development Goals (SDGs). The efficacy of green entrepreneurship in driving sustainable change is significantly enhanced when it becomes knowledge-intensive, with an enhanced capacity to launch innovative products, processes, and services. Against this backdrop, this study aims to examine the environmental issues addressed by knowledge-intensive ecological businesses in a developing country. Our empirical analysis involves a sample composed of 284 firms with approved projects between 2020 and 2023 under Brazil's Innovative Research in Small Businesses Program (PIPE), managed by the São Paulo Research Foundation (FAPESP), an initiative analogous to the Small Business Innovation Research (SBIR) program in the United States. The classification of ecological business was conducted by four sustainability-oriented researchers based on a detailed description offered by the projects. Of the 284 firms, 66 were classified as green. Projects content analysis revealed that the main issues addressed were related to: (i) natural resources, agriculture, and the environment, with 53 projects (80%); (ii) remote sensing for environmental monitoring and management, with six projects (9%); (iii) smart technologies for environmentally friendly energy production, with four firms (6%); and (iv) sustainable management of the urban environment, with only three companies (5%). Results highlight a predominance of businesses operating in the agriculture sector, a critical area in Brazil. The evidence suggests that initiatives such as PIPE, which provides public funds to companies, can be leveraged to foster the creation of new businesses that employ cutting-edge technologies to address environmental issues effectively. Our findings contribute to the policymaking process to promote the connection between knowledge-intensive ecological entrepreneurship and environmentally sustainable transitions in developing countries while addressing SDGs challenges.

Keywords

Environmental issues · Knowledge-intensive ecological business · Green entrepreneurship · Sustainable Development Goals · Sustainable change

1 Introduction

Green entrepreneurship, also known as eco entrepreneurship or sustainable entrepreneurship, has emerged as an important driver of sustainable change in economic systems (Gast et al. 2017; Prado et al. 2022). By integrating environmental sustainability into their business activities, green entrepreneurs assume responsibility for assessing the social, environmental, and economic implications of their business decisions, ensuring that their current needs are met without compromising the living conditions of future generations. This approach recognizes entrepreneurship as a means of mitigating contemporary socio-environmental problems and contributing to the Sustainable Development Goals (SDGs) (Horne et al. 2020).

N. B. do Prado · G. H. S. M. de Moraes (✉)
School of Applied Sciences, University of Campinas, Limeira, Brazil
e-mail: salati@unicamp.br

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The effectiveness of green entrepreneurship in driving sustainable change increases significantly when it becomes knowledge-intensive, with an enhanced ability to launch innovative products, processes, and services (Fischer et al. 2022). Aiming at the creation and dissemination of knowledge through new products and technologies, knowledge-intensive entrepreneurship innovates in the use of resources and its creations make the market more dynamic, especially if we consider the entrepreneur as a vector of transformation of society (Malerba and McKelvey 2020).

The existing body of research requires more comprehensive exploration regarding the potential impact of localized phenomena, such as green entrepreneurship, on facilitating the progression toward environmentally sustainable economic structures and regions, particularly in non-developed nations (Demirel et al. 2019; Potluri and Phani 2020). This research gap assumes paramount significance, given the challenges faced by countries and regions in effectively promoting ecosystems dedicated to addressing pertinent ecological concerns (Fischer et al. 2022).

In this context, this study aims to examine the environmental issues addressed by knowledge-intensive ecological companies in a developing country.

2 Methods

Our empirical analysis involves a sample composed of 284 firms with approved projects between 2020 and 2023 under Brazil's Innovative Research in Small Businesses Program (PIPE), managed by the São Paulo Research Foundation (FAPESP), an initiative analogous to the Small Business Innovation Research (SBIR) program in the United States.

The PIPE Program provides subsidies to support entrepreneurial projects demonstrating high levels of knowledge intensity and innovative potential in small ventures situated in the State of São Paulo. The State of São Paulo presents an intriguing case for investigating the dynamics of green knowledge-intensive entrepreneurship within the context of developing nations. Despite being the foremost economy in Brazil, this region still grapples with numerous challenges commonly observed in catching-up economies. These challenges encompass significant institutional voids, pronounced agglomeration diseconomies arising from infrastructural deficiencies, and a fragile business environment for entrepreneurship driven by innovation (Fischer et al. 2018). Additionally, this particular region accounts for the majority (approximately 80%) of start-ups operating in sectors related to green entrepreneurship in Brazil.

Each of the 284 companies has provided a comprehensive account of their approved projects on the institutional website of FAPESP. To analyze this information, we used the content analysis technique. Content analysis represents a research instrument employed to ascertain the occurrence of specific words, themes, or concepts within qualitative data, particularly textual data. Through content analysis, researchers can quantitatively and analytically assess the prevalence, significance, and interconnections of these identified words, themes, or concepts (Bryman and Bell 2011).

By implementing the content analysis technique on the project descriptions from these companies, we proceeded to categorize those entities that exhibit attributes fitting the classification of ecological firms. In this context, the categorization was based on the companies' commitment to environmental concerns within their business undertakings, regardless of their primary profit orientation (Demirel et al. 2019; Fischer et al. 2022; Neumann 2022). More specifically, we considered in our sample ventures that operate in green sectors. Consequently, within the scope of this research, we define knowledge-intensive ecological businesses as innovative organizations that actively foster positive impacts on the natural environment, irrespective of whether such aspects form a deliberate part of their explicit value proposition.

Four researchers carried out the classification of ecological businesses focused on sustainability. All four researchers had more than ten years of research experience; one is an associate professor at a university, two are postdoctoral research fellows, and one is a PhD candidate. To ensure adherence to the established criteria, the researchers independently conducted this analysis of the projects. In other words, they read the projects abstract looking for some adherence in the green sector. Any discrepancies that arose during the assessment process were resolved through discussions among the researchers.

Then, through content analysis, green projects were classified according to the main environmental issues they addressed. The exact process was conducted in this new classification, where the researchers ranked independently, and discrepancies were jointly resolved.

3 Results

The results showed that of the total number of projects analyzed (284 companies), only 66 were classified as green, corresponding to 23%. For the classification of these green firms in themes, the cross-cutting themes of the environmental sciences and engineering were considered, considering the ecological problems and the technologies involved in the projects.

Thus, the content analysis of the projects revealed that the main topics addressed were related to: (i) natural resources, agriculture, and the environment, with 53 projects (80%); (ii) remote sensing for environmental monitoring and manage-

Table 1 Main issues addressed by green projects

Issue	Number of projects	Percentage (%)
Remote sensing for environmental monitoring and management	6	9
Smart technologies for environmentally friendly energy production	4	6
Sustainable management of the urban environment	3	5
Total	66	100

ment, with six projects (9%); (iii) intelligent technologies for the production of ecological energy, with four companies (6%); and (iv) sustainable management of the urban environment, with only three companies (5%).

Table 1 presents the classification.

4 Discussion

The results showed that 23% of the projects were considered green. Although the number seems low, it should be noted that the PIPE program is not focused on ecological companies, so the number can be regarded as reasonable. The results are similar to a previous study that analyzed 1372 PIPE firms and classified 25% as green (Fischer et al. 2022).

Results highlight a predominance of businesses operating in the agriculture sector, a critical area in Brazil, but without intense technological use. Findings also showed projects distributed in remote sensing, smart technologies, and sustainable management areas. The evidence suggests that initiatives such as PIPE can be leveraged to foster the creation of new ecological businesses that employ cutting-edge technologies to address environmental issues effectively. Through our research, we have made significant contributions relevant to the policymaking sphere. Specifically, our findings serve to bolster efforts aimed at fostering a synergistic relationship between knowledge-intensive ecological entrepreneurship and the imperative of achieving environmentally sustainable transitions within developing nations. Moreover, our study seeks to confront the challenges of the SDGs.

By delving into this domain, we shed light on the potential pathways that can effectively bridge the gap between knowledge-intensive ecological entrepreneurship and the pursuit of sustainability in developing countries. This alignment has far-reaching implications for attaining the SDGs, as it offers opportunities to address pressing global challenges such as climate change, biodiversity loss, resource depletion, and social inequalities.

5 Conclusions

This research examined the environmental issues addressed by knowledge-intensive ecological companies in a developing country. The study achieved its objective by identifying and classifying the ecological firms of a program that provides subsidies to support entrepreneurial projects demonstrating high levels of knowledge intensity and innovative potential in small ventures in the State of São Paulo.

The study contributes to the academic literature with valuable insights on Brazilian initiatives by analyzing a context still little explored in a developing country. For practice, our findings contribute to the policymaking process to promote the connection between knowledge-intensive ecological entrepreneurship and environmentally sustainable transitions in developing countries while addressing SDG challenges.

The research has some limitations. Only one public initiative to support entrepreneurship was used in only one country and with a limited number of green entrepreneurs. Future research can deepen the findings by in-depth analysis of green entrepreneurs and managers responsible for similar programs to understand how knowledge-intensive ecological entrepreneurship can be encouraged in developing countries.

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The Digitization of Public Administration

Mircea Popa

Abstract

Public administration has several benefits as a result of transforming to digital, for both citizens and employees. As a result, at the institutional level of public institutions, digitization ensures efficient utilization of resources and provides opportunities for creating cutting-edge public services. The digitalization process must give particular attention to and clearly state the needs of consumers. The facts indicate that lately, customers have raised the standard for public administration and demand easy, quick, and transparent services. An integrated process that stimulates review and standardization of administrative procedures is essential for efficient digital transformation. The digital revolution of government unveils opportunities for more transparency, reliability, efficiency, and collecting revenue. The digitization of public administration gives several advantages for both employees and citizens. Therefore, at the administrative level of public institutions, digitalization guarantees efficient utilization of resources and provides opportunities to deliver unique public services. The digitalization process should pay particular attention to and completely convey the demands of citizens. Clients are now increasingly demanding in terms of public administration, expecting simple, fast, and transparent services. Successful digitization involves an integrated process which provides an optimal setting to assessing and optimizing administrative activities. In this context, we carried out a research in Călărași County, Romania, at the level of representatives of territorial administrative units (mayors, vice-mayors, president and vice-president of the county council, civil servants with management and execution functions) to capture the perception regarding the transformation and the transition from traditional public services to digitalization.

Keywords

Public services · Services marketing · Digitalization · Cloud resources · Public administration

1 Introduction

Local authorities confront a challenging responsibility of dealing with challenging and nuanced issues in their communities. The public authority oversees financial resources, but their usage is decided by electoral programs and studies in order achieve strategic objectives to meet the immediate or long-term needs of local communities.

Local communities in Romania and the EU countries are now being called upon to deliver local public services that fulfill the needs of both long-term and temporary residents, whose character has proven to be limitless over time. People's requirements are many and varied, and they become more pressing by societal and national growth. As a result, the evolution of society, which has set up new demands for the population, has generally fostered the development and diversity of public services. The local government was compelled to fulfill these demands for reasons of public interest.

Currently, society is experiencing significant and strong changes in all sectors, which are mainly caused by cutting-edge technology, which act as promoters of higher quality of life requirements and being used as vectors of sustainable development in line with the needs of the community and society in general (Raiu 2015).

The public sector is now being analyzed more deeply, with the belief that a more efficient and public-oriented public sector provides specific economic performance.

According to Kotler "marketing is a social and managerial process by which individuals or groups of individuals obtain

M. Popa (✉)
Bucharest University of Economic Studies, Bucharest, Romania
e-mail: mirceapopa2@yahoo.com

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what they need and want by creating, offering, and exchanging products and services having a certain value" (Kotler 2008).

The significant expansion of the tertiary sector, known in specialist literature as the service economy, in the previous five decades resulted in the introduction and full expression of services marketing (Munteanu 2006; Olteanu 2003).

This marketing industry has certain characteristics that distinguish it from other areas of activity. Thus, the inseparability of service production and consumption resulted in the producer's proximity to the user in order to understand the preferences and expectations of prospective beneficiaries.

Thus, public administration has shifted from a system based on the application of existing legislation to one based on development programs (Zamfir et al. 2006), implying a greater role for technical expertise in the analysis, implementation, monitoring, and evaluation of various public policy options. Apart from the impact of political, cultural, legal, or other variables on administrative efficiency, the human component plays the most crucial effect.

Governments typically function in a supply-oriented way, paying attention on their own necessities and activity instead of the needs of the people they serve (Dudley et al. 2015). Dissatisfaction with government performance, as shown by the bureaucratic public administration method, paved the way for the New Public Management paradigm, which encompasses a focused on outcomes, entrepreneurial, and citizen-centric management style (Gaebler & Osborne 1993). The public sector was urged to benefit from the private sector's expertise and lessons learned in order to ensure successful service design and delivery. According to Gash et al. (2013), "*government should swiftly strengthen its strategy for commissioning and supervising public service markets, embracing what we call a'market stewardship' approach.*"

2 Methods

In this context, we opted for a questionnaire in which individuals from the local authority's management and executive levels participated. (N = 323). 56% of the total are female, while 44% are male.

The main objective pursued by this questionnaire was to capture the perception of civil servants of public institutions regarding the influence of digitization in terms of improving the public services offered. In other words, we were interested in researching whether, at the level of employees, there is a perception according to which the digitalization of services can influence the quality of the services offered.

Another objective was to investigate both digital literacy in an institutional context and in a personal context (use of modern tools to access public services, use of social networks, etc.)

Table 1 Level of education

		Frequency	Percent
Valid	Undergraduate	27	8.4
	Highschool	62	19.2
	University	200	61.9
	Master	32	9.9
	PhD.	2	0.6
	Total	323	100.0

Table 2 Age frequency

		Frequency	Percent
Valid	20 and 24 years	1	0.3
	25 and 29 years	2	0.6
	30 and 34 years	15	4.6
	35 and 39 years	32	9.9
	40 and 44 years	48	14.9
	45 and 49 years	61	18.9
	50 and 54 years	85	26.3
	55 and 59 years	54	16.7
	60 and 64 years	21	6.5
	Over 65 years	4	1.2
	Total	323	100.0

We underline the fact that the largest share of respondents is represented by people who indicated "*university studies"* as their level of education (61.9%). (see Table 1).

Regarding the distribution by age groups, we note that the highest frequency is represented by the interval between 50 and 54 years (26.3%, M = 6.32, SD = 1.662). The average age of the research participants is 48.24 years (Table 2).

At the same time, from the recorded data, we note that the highest share in terms of education level is represented by female persons who indicated "university studies" (122 female persons compared to 78 male persons) (see Table 3).

3 Results

3.1 Frequency of Digital Services in Personal Activity

As mention before, one of the research aim was to investigate the frequency of using digital services in personal activity.

Data recorded showed that 49.2% of the participants indicated "often," while 22.6% indicated "very often" (see Table 4).

Table 3 Education × gender crosstabulation

		Gender		Total
		Female	Male	
Education	Undergraduate	5	22	27
	Highschool	33	29	62
	University	122	78	200
	Master	20	12	32
	PhD.	1	1	2
Total		181	142	323

Table 4 Frequency of digital services in personal activity

		Frequency	Percent
Valid	Never	15	4.6
	Rarely	7	2.2
	Rare	29	9.0
	Often	159	49.2
	Very often	73	22.6
	Always	18	5.6
	Can't appreciate	22	6.8
	Total	323	100.0

Table 5 Digital certificate courses among institution

	Frequency	Percent
None	74	22.9
< 10%	160	49.5
10–25%	41	12.7
25–50%	11	3.4
50–75%	17	5.3
>75%	20	6.2
Total	323	100.0

Table 6 Percentage of using digital services

		Frequency	Percent
Valid	< 10%	165	51.1
	10–25%	67	20.7
	25–50%	57	17.6
	50–75%	28	8.7
	> 75%	6	1.9
	Total	323	100.0

Starting from this results, we can appreciate that the participants perceive digital services as useful tool for solving their currently situation.

Moreover, 94.7% of the participants indicated that they are users of social platforms. Therefore, at least on a theoretical level, we could assume that, at the individual level, there is a degree of digital literacy.

At the same time, 85.8% of the participants indicated that the frequency of use of social platforms is "daily."

49.22% of female persons indicate a "daily" frequency of using these platforms, while, in terms of level of education, 54.79% are graduates of "university studies."

3.2 Results Employees Level of Literacy

Regarding the level of digital education at the institutional level, the recorded data indicate that 22.9% of employees do not hold a digital skills certificate, while a percentage of less than 10% hold such a certificate (49.5%) (see Table 5).

Regarding the institution-level assessment, civil servants appear to have a high level of digital literacy (91.6%). This percentage is relatively surprising, in the context in which the recorded data shows that only 40.9% of employees indicate that they have a digital certificate, while 31.6% indicate that they do not have such a certificate. However, only 27.6% of participants indicate that they "*intend to obtain such a certificate.*"

Also, the recorded data also demonstrate the fact that 77.4% of local payments and taxes were made through digital tools (payments via web page). Therefore, starting from these data, we can conclude that at the level of the community served by the public institution, digital public services are appreciated/requested by consumers.

If in 2020, public services in digital format were used in relatively low percentages (under 10% approximately 57.3%, between 10 and 25%–18.9% between 25 and 50%–12.1%), in 2021 the percentages underwent slight changes (see Table 6).

4 Conclusions

In conclusion, when we consider the transition to the digitization of public services offered by local institutions, we must take into account a number of aspects.

Thus, even if, from the perspective of service marketing, digitization represents the possibility for the service provider to offer a higher quality level, but also a degree with a much higher personalization, this transfer is strongly influenced first of all by the degree of digital literacy of the staff. Given that, at the staff level, there are no specific procedures, then the promotion of services and related support has a negative impact in the relationship with consumers.

Also, the research indicated to us the existence of a discrepancy between the institutional assessment of staff in terms of digital literacy and reality. In other words, in the absence of an audit, but, above all, in the absence of high digital skills of the management of local institutions, the degree of consumer satisfaction with regard to the services provided is low.

Last but not least, the research was carried out in a county where, according to the data provided by INSSE, the aging of the population is high, while the level of education is low. Or, in this context, the digitization of public services represents a challenge in the sense that their use requires the existence of consumers capable of using the means specific to digital transformation (owning equipment such as a tablet, laptop, smartphone, bank card, etc.).

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MUNA Satellite Event. Biodiversity Conservation: Challenges and Opportunities

Biological, Chemical, and Ecotoxicological Assessment of Seawater and Marine Sediments Sampled in Correspondence of Four Torrents Outlets of the Ionian Coast of Regione Calabria

Antonio Nappo, Federica Carraturo, Marco Trifuoggi, Valerio Zupo, Maria Costantini, Sureyya Meric, Lea Di Massa, Giovanni Libralato, and Marco Guida

Abstract

During the last decades, several Calabrian habitats have been altered: most productive lands were indeed converted into agricultural and industrial areas, and fisheries were overexploited. Nonetheless, punctual assessment of coastal resources health are currently missing. The purpose of the present study, part of BluCaProd project, was to assess the anthropic impacts on the ecosystem of the Calabrian Ionian coast, through the conduction of microbiological, chemical, ecotoxicological, and molecular analyses. Monitoring was conducted on 4 sampling sites located in the province of Cosenza (Regione Calabria), in correspondence of four torrent outlets: Amendolara, Sibari, Corigliano, and Calopezzati. Total bacterial counts, contamination indicators such as fecal Enterococci, total Coliforms, *Escherichia coli*, sulfite-reducing Clostridia, molds and yeasts were selected as microbiological parameters. Moreover, cultural methodologies, performed according to standardized ISO guidelines, were complemented with molecular microbiology techniques, targeting 16S bacterial and 18S fungal genes: Sanger sequencing and NGS analysis allowed the characterization of the microbiota of the sampled sites. In addition, marine water and sediment samples underwent chemically and ecotoxicological (using the bioindicators *Aliivibrio fischeri*, *Phaeodactylum tricornutum,* and *Brachionus plicatilis*) analysis. Hygiene monitoring conducted in two seasons, winter and spring 2023, allowed to evidence high concentrations of Enterococci and fecal Coliforms in Sibari and Corigliano sites, in both marine water and sediments: results may depend on the anthropic impact on the specific areas in the highest production period. The outcomes obtained during winter and spring seasons showed a substantial difference in terms of total bacterial counts and indicators of fecal contamination between the areas of Sibari and Corigliano, and those of Amendolara and Calopezzati. Molecular analyses allowed the characterization of more than 100 colonies including bacteria, yeasts, and molds. The sampling campaign was finalized in September 2023, with the collection of samples at the end of summer season. The association of microbiota composition with microbiological, chemical, and ecotoxicological metadata will be essential to provide an overview, in a One Health approach, of the anthropogenic impact on the Regione Calabria Ionian coast's ecosystem, supporting the mitigation strategies to protect human, environmental, and animal health.

Keywords

Hygiene monitoring · Calabria Ionian coast · BluCaProd · *Escherichia coli* · ecotoxicology

1 Introduction

Since the beginning of the Industrial Revolution, the environmental pollution attributed to anthropogenic activities intensified worldwide (Nfon et al. 2008). The discharge into nearby water systems (e.g., rivers, lakes, seas, or oceans) results in accumulations of cocktails of pollutants at above natural levels, contaminating waters and sedi-

A. Nappo (✉) · F. Carraturo · L. Di Massa · G. Libralato · M. Guida
Hygiene Laboratories, Department of Biology, University of Naples Federico II, Naples, Italy
e-mail: nappoantonio97@gmail.com

M. Trifuoggi
Department of Chemical Sciences, University of Naples Federico II, Naples, Italy

V. Zupo · M. Costantini
Anton Dohrn Zoological Station, Naples, Italy

S. Meric
Environmental Engineering Department, Çorlu Engineering Faculty, Namik Kemal University, Çorlu, Tekirdağ, Türkiye

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ments, and causing detrimental impacts on aquatic ecosystems and the resident biota (Maczulak 2010). Demand for harvestable biomass (food, nutraceuticals, scientific research) by a growing, wealthier, and increasingly urbanized human population is placing pressure on marine ecosystems. In fact, several Calabrian habitats have been altered in the last century and most productive lands were converted into agricultural areas. Industrial fisheries are overexploited in Calabrian seas, although punctual data on health of coastal resources are missing. The purpose of the study, which is part of the CRIMAC project "BluCaProd," is to evaluate the local anthropogenic impacts on the ecosystem of the Calabrian Ionic coast by means of microbiological, chemical, and ecotoxicological analyses. Both microbiological analyses are foreseen for the search of the parameters: Total Bacterial Count, Fecal Enterococci, Fecal Coliforms, Reducing Sulphite Clostridia, Moulds, and Yeasts, which molecular biology analysis for the extraction of genomic material and subsequent characterization of microbial species found in the matrices analyzed. In addition, water and sediment samples are evaluated chemically and ecotoxicologically (*Aliivibrio fischeri*, *Phaeodactylum tricornutum,* and *Brachionus plicatilis*).

2 Materials and Methods

Marine sediment and surface and bottom water samples were collected at depths of 5 and 15 m in each study area (Amendolara, Sibari, Corigliano, and Calopezzati). Except for Amendolara, at which an additional point at the shoal was analyzed at depth of 24 m. The total number of points sampled is therefore nine, and each point involved the collection of 2 marine sediment samples and 2 water samples (surface and bottom). Monitoring was carried out in February and May, at the exact same points, using the geographical coordinates. Physical, chemical, microbiological, and ecotoxicological parameters have been investigated in compliance with D. Lgs. 190/210 (EC 2008/56). Samples (marine water and sediment samples) were collected and analyzed according to the most recent standardized guidelines (UNI EN ISO, ISPRA, APAT-IRSA, and CNR). Physical and chemical descriptors include pH, EH, salinity, dissolved oxygen, $N\text{-}NH^{4+}$, $N\text{-}NO^{2-}$, NNO^{3-}, $P\text{-}PO4^{2-}$, metals, metalloids, and polyaromatic hydrocarbons. Microbiological characterization provided information on *Escherichia coli*, Enterococci, Reducing Sulphite Clostridia, Moulds and Yeasts, and total number of bacteria (TB) (22 and 37 °C). Molecular characterization of microorganisms isolated from culture media was performed by targeting 16S bacterial and 18S fungal genes by Sanger sequencing, while NGS analyses allowed characterization of the microbiota of the sampled sites. The toxicity of the matrices was assessed through toxicity tests on the following organisms: *Aliivibrio fischeri* (ISO 11348-3:2007), *Phaeodactylum tricornutum* (ISO 10253:2016), and *Brachionus plicatilis* (ISO 19820:2016). All information will be processed by uni- and multi-variate statistical analysis to provide a final summary assessment of the study area.

3 Results

3.1 Results Microbiological Analyses of Sediment Samples

The graph referring to the colony-forming units of fecal enterococci present per gram of marine sediment shows that the areas of Sibari and Corigliano are the most impacted. In particular, an exponential increase was recorded in the Corigliano area, at the point closest to the coast, i.e., at the produndity of 5 m (Fig. 1).

3.2 Results NGS Analysis of Sediments Samples

Barplot at family level according to 16 s rRNA sequencing analysis shows the relative abundance in percentage terms of the bacterial families most commonly found in the sediments collected in the winter sampling session at each of the nine analysis points in the four different areas (Fig. 2).

3.3 Results of Ecotoxicological Analyses

With reference to DM 260/2010 (technical criteria for the classification of the state of surface water), acute toxicity tests on *B. plicatilis e A. fischeri* showed 15% lower toxicity in all waters for both winter and spring sampling. Increased acute toxicity was recorded in sediment, almost always above 15%, mostly in winter. The chronic toxicity test with *P. tricornutum* showed toxicity of less than 30% in all samples except for sediments sampled in Sibari.

4 Discussion

Regarding the first two sampling campaigns carried out, in the winter and spring seasons microbiological analyses showed that marine water and sediment samples in the Sibari and Corigliano areas were the matrices with the highest concentration of potentially pathogenic microorganisms, with no significant differences between the two seasons. While Amendolara and Calopezzati, which are the least impacted sites. In addition, it was found that molds and yeasts are highly

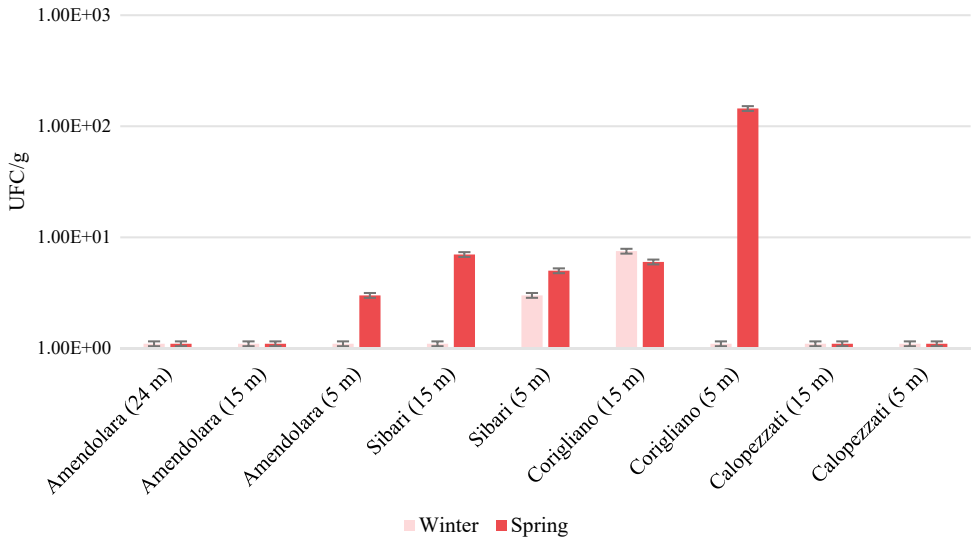


Fig. 1 Fecal enterococci characterized from sediment samples collected in Winter 2022 and Spring 2023

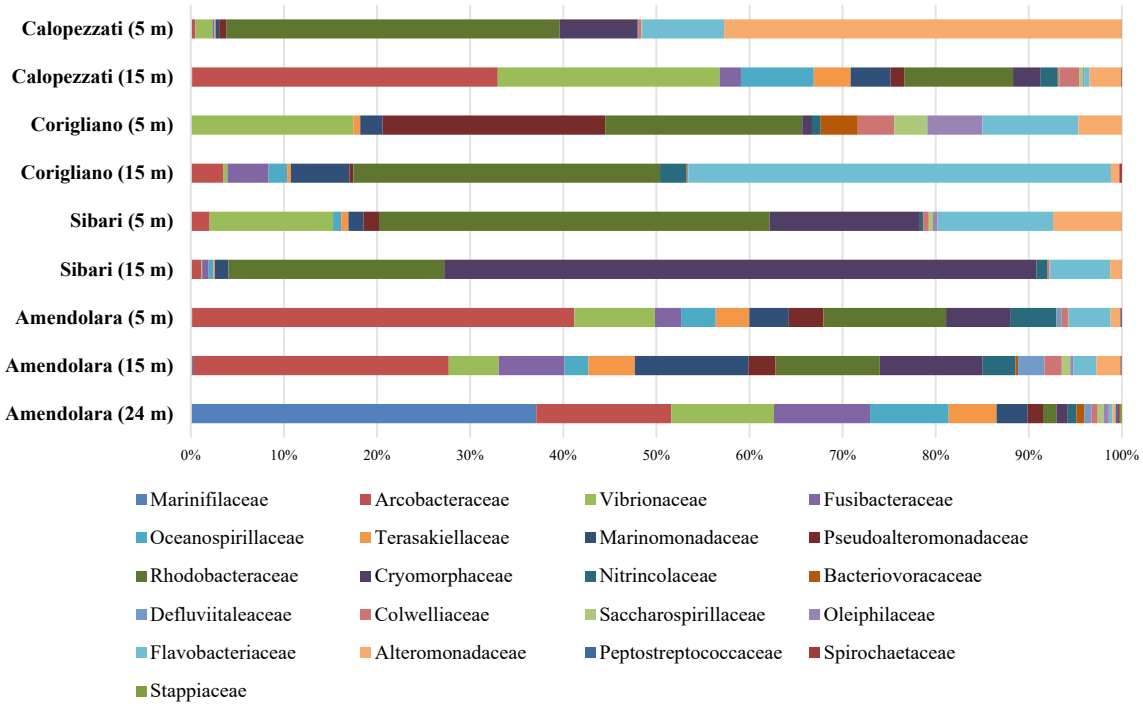


Fig. 2 Barplot at family level according to 16 s rRNA sequencing analysis. Results are expressed as relative abundance of reads

present, in almost all samples. From the point of view of ecotoxicity, a higher toxic effect was observed in the samples taken in the winter season than in those taken in May, so it is possible to hypothesize a role of freshwaters flowing into the area in the conveyance of contaminants from land to sea.

5 Conclusions

Hygiene monitoring conducted during two seasons, winter 2022 and spring 2023, showed high concentrations of Enterococci and fecal Coliforms at the Sibari and Corigliano sites, both in marine water and sediments: the results may depend on the anthropogenic impact on the specific areas during the industrial production peaks. The results obtained during the winter and spring seasons showed a substantial difference in total bacterial counts and indicators of fecal contamina-

tion between the areas of Sibari and Corigliano and those of Amendolara and Calopezzati.

Accordingly, ecotoxicological analyses confirmed the microbiological results; in fact, Sibari was found to be the area with the highest toxicity rate toward the target organisms. Molecular analysis by Sanger sequencing allowed characterization of more than 100 colonies including bacteria, yeasts, and molds.

The sampling campaign will be finalized in September 2023, with samples collected at the end of the summer season. The association of microbiota composition with microbiological, chemical, and ecotoxicological metadata will be essential to provide an overview, in a One Health approach, of the anthropogenic impact on the ecosystem of the Ionian coast of the Calabria Region, supporting mitigation strategies to protect human, environmental, and animal health.

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Pesticides Toxicant's Role on Fish: A Miniview

Binay Kumar Chakraborty, Anisa Mitra, and Loredana Assisi

Abstract

Fish are valuable providers of vitamins, fats, and proteins for humans. Pesticide contamination of surface water bodies is a global concern. They have the capacity to build up in sediment and water, which makes them strong poisons due to their persistent toxicity. Fish development, survival, and reproduction are all impacted by these factors. The review's data and information sources were from related published and unpublished grey literature as well as pertinent publications. A brief summary is provided on the characteristics, introduction of the primary pesticides into living organisms, and effects on fish health. The use of pesticides in conjunction with alternative methods of pest control should be justified by appropriate measures, environmental laws, and the Fisheries Act in order to preserve water quality, protect fish and humans, and reduce the health risks associated with feeding fish that have been exposed to pesticides.

Keywords

Pesticides · Insecticides · Herbicides · Toxicants · One-health · Sustainability

B. K. Chakraborty (✉)
Mud eel, Mud crab, Aquaculture and Management Centre, Mymensingh, Bangladesh
e-mail: bborty@gmail.com

Department of Fisheries, Mathshya Bhabon, Dhaka, Bangladesh

Swami Vivekanand Subharti University, Meerut, UP, India

A. Mitra
Department of Zoology, Sundarban Hazi Desarat College, Pathankhali, India

L. Assisi
EClab, Department of Biology, University of Naples Federico II, Naples, Italy

1 Introduction

Aquatic resources, such as ponds, rivers, streams, canals, seas, and oceans, as well as fisheries, provide employment, generate revenue and cost savings. Fish provides high-quality protein and trace minerals, making it an important food source for humans (Mitra et al. 2023). Pesticide application impacts both the quantity and quality of food produced, yet it is a useful tool for controlling a wide range of herbaceous and insectivorous pests. The synthetic chemical compounds have serious negative effects on biodiversity, ecological interaction, and the long-term survival of important ecosystems. Fish have the ability to bio accumulate environmental pollutants from surrounding water and food, and this process is known as bio magnification, which affects apex predators through the food web (Chabchoubi et al. 2023). This brief message aims to provide an overview of the harmful effects of pesticides on fish and human health.

2 Materials and Methods

Data and information source utilized in this study have been collected from relevant literature and related published and non-published grey literature (years 2013–2023).

3 Results

Pesticide Toxicity in Fish:

Pesticides are divided into groups based on the intended purpose, including Insecticides, Fungicides, Herbicides, Rodenticide, Nematicides, Acaricides, Molluscicides, Homicides, Ovicides etc.. Herbicides, which control weeds, insecticides, which control insects, and fungicides, which control mycotics, are the three main categories of pesticides. They

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weaken fish's health by interfering with their metabolism, which can occasionally result in fish death. Concerns about maintaining a safe and sustainable environment have increased due to the overuse of pesticides (Louis & Diana 2013).

Effect of the three main types of pesticides:

A. **Insecticides**

Insecticides are mostly released into urban water ecosystems via rainfall, runoff, air deposition, and discharges from factories and cities. The majority of pesticides end up in rivers, lakes, and ponds where they have been shown to be extremely hazardous to organisms that are not their intended targets and to disrupt the natural ecosystems near agricultural fields. The histopathological changes caused by pesticide poisoning in fish species are displayed in Table 1.

Insecticides are categorized based on their chemical groups:

a. Chlorocyclines: Dieldrin, Endosulfan, TDE, Mirex, Lindan, Hexaclorobenzine, Chlordane, Dieldrin, DDT, and TEP. Organochlorines affect the neurological system of the insect.
b. Pyrethroids: Made up of an acid and an alcohol, pyrethroids including allethrin, bifenthrin, cyclothrin, cypermethrin, cyfluthrin, deltamethrin, fenvalerate, phenothrin, and parallelethrin are produced from naturally occurring pyrethrins. The electrical signaling of the insect nervous system is disrupted by pyrethroids, which alter the sodium channels in neuronal membranes.
c. Neonicotinoids: These are artificial versions of the natural nicotine-based insecticides and agonists of the nicotinic acetylcholine receptors that are sprayed, soaked, incorporated into seed, and applied to soil. Among these categories are thiamethoxam, acetamiprid, clothianidin, imidacloprid, nithiazine, and thiacloprid. As an alternative to carbamate and organophosphate, they are used.
d. Ryanoids: Insecticides derived from the Flacourtiaceae family plant Ryania. They bind the calcium ion in the cardiac and skeletal muscles and inhibit the passage of nerve signals.
e. Biological insecticides: Plants that produce myrosinase release compounds that keep insects from feeding. This enzyme changes glucosinolates into a number of other substances. Allylisothiocynate is one of the products of this enzyme; other biological insecticides are derived from entomopathogenic fungi (Beauveria bassiana).
f. Bacterial insecticides: These are made by Bacillus thuringiensis and, by genetic engineering, are employed as larvicides against mosquitoes, beetles, and caterpillars.
g. The following pesticides are made from plants: gaussia, derris, neem, polyketide, pyrethrum, anabasine, anonin, caffeine, carapa, cinnamona leaf oil, tetranortriterpenoid, thymol, and linalool.
h. Other compounds such as diatomaceous earth, boric acid, borax, and borate—do not fall into the aforementioned categories.

2 **Use of Herbicides**

Herbicides used on gardens, forests, and agricultural crops include copper sulfate, fluridone, 2–4-D, glyphosphate, rodeo, diquat, and hydrothol. However, to manage the growth of algae, submerged water grasses, flowering water plants, and emergent water plants (cattails, rushes, and reeds), herbicides are sprayed directly into lakes and ponds. Fish suffocation is the cause of death.

3 **Insecticides**

Fungicides are often less hazardous to fish and other aquatic life than insecticides. However, because of their detrimental effects on the environment, several fungicides have been outlawed. Certain fungicides are incredibly harmful to fish.

4 Discussion

Fish exposed to pesticides over an extended period of time pose a constant health risk to humans (Akhter & Saha 2013; Al-Emran et al. 2018; Banaee et al. 2011; Deka & Mahanta 2012; Haque et al. 2018; Karim et al. 2016; Louis & Diana 2013; Sharma & Sharma 2016; Sharma & Jindal 2020; Uddin et al. 2022; Vajargah et al. 2017). In addition to the application of certain pesticides, alternative approaches such as biocontrol, integrated pest management, genetic control, physical interventions, and the sterile insect technique can be used in place of pesticides to maintain ecological stability (Akhter & Saha 2013; Louis & Diana 2013). More research is needed to develop herbicides that are species-specific, safe for the ecosystem, and don't harm uninvited organisms (Akhter & Saha 2013; Boran et al. 2010; Yalsuyi et al. 2021). By applying methods to extrapolate genetic, ecological, and mechanistic information across species, we should be able to better understand the intrinsic vulnerability of local species (Akhter & Saha 2013).

The long-term exposure of fish to pesticides is a continuous health hazards for the human population (Louis & Diana 2013). Pesticides can be replaced with alternative strategies like biocontrol, integrated pest management, genetic control, physical interventions, and the sterile insect technique in addition to the use of specific pesticides in order

Table 1 Histopathological alterations resulted from insecticides toxicity in fish

Species	Pesticide	Doses	Exposure day	Effect	References
Mystus cavasius	Cypermethrin (insecticide)	0, 4, 8 & 16 µg/L	90	The ovary may exhibit wrinkled eggs, cytoplasmic clumping, atretic follicles, a degraded granulose layer, a degenerated oocyte wall, increased interfollicular space, adhesion, cysts, and necrosis	Uddin et al. (2022)
Mystus tengara	Cypermethrin (insecticide)	0, 0.026, 0.052 & 0.104 mg/L	28	Necrosis, vacuoles, ruptured hepatic cells, pyknotic nucleas, swollen hepatocytes, and degraded hepatic cells	Haque et al. (2018)
Oreochromis niloticus	Sumithion (insecticide)	0, 1.5, 2, 2.5, 3, 3.5 & 4 mg/L	4	Shortened and clogged gill lamellae, damaged gill filaments, liver: blood congestion, MMC, pyknosis, kidney: degraded patch, vacuolation, and pyknotic nuclei	Vajargah et al.(2017)
Ctenopharyngodon idella	Lindane (insecticide)	0, 0.25, 0.75, 1.25 & 2.0 mg/L	4	Deformed and degenerate epithelial cells, bleeding, necrosis, and destroyed intestinal villi	Vajargah et al. (2017)
Cyprinus carpio	Diazinon (insecticide)	0.06 & 0.12 mg/L	30	Renal tubules: atrophic and necrotic; contracted glomerulus; degraded tubular epithelium Bowman's capsule	Banaee et al. (2011)
Catla catla	Cypermethrin (insecticide)	0.21 and 0.41 µg/L	45	Several histopathological abnormalities observed in liver tissues	Sharma and Jindal (2020)
Labeo rohita	Endosulfan and Lindane (insecticide)	10, 20 & 30% of LC50 (0.12 ppm) / 96 h	45	Atrophy of secondary lamellae, congestion and bleeding of blood capillaries, multifocal necrosis of lamellae, mild blood vessel bleeds and congestion, as well as hemopoetic tissue loss	Sharma and Sharma (2016)
Barbonymus gonionitus	Sumithion (insecticide)	0.00, 0.025, 0.05& 0.1 mg/L	30	Hypertrophic, pyknotic, necrotic, hemorrhagic cells in liver and kidney tissues	Al-Emran et al. (2018)
Hypophthalmicthys molitrix	Pyrethroid (insecticide)	0.4, 0.8 & 1.2 µg/L	14	Necrosis, pyknotic, hypertrophic and atrophic nucleus, congested blood vessels	Karim et al. (2016)
Heteropneustes fossilis	Malathion (insecticide)	0.2 mg/L	30	The hepatocytes exhibited a condensed nucleus and cytoplasm, ruptured blood vessels, fractured sinusoidal endothelium, disintegrated renal tubules, ruptured blood vessel and pyknosis, and broken blood capillary	Deka and Mahanta (2012)
Chana punctatus	Fenitrothion (insecticide)	0.01,0.02, 0.03, 0.04 &0.05 mg/L	21	Hepatic cells include vacuoles that are fibrosic and necrotic. Hemorrhagic, edematous Bowman's capsule, damaged hepatorenal tissues, and atrophic glomeruli in the kidney	Akhter and Saha (2013)
C. carpio	Glyphosate (herbicide)	68.788 mL/L	96	The gills contain raised epithelial cells, fused lamellae, hyperplastic lamellae, and proliferating filament cells. Liver necrosis and vacuolation	Yalsuyi et al. (2021)
O. niloticus	Maneb Carbaryl (fungicide)	0.1–2, 0.2–3.9 mg/L	4	Edematic, separated and fused gill lamellae; necrotic and swelled epithelial cells	Boran et al. (2010)

to preserve ecological stability. It will take more research to create environmentally friendly, species-specific herbicides that don't harm unintended organisms. We may be better able to comprehend the inherent vulnerability of local species by using techniques to extrapolate genetic, ecological, and mechanistic information across species (Uddin et al. 2022). Particularly vulnerable may be sensitive life stages of species with highly specialized life history features, although there is currently insufficient evidence on toxicity for non-model species (Akhter and Saha) to conduct a thorough review across species (Akhter & Saha 2013).

5 Conclusions

A variety of appropriate measures, including environmental laws and the Fisheries Act, should be implemented to rationalize the use of pesticides in conjunction with alternative methods of controlling pests. This will help to protect water quality, protect fish and humans by reducing the health risks associated with feeding fish that have been exposed to pesticides, and mitigate overall fish and human health losses.

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Multi-species Detection Through Environmental DNA in Central Italy Freshwaters. A Focus on Protected and Invasive Alien Species

Simone Giovacchini, Enrico Mirone, Antonia Bruno, Fausto Ramazzotti, Luca Caprotti, Pamela Monaco, Pushpinder Singh Jamwal, Marina Melchionna, Mirko Di Febbraro, Andrea Galimberti, and Anna Loy

Abstract

Environmental DNA-based approaches (eDNA) are innovative tools to support traditional species monitoring methodologies. We implemented a multi-species monitoring protocol in freshwater bodies of Central Italy aimed at a rapid identification of threatened, cryptic, and invasive alien species whose early detection is a key factor in either their protection or eradication. We selected 22 target species, including 14 endangered taxa listed in annex II, IV, and V of Habitat Directive 92/43/EEC (*Lutra lutra, Mustela putorius*, *Emys orbicularis*, *Bombina pachypus*, *Lissotriton italicus*, *Triturus carnifex, Squalius lucumonis*, *Alosa fallax*, *Austropotamobius italicus*, *Coenagrion castellani*, *Lindenia tetraphylla*, *Oxygastra curtisii, Unio elongatulus*, *Vertigo* spp.), six invasive alien species of EU relevance according to the EU Regulation 1143/2014 (*Trachemys scripta*, *Lithobates catesbeianus, Pseudorasbora parva*, *Faxonius limosus*, *Procambarus clarkii, Dreissena polymorpha*, the fungal pathogen *Batrachochytrium dendrobatidis),* and the translocated native fish *Padogobius bonelli.* Water samples (3 l) were collected and filtered through mixed cellulose esters membranes at 52 sites with two-time replicates (2021 and 2022). Species specific oligos and qPCR TaqMan probes were developed and validated in silico, in vitro and in operational environment. All species were detected at least at one sampling site except for odonates and *Trachemys scripta* (not detected), with a detection rate ranging from 0.04 to 0.77 suggesting this approach as highly promising compared to traditional multi expert-based surveys.

Keywords

eDNA · Freshwater · Multispecies · Habitat directive · Invasive · Alien · Protected

1 Introduction

Dead or living organisms release DNA in the surrounding environment from diverse sources such as sloughed cells, gametes, metabolic waste, and carcasses. That kind of DNA is called environmental DNA (eDNA). The analysis of eDNA is a novel approach to detect species occurrences from different environmental matrices, such as water, soil, or air (Bohmann et al. 2014). It is particularly useful to investigate biodiversity in harsh environments and when elusive and rare species occur. Also, the detection of species belonging to different taxa is time-consuming and requires many experts and high costs. Moreover, although eDNA is now widely used to detect individual species, it is still rarely applied for the simultaneous detection of species belonging to different systematic groups (Civade et al. 2016).

We tested an eDNA protocol to simultaneously detect 22 species living in freshwater bodies of Central Italy, including 14 endangered species listed in the Habitat Directive 92/43/EEC—for which monitoring and conservation status reporting is mandatory under Art. 17 (*Vertigo* sp., *Unio elongatulus, Austropotamobius italicus, Coenagrion castellani, Lindenia tetraphylla, Oxygastra curtisii, Alosa fallax, Squalius lucumonis, Bombina pachypus, Triturus carnifex, Lissotriton italicus, Emys orbicularis, Mustela putorius, Lutra lutra*), six Invasive Alien Species (IAS) of European Concern under the 2014/1143/EEC (*Trachemys scripta*, *Lithobates catesbeianus, Pseudorasbora parva*, *Faxonius limosus*, *Procambarus clarkii, Dreissena polymorpha*, the

S. Giovacchini (✉) · E. Mirone · P. Monaco · P. S. Jamwal · M. Melchionna · M. Di Febbraro · A. Loy
University of Molise, Pesche, Isernia, Italy
e-mail: s.giovacchini@studenti.unimol.it

A. Bruno · F. Ramazzotti · L. Caprotti · A. Galimberti
University of Milano-Bicocca, Milan, Italy

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fungal pathogen causing the chytridiomycosis amphibian disease *Batrachochytrium dendrobatidis),* and the translocated native fish *Padogobius bonelli*. Two of the six IAS, i.e., *D. polymorpha* and *T. scripta*, are also listed under the 100 of the World's Worst Invasive Alien Species (Lowe et al. 2004).

2 Materials and Methods

We collected 3 l of water from 52 sampling sites located in the Latium region (Central Italy), covering various freshwater habitats (rivers, lakes, creeks, marshes, and ponds). We performed two sampling sessions spaced out one year. The first session was performed during the driest season (summer 2021) while the second one was undertaken either in spring or autumn 2022 according to the phenology of the target species.

Water samples were filtered through a vacuum pump on mixed cellulose esters filters, first with a pore size of 8 µm (prefilters) and then 0.22 µm.

DNA was extracted from the filters using the DNeasy Power Soil Pro Kits (Qiagen) and following the manufacturer's instructions with some modifications. To detect the presence of the target species in the water samples, the DNA extracted was amplified by using genetic probes properly designed for each target species. Species specific flanking oligos and probes were developed for 13 taxa (*B. pachypus*, *E. orbicularis*, *F. limosus, C. castellani, L. tetraphylla, O. curtisii, M. putorius*, *P. bonelli*, *S. lucumonis*, *T. carnifex*, *L. italicus*, *U. elongatulus*, *Vertigo* spp.). Probes were validated in silico (checking genetic databases for possible matches with congenerics and possibly sympatric species), in vitro (on tissues samples collected from the target species), and in the operational environment (on environmental samples from ascertained presence and absence sites of each target species and from the sites of investigation). eDNA extracts were analyzed through qPCR TaqMan assays, using different serial dilutions of eDNA extracts with three different reaction replicates (Higuchi et al. 1993).

3 Results

During the two years of eDNA sampling at 52 sites we obtained 106 species detections, covering 18 out of the 22 target species. Fish and amphibians exhibited the highest detection rates, whereas arthropods and reptiles the lowest (Table 1). No detections were obtained for *T. scripta* and the three species of dragonflies, apart from the certain presences in positive control sites.

P. bonelli, *A. fallax* and *T. carnifex* showed the highest values in detectability (respectively 0.77, 0.75, and 0.75).

Table 1 eDNA single species approach detection rates summarized for different taxa

Taxon	Detection rate (x ± sd)
Fungi	0.05
Molluscs	0.30 ± 0.12
Arthropods	0.08 ± 0.11
Fish	0.59 ± 0.20
Amphibians	0.43 ± 0.30
Reptiles	0.02 ± 0.02
Mammals	0.27 ± 0.29

Apart taxa with no observations, the lowest detection rates were observed for *E. orbicularis* (0.04) and *P. clarkii* (0.09).

The average detection rate of native species (0.3 ± 0.27) was higher than the one of invasive species (0.24 ± 0.26).

When we compared individual sampling replicates, the DR of all taxa increased in the second replicate, when we took advantage of the phenological stages. Molluscs only showed a higher DR during the first over the second replicate (0.27 vs. 0.23).

4 Discussion

Freshwater species with high metabolic rates, such as fish and amphibian, are known to be particularly efficient in eDNA detectability, probably due to the easy loss of skin cells and mucus during the life stage they spend in the water (Collins et al. 2018). On the other hand, species with an exoskeleton, like dragonflies, crayfish, or with a hard sclerified skin, like reptiles, likely shred less DNA in the environment (Collins et al. 2018).

For some species we obtained a high detection rate, confirming an optimized selection of testing sites to monitor simultaneously several species. It is the case of newts and most fish.

Compared with previous data on species distribution obtained with classical monitoring techniques (Stoch & Genovesi 2016) our results evidenced new areas of occurrence. Seven species listed in Annex II of Habitat Directive 43/92/EC followed outside the Natura 2000 Network of the region. Up to two new Annex II species were detected at one site.

eDNA allowed to spot new occurrences also for IAS observed for the first time in the study area (*D. polymorpha*) and revealed the expansion of other (*P. bonelli*). An overall low detection of invasive alien species suggests a low spread of IAS in the study area. This outcome may be masked by the low presence of some species and the low detectability of others. Empirical evidence suggests that our technique underestimated the distribution of allochthonous species like *P.*

clarkii that are known to be widespread throughout the study area.

The timing in which eDNA is more abundant in water is based on specie seasonality (Collins et al. 2018). Wildlife is more active during spring or autumn depending on their biology and natural history. For example, those species that hibernate during winter tend to reawaken during spring, releasing more eDNA in this season. In other cases, some species synchronize their spawning in autumn (Stoch & Genovesi 2016). Conversely, some species are more difficult to detect in summer as they abandon water habitats or are subjected to some forms of estivation. Thus, following the correct phenological stages improves target species detections with eDNA techniques.

5 Conclusions

The use of eDNA techniques proved to be successful in multi-species detection and could greatly contribute to future monitoring freshwater wildlife on a large geographical scale. The efficacy of protected areas can also be assessed with this new method. The implementation of eradication plans for invasive species can be drive as well by means of eDNA survey. Nevertheless, these methods need a refinement for those species that showed a low detectability, especially those that likely shred low DNA.

Incorporating the phenological stage in the sampling design will be fundamental to support the best recovery of target species eDNA and accurately depict rare endangered species distribution and early warn biological invasions.

We finally underline how species distribution modeling could likely improve the identification of potential sites of occurrence and optimize the sampling design.

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Investigating the Invasion Mechanisms of *Ailanthus altissima* (Mill.) Swingle by Means of Remote Sensing, Stable Isotopes, and Soil Metagenomic Sequencing Techniques

Marco Ciolfi, Francesca Chiocchini, Paola Pollegioni, Emilio Badalamenti, Carlotta Volterrani, Tommaso La Mantia, and Marco Lauteri

Abstract

The tree of heaven (*Ailanthus altissima*), a pioneer plant native of Asia, was spread through the old continent since the middle of the eighteenth century. *A. altissima* is currently considered as one of the most dangerous and widespread alien trees in the Mediterranean region. In fact, it is listed among the invasive alien species (IAS) introduced in the European Union. *A. altissima* shows a pronounced adaptability to many warm-temperate environments. The dispersal of its winged seeds at considerable distances, the ability of its root system to generate numerous suckers and progeny plants together with the capacity to cope with a number of pedological and climate conditions, fostered the species, particularly following anthropic disturbance. *A. altissima* constitutes a relevant threat for natural ecosystems because of competition, reduction or local extinction of native species, habitat modification and ecosystem degradation. Effective management and control of *A. altissima* should be addressed to preserve the ecosystems' biodiversity. To achieve this goal, the Italian project USEit adopted a multidisciplinary strategy of investigation and monitoring of *A. altissima* invasion dynamics. The project focused 17 invasion locations in order to compare the center to the south of Italy, pursuing several aims: (i) to define the invasion geography; (ii) to investigate possible mycorrhizal mutualisms by means of isotope ratio mass spectrometry (IRMS); (iii) to understand the microbiota role in the specific evolution of increased competitive ability (EICA) by using metagenomic sequencing analysis of fungal and bacterial soil biocenoses. Partial findings from USEit are shown and compared to what is currently known on *A. altissima* mechanisms of invasiveness.

Keywords

Invasive alien tree species · Remote sensing · Carbon and nitrogen stable isotopes · Metagenomic sequencing analysis · Microbiome

1 Introduction

Alien plant species, generally, display their invasive character owing to multiple factors, which depend on ecological and physiological features (Blumenthal 2005). For instance, invasiveness may be supported by the lack of antagonistic species and by the capability to produce allelopathic compounds with inhibitory effects against native species (Hierro and Callaway 2003). Furthermore, the phytochemicals released by alien species may strongly impact native soil biota, favoring their own growth and establishment whereas reducing the growth potential of coexisting native flora (Stinson et al. 2006). Different proportions of release of the specialist enemies, which are co-evolved with native populations, might enhance the competitive ability of the aliens. In fact, several hypotheses have been invoked to explain the evolution of increased competitive ability (EICA) in invasive alien species (IAS). In addition to the explanatory option of the native enemies' deficiency, exhibiting an invasive behavior has been conceivably attributed to the "novel weapons" hypothesis (NWH) (Inderjit and Vivanco 2006). For instance, roots exudates containing toxic compounds can result in heavy limitations for growth and survival of native species. Furthermore, the invasion process is known to affect the soil microbiota, causing significant structural and functional changes within the soil communities (Badalamenti et al. 2018). In fact, to establish within a novel environment, an IAS should be capable to

M. Ciolfi · F. Chiocchini · P. Pollegioni · C. Volterrani · M. Lauteri (✉)
CNR-IRET, Porano, Terni, Italy
e-mail: marco.lauteri@cnr.it

E. Badalamenti · T. La Mantia
SAAF Department, University of Palermo, Palermo, Palermo, Italy

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modify the local biota, including microorganisms, for its own convenience.

Within this context, *Ailanthus altissima* (Mill.) Swingle is a well-suited study object, due to its considerable capability to invade new habitats. Its origin range belonging to south-east Asia, unfortunately the species was brought to the old continent around the mid-eighteenth century. It is currently considered as one of the most dangerous and widespread alien trees in the Mediterranean region. In fact, it is listed in Europe as a dangerous IAS. Several physiology and ecology explanations could be invoked to justify its prominent invasiveness and EICA against the autochthonous species: allelopathy; natural antagonists' release; impressive growth rates; high resprouting capacity; abundant seed production; remarkable drought resistance and strong recovery capacity following human disturbance.

Effective management and control of *A. altissima* should be addressed to preserve the ecosystems' biodiversity in invasion prone areas. To achieve this goal, the Italian project USEit adopted a multidisciplinary strategy of investigation and monitoring of *A. altissima* invasion dynamics. The project focused 17 invasion locations in order to compare the center to the south of Italy, pursuing several aims: (i) to define the invasion geography; (ii) to investigate possible mycorrhizal mutualisms by means of isotope ratio mass spectrometry (IRMS); (iii) to understand the microbiota role in the specific evolution of increased competitive ability (EICA) by using metagenomic sequencing analysis of bacterial and fungal soil biocenoses. In this short conference paper, we focus on some stable isotope ecophysiology assays and discuss preliminary results to support planned metagenomic sequencing applications on the complex microbiological interactions at the soil–root interface.

2 Materials and Methods

Three sites subjected to *A. altissima* invasion were sampled in central Italy, two in Umbria region and one in Lazio region. Three different ecological conditions, all falling into the meso-Mediterranean region, were represented: an historic park surrounding Villa Paolina at Porano (TR); an abandoned hardwood (walnut) plantation on an alluvial plane at Allerona (TR); an olive grove on the margin of an arable field nearby Bolsena lake, Bolsena (VT). In Sicily, southern Italy, we sampled 14 different invasion sites in between the provinces of Palermo and Enna, representing a range from thermo- to meso-Mediterranean climates and from natural (e.g., *Ficuzza* Natural Reserve) to heavily disturbed conditions (e.g., royal stables at the *Favorita* Estate, Palermo). Soil samples were taken at around 30 cm depth. Leaf samples were collected from *A. altissima* individuals and from further native tree species facing the invasive one. Whenever possible, local transects were defined in each sampling site to represent invaded, transitional and unaffected areas.

Carbon and nitrogen stable isotope ratios ($R = {}^{13}C/{}^{12}C$ and $R = {}^{15}N/{}^{14}N$, respectively) were determined by means of an isotope ratio mass spectrometer (Isoprime, GV, Manchester, UK) on CO_2 and N_2 obtained by Dumas combustion of dried leaf and soil sub-samples in an elemental analyzer (NA 1500, Carlo Erba, Milan, Italy). The carbon and nitrogen isotopic compositions ($\delta^{13}C$ and $\delta^{15}N$, respectively) were subsequently calculated for each sample adopting the current definitions (Farquhar et al. 1989) and referring to IAEA international standards on the VPDB and atmospheric nitrogen scales, respectively for $\delta^{13}C$ and $\delta^{15}N$. Percentage determinations of carbon and nitrogen contents were executed by means of elemental analyzer (NA 1500, Carlo Erba, Italy).

Next research plans concern metagenomic sequencing analysis of fungal and bacterial soil biocenoses that will be performed on fresh soil samples. These latter will be collected from a selected sub-set of sites and immediately stored in ice to be transferred to the laboratory. Particularly, DNA extraction and amplification of the ITS1–5.8S region of the fungal rRNA gene and of the bacterial 16S rRNA gene for metabarcoding analysis will be performed on the sub-set of sites, selected based on the stable isotope analyses.

3 Results

The results here shown are limited to the stable isotope analysis performed on the central Italy sites. Although the work is in progress and we still miss data from the complexity of the 14 southern Italy sites, the ecological diversity of the three sites in central Italy provides first information on soil organic carbon and total nitrogen contents, leaf nitrogen contents of *A. altissima* and associated species, $\delta^{13}C$ and $\delta^{15}N$ in soil and leaf samples, respectively.

Soil organic carbon results largely variable among and within the three sites, the highest value being 4.6% at Porano, in the not-invaded end of the invasion transect (dominated by *Tilia cordata* Mill.), and the lowest 0.9% at Bolsena in the transitional portion of the transect (dominated by olive trees). Following a highly significant positive relationship ($P \leq 0.01$; $r = 0.95$, df $= 6$), the soil organic carbon content across the three sites drives that of total soil nitrogen. This latter shows a range of values between 0.1 and 0.3%.

Values of $\delta^{13}C$ also show large among and within sites variations, both when determined on leaves of *A. altissima* and associated species (about 4.5‰ variation) and on soil organic carbon (about 2.5‰ variation). Interestingly, a positive linear relationship links $\delta^{13}C$ of soil organic carbon to leaf $\delta^{13}C$ ($P \leq 0.01$; $r = 0.61$, df $= 13$).

Concerning the observations of $\delta^{15}N$ in soil and leaf samples, once again large variations are observed although

a weaker positive relationship exists between the two parameters rather than that found for $\delta^{13}C$ ($P \leq 0.05$; $r = 0.54$, df $= 13$). Variations in soil $\delta^{15}N$ across sites and species are as large as 5‰ while those in leaves diverge about up to14‰. Looking at the apparent isotopic discrimination between the soil and the leaf $\delta^{15}N$, a parameter indicating possible microbiological effects on nitrogen uptake by the plant, once again a large variability is encountered among and within both sites and species. Interestingly, such an isotope discrimination against ^{15}N along the complex metabolism driving the nitrogen from the soil to the leaf is apparently dominated by the leaf $\delta^{15}N$, irrespective of the species. In fact, we observe a highly significant negative relationship linking the two parameters ($P \leq 0.01$; $r = -0.94$, df $= 13$). Finally, and interestingly, the soil to leaf ^{15}N discrimination appears to determine the leaf $\delta^{13}C$ of *A. altissima*, irrespective of the site ($P \leq 0.01$; $r = -0.97$, df $= 3$). The same does not appear for the native species coexisting with the invader.

4 Discussion

Although limited to three sites of invasion, the stable isotope ecophysiological analysis here presented is clearly propaedeutic to a subsequent application of metagenomic sequencing analysis of soil bacterial and fungal communities. In fact, metagenomics observations are expensive and time consuming in ecophysiological studies, thus requiring a previous assessment of site-specific conditions.

The stable isotope information in this work, while confirming previous observations on the remarkable plasticity of *A. altissima*, highlights for the first time in real environments, in our knowledge at least, a strict coordination between its carbon related primary productivity and microbiology driven nitrogen economy. Leaf $\delta^{13}C$ is a recognized proxy of water-use efficiency (WUE) in C_3 metabolism plants. Furthermore, variations in $\delta^{13}C$ can be addressed to several environmental drivers affecting stomatal or extra-stomatal photosynthesis limitations (Brugnoli and Farquhar 2000). In our study, we observed a close to 4‰ span in $\delta^{13}C$ comparing *A. altissima* leaves from three sites and five invasion conditions, indicating relevant intra-specific diversity in photosynthesis performance and WUE. On the nitrogen nutrition side, we observed diversity in apparent ^{15}N discrimination in the path from the soil to the leaf, with a range of values spanning from ^{15}N enriched to ^{15}N depleted leaves (Hobbie and Högberg 2012). While suggesting different microbiological effects at the rhizosphere interface, this diversity in soil to leaf ^{15}N discrimination is also negatively related to leaf $\delta^{13}C$, further suggesting that an enhanced ^{15}N depletion in leaves could correspond to a favorable photosynthesis performance in *A. altissima*.

5 Conclusions

The preliminary assessment of stable isotope ecophysiological conditions in several Italian sites invaded by *A. altissima* is a prerequisite for the selection of suitable sites for metagenomic sequencing analysis of soil bacterial and fungal cenoses. Accomplishing such a purpose within the USEit project could provide novel information on the EICA of *A. altissima.*

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Training Innovators of Sustainable Development: A Cornerstone Role of Science Dissemination Events

Rosanna del Gaudio

Abstract

Innovation is a crucial catalyst and driver for sustainable development, playing a vital role in the advancements and growth of twentieth-century society. Scientific and technological advances have significantly enhanced living standards and improved quality of life, boosting industrial productivity and competitiveness. However, the rapid expansion of industrial production has also led to increased consumption of energy and natural resources, resulting in environmental consequences that pose threats to ecosystems, including global warming and the overuse of energy, water, and land resources. Recently, educational systems across European countries have initiated innovative strategies to adapt to complex societal changes and address the challenge of improving citizens' educational levels to enhance the triple bottom line: economic, environmental, and social well-being. I developed, conceived, and proposed straightforward experimental interdisciplinary activities for science dissemination events, aimed at discovering and nurturing creative learners by enhancing their focused attention and inspiring teachers in their everyday teaching practices as well. Therefore, during the European Researchers' Night last year, the European Commission introduced the Researchers Schools actions by bringing researchers into schools, allowing teachers and students to exchange views with them on important current topics such as climate change, sustainable development, health, and diet. I have used flowers and natural foods to easily present abstract scientific concepts reinforcing the idea that biology, physics, and chemistry are present in our everyday lives, even if many remain unaware of it. Both educational outreach and game-based learning are gaining traction as effective means for engaging the public in scientific understanding. These approaches also serve to crowdsource solutions to problems related to molecular structures through puzzle games, inviting non-scientists to contribute to scientific research and various publications. To inspire a new generation of creative citizen scientists committed to sustainable development, I crafted a proposal for collaborative learning focused on teaching scientific concepts and fostering innovation.

Keywords

Innovators training · Innovative teaching STEM disciplines · Inquiry based science education and learning (IBSEL) · Science popularization · Sustainable development · Biodiversity · Sustainable science

1 Introduction

Sustainability problems (e.g., climate change, pollutions, waste, resource depletion) go beyond traditional national and sectoral boundaries. Cross-industry and cross-border collaborations on a global scale are indispensable and fundamental, to deal the global consequences of these challenges, to develop new circular productions. Sustainable entrepreneurs identify sustainability challenges and convert these into practical profitable business solutions.

Due to the growing global threats of climate change, pollution, and resource depletion, global sustainable entrepreneurship is becoming increasingly important (Kim and Coonan 2023).

In 2015, all United Nations member states unanimously adopted the 2030 Agenda for Sustainable Development. the 2030 Agenda for Sustainable Development. This Agenda is an action program for planet, people, and prosperity and, sets out 17 Sustainable Development Goals (SDGs), (Rieckmann 2017) which are an urgent call for action by all

R. del Gaudio (✉)
Department of Biology, University of Naples Federico II, Naples, Italy
e-mail: rosanna.delgaudio@unina.it

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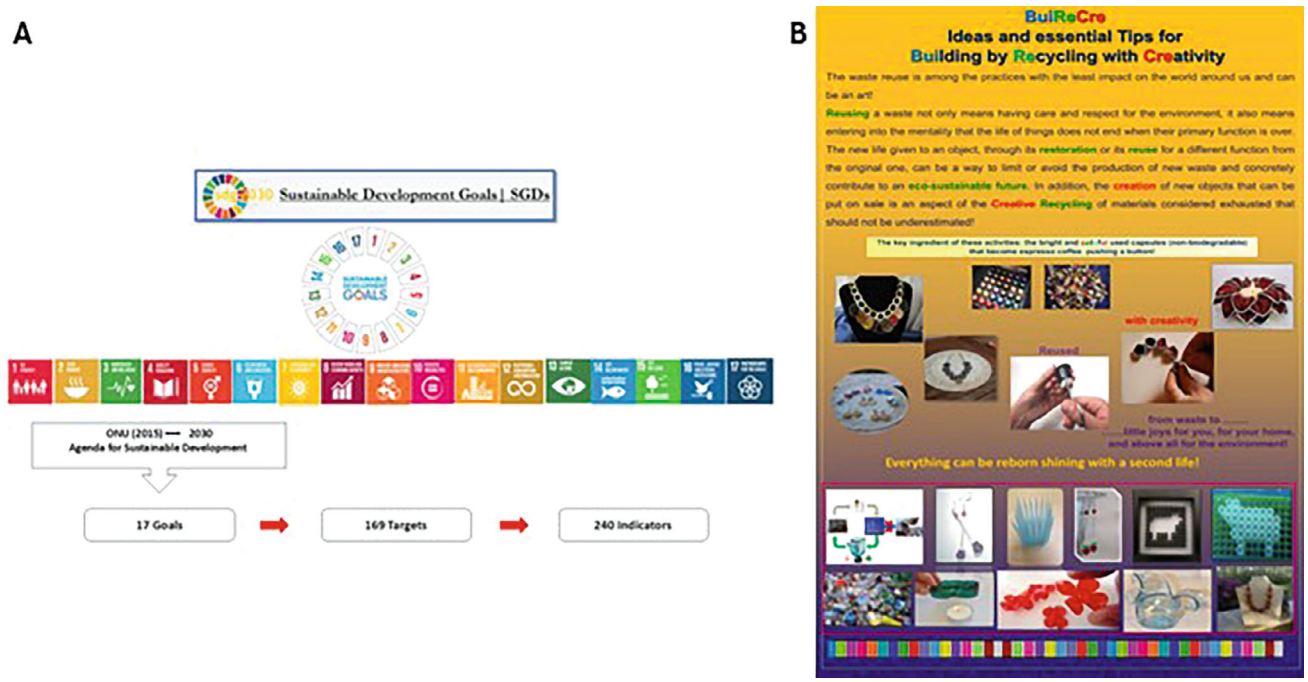


Fig. 1 Global commitment to eradicate extreme poverty, combat inequality, injustice, climate change, environmental degradation, and ensure prosperity and peace for all people by 2030 (Panel A). An example of poster showed during the outreach science events. The coffee capsules and plastics tips used in my laboratory have become earrings or necklaces or little joys for home (Panel B)

countries while also seeking to strengthen local and global peace in larger freedom aiming to end poverty, protecting the planet, and ensuring prosperity for all people by 2030 (United Nations 2023).

The SDGs cover a wide range of areas including poverty, hunger, health, clean water and sanitation, sustainable cities and communities, responsible consumption and production, climate action, life below water, life on land, peace, justice and strong institutions, and partnerships for the goals (Fig. 1). The SDGs assumes that sustainable development requires the integration of social, economic, and environmental dimensions, and that progress toward these goals will require collective action by governments, civil society, the private sector, and individuals around the world.

One of the key elements to reach these SDGs is the development of strategies to foster the SDG education at all education levels, but especially in higher education. Unlike the mono-thematic choices made so far, by decision of the United Nations General Assembly, last year (2022) was the international year of basic research for sustainable development, emphasizing that all types of basic research can (and should) contribute to the 17 SDGs included in the 2030 ONU Agenda. In Spain, Royal Decree 822/2021 (RD822/21), adopted in 2021 for regulating university teaching activities, establishes that professionals coming from universities must be able to lead transformations in line with the SDGs.

Equipping people with the values, knowledge, skills needed to pursue sustainable living and working practices is essential. Universities are the primary institutions for the dissemination of knowledge, through teaching, with a responsibility to educate the new generation of leaders, and for the generation of new knowledge, through research expertise, the intellectual capacity, and innovation skills. These aspects make universities essential players in achieving the Sustainable Development Goals and promoting sustainable practices through their operations and community outreach activities.

2 Overview of the Methodology

I conducted practical experiences as previously reported (Gaudio 2020; 36 Years of FUTURO REMOTO 2023) with students or citizen and specifically focusing on responsible consumption and production, well-being and good health. Visitors participating to science dissemination events were also formed through informative panels, not shown here on the specific and foundational issues of eco-sustainable development.

The additional goal of the dissemination activities was to design game and quizzes centered on SDG goals that the citizens played and solved in a collaborative manner.

3 Results

Education for sustainable development aims to enable people to participate in society's learning and communication processes for sustainable development. For this purpose, I have developed specific learning and educational activities conceived and presented during science dissemination events open to all citizens, therefore also to students of all age groups and their teachers, parents, etc. (Gaudio 2020; 36 Years of FUTURO REMOTO 2023). In the belief that meeting opportunities during science dissemination events can be useful not only as a showcase of my research activities, but that they play a cornerstone role in educational dissemination, both to discover and give focus on creative learners and both to promote innovation culture among their teachers.

Along these lines, therefore, within the European Researchers' Night Researchers, last year I participated to Researchers@Schools actions developed throughout the school year by bringing researchers into schools, allowing teachers and students to exchange views with them on important current topics such as climate change, sustainable development, health, or the diet. The two activities, entitled "From waste to resource: BuiReCre tips and tricks to build by recycling with creativity" and "Visual Food: fruits and vegetable as educational and learning tool promoting healthy eating" were realized, respectively, within the XXX and XXXII edition of "FuturoRemoto," the first manifestation of Science and technological culture dissemination that focuses each year, in Italy, since 1987 on a peculiar mono-graphic theme (36 Years of FUTURO REMOTO 2023).

3.1 From Waste to Resource: BuiReCre Tips and Tricks to Build by Recycling with Creativity

BuiReCre, we build by recycling with creativity, fits in the "building" theme chosen for the XXX edition of FuturoRemoto (36 Years of FUTURO REMOTO 2023), making its foundations and the absolute principle of respect for the environment its own, which looks to eco-sustainability and the rationalization of consumption as essential elements of the Smart cities contest. The new life given to an object, through its restoration or its reuse for a function different from the original one, can be a way to limit or avoid the production of new waste. In addition, the creation of new objects that can put up for sale is an aspect of the creative recycling of materials considered exhausted that should not be underestimated. The categorical imperative to follow will be: "From waste to resource"! So much so that even the European Community has embarked on a path that considers reuse as one of the main models for the development of the Union. Various topics will be tackled step by step, from the research of materials to the organization of the workstation and of the necessary equipment, to the techniques for stimulating creativity which is the basis of every project that one wants to start, to the application with the in practice some ideas, up to the topic of selling creations, from direct sales to e-commerce. In the specific case, of coffee capsules and plastics tips used in laboratories have become jewels, necklaces, earrings (Fig. 1, Panel B). BuiReCre's aim was to raise everyone's awareness to play their part, first universities and researchers, for a cleaner world. It is ethically right and convenient because recycled materials can become a source of wealth: resources and no more waste!

3.2 Visual Food: Vegetable and Fruits as Learning and Educational Tools Promoting Healthy Food-Lifestyle

An interactive laboratory to discover that our well-being begins with eating with a look at the most recent discoveries in nutrigenetics and nutrigenomics. From the kitchen to the laboratory, from the calories to the molecular nutrients several educational strategies have been designed involving games and related activities with the aim of increasing awareness that our destiny is written in DNA of each of us, but this can be modified epigenetically, i.e., not by affecting the DNA sequence, but by modifying the molecules that are "bind" to it. Furthermore, the goals were also to improve student performance in topics related to molecular biology and the relationship between food, cells, and DNA and of how to choose and combine foods to obtain the best results and improve the "defective" genetic aspects. This is because foods are not just energy and nutrient molecules!

4 Discussion

Here, I report first record that the promotion of human development can also be achieved through the incorporation of the SDG in the contexts of science dissemination events in which the audience is large and contains citizens of all age groups. The preliminary results of my study could be an example of integration of the SDGs also in the context of Science Dissemination events. Education for sustainable development involves educating citizens of all ages to take responsibility and create a sustainable future ensuring that by 2030, all have education for sustainable development (ESD), the skills and knowledge to achieve sustainable development (SD), sustainable lifestyles, gender equality, global citizenship, peace and cultural diversity (Kioupi and Voulvoulis 2019). Universities play a key role in promoting such education through their functions of education, research, and dissemination for sustainability.

5 Conclusions

Through their sustainable teaching, research, outreach, and practices and, by integrating the SDGs into their curricula and practices, universities can prepare students to meet global challenges contributing to sustainable development in their communities and around all the world. My proposal, here presented and shared is that active learning methodologies such as during science dissemination events are to be considered as interesting additional options for approaching SDG and increasing the awareness of higher university students, and citizen in general on these themes.

The idea of administering questionnaires and/or games centered on the SD Goals during Science Dissemination Events has all the necessary requirements to achieve the desired results. There is still no evidence that the expected results will be achieved. Future work will allow for this verification.

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Innovative Monitoring of Human Health Using a Geographic Information System (GIS) Applied to *Oreochromis niloticus* (Actinopterygii, Cichlidae) in Manzala Lagoon (Egypt)

Rubina Vangone, Samah M. Bassem, Salvatore De Bonis, Noureddine Guezgouz, Marco Trifuoggi, Loredana Assisi, and Fagr Kh. Abdel-Gawad

Abstract

This work aimed to propose an innovative approach applied to a fillet of representative edible lagoon fish and useful for human health assessment, monitoring and alert. The census of two sites of Manzala Lagoon (Egypt) was performed by a morphological and molecular approach; the selection of the fish on the basis of its numerousness and resistance to contaminants and the fillet bioaccumulation of metals (Mn, Ni, Cu and Zn) measured by inductively coupled plasma mass spectrometry (ICP-MS). Potential health risk indices assessment was evaluated by standard math equations. Subsequently, graphical representations of metals bioaccumulation and carcinogenic risk (CR) were created using the Geographic Information System (GIS) tool. Fish biodiversity of two sites is relatively rich (9 orders, 11 families, 18 genera and 21 species) and show a common invasive species *Oreochromis niloticus* (Actinopterygii, Cichlidae). Colour-coded GIS maps of two sites show that metal bioaccumulation and potential health risk of CR values pose no appreciable risk in tilapia at the two sites examined. These findings highlighting the evaluation as example of innovative GIS evidence of *one-health* assessment call for greater efficiency and accuracy in chemical exposure assessments and harmonization of data collection needed to conduct human health-prevention culture assessments.

Keywords

Culture of prevention · Geographic information system (GIS) · Heavy metals · One-health · *Oreochromis niloticus*

Loredana Assisi and Fagr Kh. Abdel-Gawad—These authors are contributed equally.

R. Vangone (✉) · L. Assisi
EClab, Department of Biology, University of Naples Federico II, Naples, Italy
e-mail: vangoneeclab@gmail.com; rubina.vangone@unina.it

S. M. Bassem · F. Kh. Abdel-Gawad
Water Pollution Research Department, Centre of Excellence for Advanced Sciences (CEAS), National Research Centre, Dokki, Giza, Egypt

Center of Excellence for Research and Applied Studies on Climate Change and Sustainable Development (C3SD-NRC), National Research Centre, Dokki, Giza, Egypt

S. De Bonis
Regional Agency for Environmental Protection of Latium (Arpa Lazio), Rome, Italy

N. Guezgouz
Department of Biology, University of Mohamed Cherif Messaadia, Souk-Ahras, Algeria
e-mail: n.guezgouz@univ-soukahras.dz

M. Trifuoggi
Department of Chemical Sciences, Federico II Naples University, Naples, Italy

F. Kh. Abdel-Gawad
Mediterranean and Middle East Universities Network Agreement (MUNA), Dokki, Egypt

1 Introduction

Aquatic ecosystems are strongly influenced by human activities that alter the quality of water, sediments, and the well-being of living organisms (Panda et al. 2023). In particular, heavy metal contamination in aquatic habitats raises global concerns due to their toxicity, durability, slow decomposition and rapid accumulation characteristics (Piscopo et al. 2018). The metals absorbed in fish can represent an important risk factor for the onset of numerous pathologies for them and for those who eat them. Since fish is a staple food in world diets, when contaminated, they cause harmful effects such as behavioural problems, kidney damage and

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cancer, widely documented in humans (Panda et al. 2023; Piscopo et al. 2018). In the last decades, in addition to the evaluation of the metal content in water and sediments, the evaluation of the bioaccumulation in the species of aquatic ecosystems has also been added. Recently, moreover, there has been a focus on the edible species of the lagoons which, as we know, are an important heritage for the conservation of biodiversity, for productivity and a source of natural resources (Parisi et al. 2022). In fact, despite their unique qualities, they are little studied both as regards species discrimination and as regards the bioaccumulation of contaminants such as metals. For this reason, our objective was to survey the species present in the Manzala Lagoon and to evaluate and monitor the impact of metals on one of the representative fish species of the Manzala Lagoon and in other Egyptian Mediterranean lagoons in different sites. Furthermore, the Geographic Information System (GIS) was used for the first time, applied to the bioaccumulation of metals and the potential carcinogenic risk in the fillet of a bioindicator fish species.

2 Materials and Methods

The initial sites chosen for the study in the Manzala Lagoon were: Alhomra (31° 18′ 00.0″ N, 32° 00′ 00.0″ E; site A) and Bahr Kromlos (31° 16′ 00.0″ N, 32° 03′ 00.0″ E; site B), about 6 km away from each other and located about 10 km from the coast facing the Mediterranean. The census of the fish present was carried out by analysing the dichotomous keys of the species, looking for the aspects attributable to the family, genus and species. Furthermore, molecular identification was carried out following reported in Di Finizio et al. (2007), for all the samples of dubious taxonomic classification. The concentration of the following metals Manganese (Mn), Nickel (Ni), Copper (Cu) and Zinc (Zn) was estimated by inductively coupled plasma mass spectrometry (ICP-MS) on 1 g of fish fillet ($n = 25$ fish/site) (Tramice et al. 2021; Guezgouz et al. 2021; Pecoraro et al. 2018). Subsequently, it was calculated the estimated of daily intake (EDI) in an adult of 70 kg, with a food ingestion rate (FIR) of ~ 64 g. To detect the potential toxic risk for public health, related to exposure to heavy metals during life, we calculated the target hazard quotient (THQ). Furthermore, the risk index (HI), i.e., the sum of the THQ values of all tested heavy metals and the carcinogenic risk (CR) was calculated as Panda et al. (2023). The indices were then used in an innovative way to create graphical representations of the spatial distribution of heavy metal concentration from fish fillet samples and carcinogenic risk.

3 Results

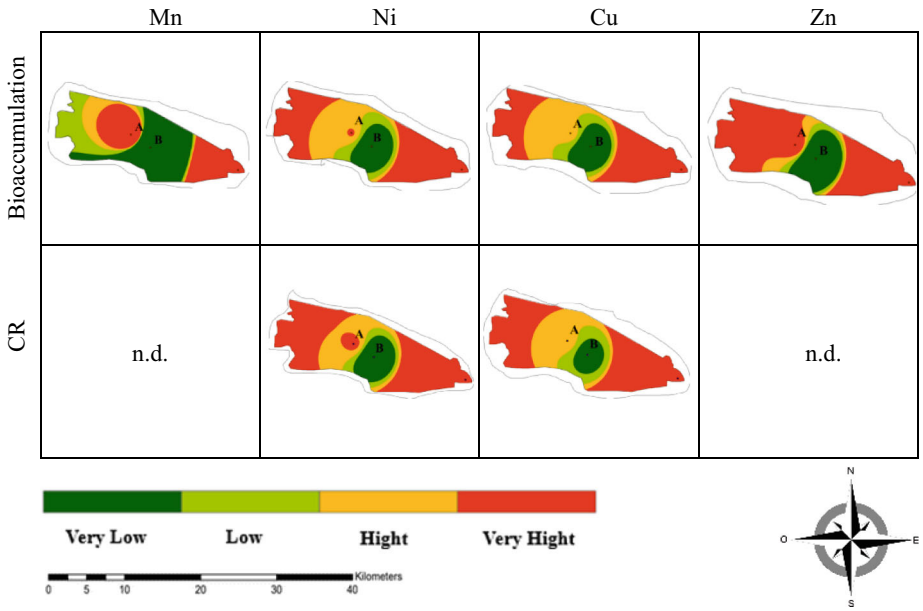
The species sampled in the Manzala Lagoon include 9 orders, 11 families, 18 genera and 21 species. The species belong to the order Anguilliformes, Beloniformes, Cyprinodontiformes, Mugiliformes, Pleuronectiformes, Siluriformes ($n = 1$ species/order), Cypriniformes ($n = 3$ species/order), Cichliformes ($n = 4$ species/order), Perciformes ($n = 8$ species/order) and 11 families (Anguillidae, Cichlidae, Clariidae, Cyprinidae, Hemiraphidae, Latidae, Moronidae, Mugilidae, Poecilidae, Soleidae, Sparidae). Among the Hemiraphidae, the Lessepsian species, *Hemiramphus far* (Forsskål, 1775; GenBank, accession number COI: OQ387646.1) has been identified and among the Poecilidae, the species of Atlantic origin, *Poecilia latipinna* (Lesueur, 1821; GenBank, accession number COI: HQ573356.1). Among the local species resistant to contaminants and invasive was the presence of *Oreochromis niloticus* (Linnaeus, 1758; GenBank accession number COI: KU565824.1) belonging to the Cichlidae and commonly known as tilapia. The estimation of metals and the graphical visualization of the risk indices shown, is shown in Table 1 by GIS in tilapia. By comparing the two sites, the bioaccumulation data show that the concentration of Mn, Ni, Cu and Zn is higher in site A than in site B. Comparing instead, the concentration of each metal for a single site what can be seen is that both in site A and in site B: Zn > Mn > Cu > Ni (data not shown). The CR potential is reported only for Ni and Cu, as there is no Cancer Slope Factor (CSF) for Mn and Zn, and has higher levels for Ni in site A.

4 Discussion

In order to propose an innovative approach for the control of human health and with it the health of the edible fish species in the Manzala Lagoon, we estimated the risk indices relating to the metals examined after census the species with a morphological and molecular approach. Biodiversity was found to be relatively rich and tilapia was selected among the species of socio-economic interest (Parisi et al. 2022) because it is more resistant to contaminants and highly invasive and therefore chosen as a bioindicator (Abdel-Gawad et al. 2020).

The graphic visualization of the metals, shown in Table 1 by Geographic Information System (GIS), highlights different colours according to the concentration of the metal. What emerges is that, even if the scale of metal concentrations in the two different sites is similar, the concentration of each metal is different and its impact on

Table 1 Geographic information system (GIS) of metals bioaccumulation and their potential carcinogenic risk (CR).



Site A: Alhomra (31° 18′ 00.0″ N, 32° 00′ 00.0″ E)
Site B: Bahr Kromlos (31° 16′ 00.0″ N, 32° 03′ 00.0″ E)
n.d., not detected
Mn and Zn has not been determined because their Cancer Slope Factor has not yet been established

human health is different. This explains how it is important to know not only the sampling site of the edible species but the depth at which they are fished. This innovative approach could be applied after estimating other contaminants such as drugs, pesticides, etc. and prove the importance of fish as bioindicators of human health (Chabchoubi et al. 2023).

Exposure to contaminants such as metals can increase the likelihood of cancer or carcinogenic risk (CR) over the course of a lifetime. According to USEPA (2012), the potential carcinogenic risk induced by Mn and Zn cannot be estimated since their cancer slope factor (CSF) has not yet been established. In our study, the concentrations of metal bioaccumulation in tilapia fillet are well within the limits of tolerability with the exception of Ni in site A, whose value is very close to the cutoff value.

Further, CR values pose no appreciable risk in tilapia at the two sites examined resulting negligible for Cu and acceptable for Ni.

5 Conclusions

Our study proposed, for the first time to our knowledge, the application of the Geographic Information System (GIS) to the potential risk of cancer consuming tilapia fillet, an invasive species selected after the census of fish present in the Manzala Lagoon. Although this application example shows results from only two sites in a lagoon, it allows realizing the potential of GIS. The display of colour maps, in fact, is able to alert, if necessary, institutions, public safety bodies and the population and consequently avoid, prevent, and mitigate risk situations. Furthermore, the large-scale construction of numerous sites in the lagoon over time will allow accurate maps capable of activating the culture of prevention and protecting and/or restoring the health of the waters, species and human health.

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Housing for Migrants. Naples as an Inclusive City

Claudia Sansò and Renato Capozzi

Abstract

The article provides a summary of research on the reception of foreigners in Campania, particularly in Naples, with regard to housing and collective spaces. More than half of the foreigners living in the Campania region (129,453, 51.3%) reside in Naples. The data reveal an urban territory that is predominantly inhabited from third countries and has a problematic reception spaces situation that hinders social integration. Most live in groups of three or four in uninhabited houses rented from private individuals and dispersed throughout the province, frequently in its periphery. In the research, the city of Napoli is used as a laboratory for experimenting with an "autonomous" housing unit as suggested by the Action Plan for Integration and Inclusion 2021–2027, promoted by the European Commission, which, in defining measures to build more cohesive and inclusive societies for all, places the issue of housing and settlements for migrants within a broader series of actions to implement the plan. Specifically, the survey focuses on North African migrants, especially those from Morocco, who (according to ISTAT 2022 data) rank third in the region after Ukraine and Romania. In addition to the housing crisis, the question of multireligion as a migration issue was also included in the survey, which led to the decision to focus the research on Moroccan immigrants. Therefore, affiliation with a particular religious matrix was also considered in the research, as this is a determining factor of the reference culture. The Islamic faith practiced by Moroccan immigrants draws attention to the issue of places of worship and, consequently, the construction of mosques for the purposes of greater integration. The research focusing on the Italian reception and integration system (SAI) proposes settlements for migrants in certain areas of the city of Naples where residences are in close proximity to both production and work spaces as well as collective spaces capable of holding together the scale of architecture and that of the city in order to build a close relationship between migrants and local inhabitants.

Keywords

Hospitality · Migration · Multi-ethnicity

1 Introduction

The paper deals with departmental research on the issue of migrant housing in the city of Naples, Italy, where there is a large and deep-rooted presence of North African migrants (Capozzi 2018). In particular, the large Moroccan community occupies with commercial activities an area close to the main railway station of the city, where one of the mosques (built in a former warehouse) of the Neapolitan Islamic community is also located (Amato et al. 1995).

However, the housing situation is unclear: the generations that have been living there the longest are renting because the housing market does not allow them to access mortgage financing to buy a house. The most critical issue, however, concerns new arrivals, which continue to grow. For the second reception of new migrants, the direction of the Ministry is to entrust cooperatives with the management of housing. These cooperatives rent houses from private individuals in various parts of the city, even in peripheral contexts, and use them to organize residences for migrants in "communal houses." Each accommodation consists of several rooms, each of which accommodates three to four people.

The research begins with the transformation of these "dormitories" into self-sufficient housing based on the Euro-

C. Sansò
University of Trento, Trento, Italy

R. Capozzi (✉)
University of Naples, Naples, Italy
e-mail: renato.capozzi@unina.it

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pean Commission's directives regarding the integration of third-country nationals.

In 2016, the European Commission adopted a plan that among specific measures includes: language education and training, employment and vocational training, social inclusion, and access to basic services such as housing.

In 2020, the European Commission presented a new EU Action Plan for Integration and Inclusion (2021–2027) and it builds on the results of the 2016 Action Plan by strengthening, at least in its intentions, housing policies by indicating that residential units must necessarily be self-contained and not constitute dormitories.

2 Research Methodology

The investigation into the second reception of migrants in Naples commenced by examining the most recent data from ISTAT (2022). This analysis aimed to determine the specific migrant groups on which the study would focus. In accordance with the research department's guidelines, the project involved the creation of an architectural model for a residential complex that incorporated both communal and public areas.

Based on the data analysis, it can be observed that the Moroccan community ranks third in the Campania region, preceded by the communities of Ukraine and Romania. Furthermore, the Moroccan community holds the second position as a community originating from a non-European Union country. Furthermore, the decision to administer the survey in a North African country holds greater importance in terms of scientific research, as it contributes to the advancement of public and communal infrastructure, as well as residential environments. One potential solution to address the issue of multi-religiosity in the city of Naples is to allocate space within a mosque (Sansò 2020) building for migrants, even if it is situated in a different area of the city. This approach aims to address the specific needs of the densely populated Islamic community, which currently faces a scarcity of suitable worship spaces.

For the development of the project, projects of migrant settlements built in different cities, based on a tissue of houses and collective spaces, were studied and analyzed typologically.

The shelter for Migrants and Travelers by Atelier RITA[1] is located on the banks of the Seine River in a suburban area. The complex is designed to be self-sufficient, providing migrants with suitable housing for a duration of up to six months. Additionally, it offers communal areas where migrants can engage with one another. The project is structured based on a spatial hierarchy, with the residences located on both sides of the central axis, and the communal spaces such as the canteen, meeting area, and children's play areas situated in the center.

SOS Children Villages represent very interesting cases from the point of view of settlement layout.

Bawana Village, India, is a facility built for orphans after World War II. Each village consists of a director's house, clinic, library, community hall, service buildings, and twenty houses. Each house houses eight children and a mother.

This small campus is designed around the central square of the village. Four gates run through four squares, which in turn lead to the courtyards of the five houses. In this way, the campus is designed as a hierarchy of social spaces, where a child can find his or her own comfort, alone in his or her bedroom reading, in the family courtyard or common room playing, in the neighborhood square or in the village square.

Another case study analyzed was the SOS Children's Village in Djibouti, designed by Urko Sanchez with a "medina" floor plan.

The design includes 10 housing units, each housing 10 children and a dedicated staff member, the so-called "mother," as well as an additional unit for services, two more for staff and a guesthouse for visitors.

Just as in the traditional medina, it is the hierarchical grades of space that structure the complex. The only fully enclosed volumes, with four walls and a roof, are the most intimate and inclusive spaces: the bedrooms, bathrooms, and staff offices. These modules are arranged around open spaces: streets and courtyards.

These case studies guided the research in developing the architectural design: a square with twelve housing modules on each side facing a large courtyard, the meeting space for all migrants.

3 Results

The idea of the settlement unit underwent a comprehensive process of development, which can be identified into three distinct levels:

1. a territorial level that identifies in the eastern region of Naples an axis running from the seaport to the slopes of Vesuvius. The hypothesis posits that there will be a significant concentration of production-related spaces and equipment in close proximity to this axis, emphasizing the connection to work. The suburban region under examination exhibits distinct features such as abandoned industrial facilities, agricultural land, and tertiary infrastructure. It serves as a significant employment hub for numerous migrants (Fig. 1);
2. an urban level that perimeters the area of interest between the port, the area near the central train station, and an area further east that borders the municipality of S. Giovanni

[1] https://www.archdaily.com/901650/shelter-for-migrants-and-travelers-atelier-rita.

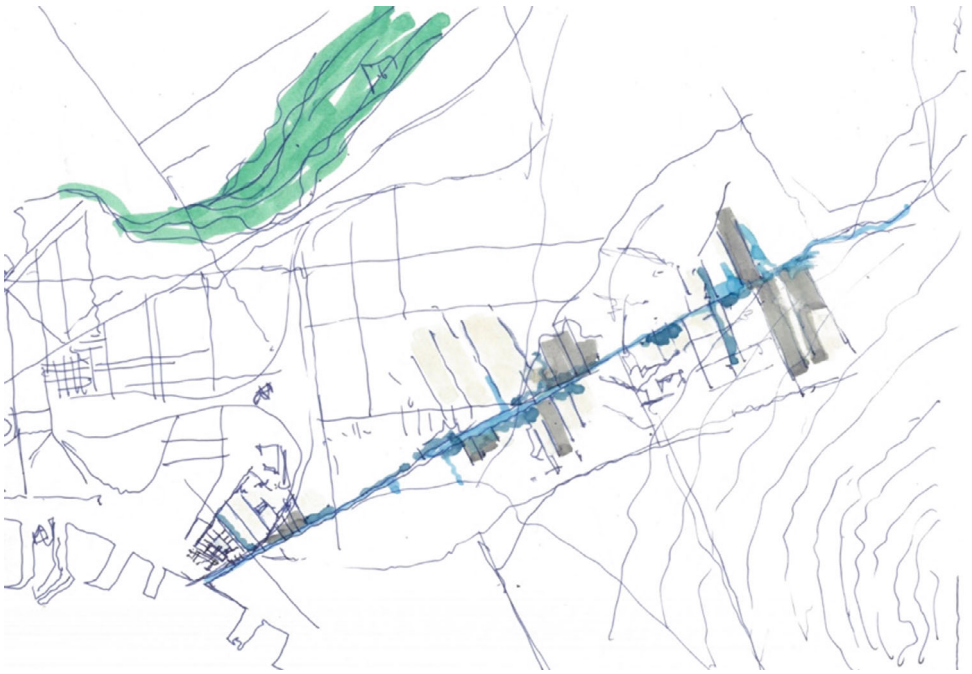


Fig. 1 Hypothesis of the migrant settlement unit—territorial level (drawing by R. Capozzi)

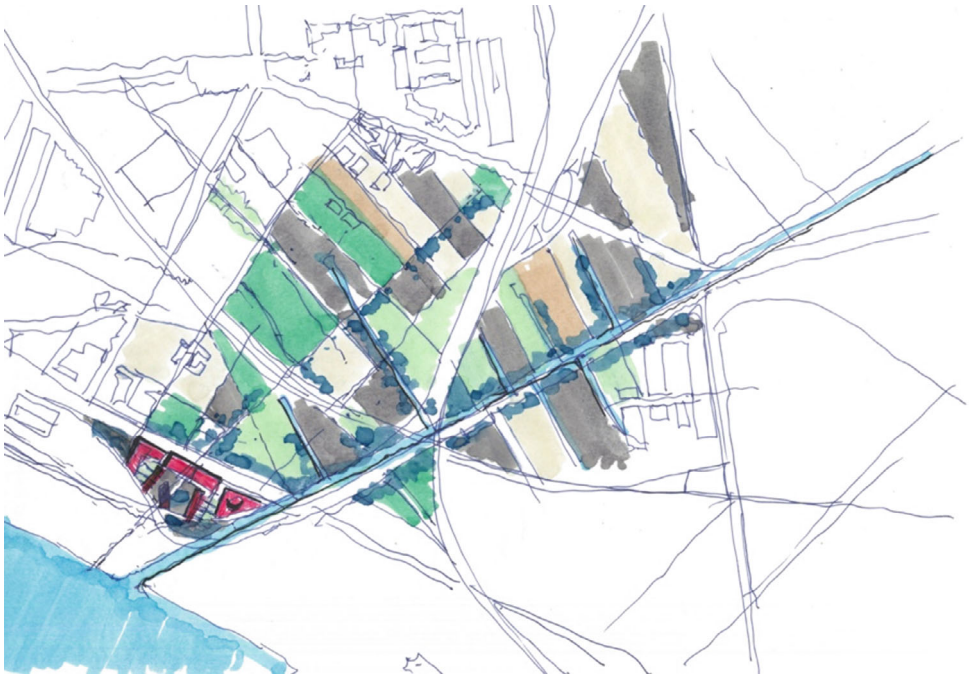


Fig. 2 Hypothesis of the migrant settlement unit—urban level (drawing by R. Capozzi)

a Teduccio. In this area, the settlement unit related to residences and some collectives—a newly established mosque—(Sansò 2020) and public spaces—a building for educational activities—related, for example, to learning the Italian language, and a market for handicrafts made by migrants) is developed on the port quay. In contrast, the area along Via Argine includes green spaces (agricultural and equipped) and water channels (Fig. 2);

3. an architectural level relating to the complex of residences, identifies—as another solution—in the "horizontal" courtyard unit a set of houses to be assigned to each family or individual in the case of smaller ones (Fig. 3).

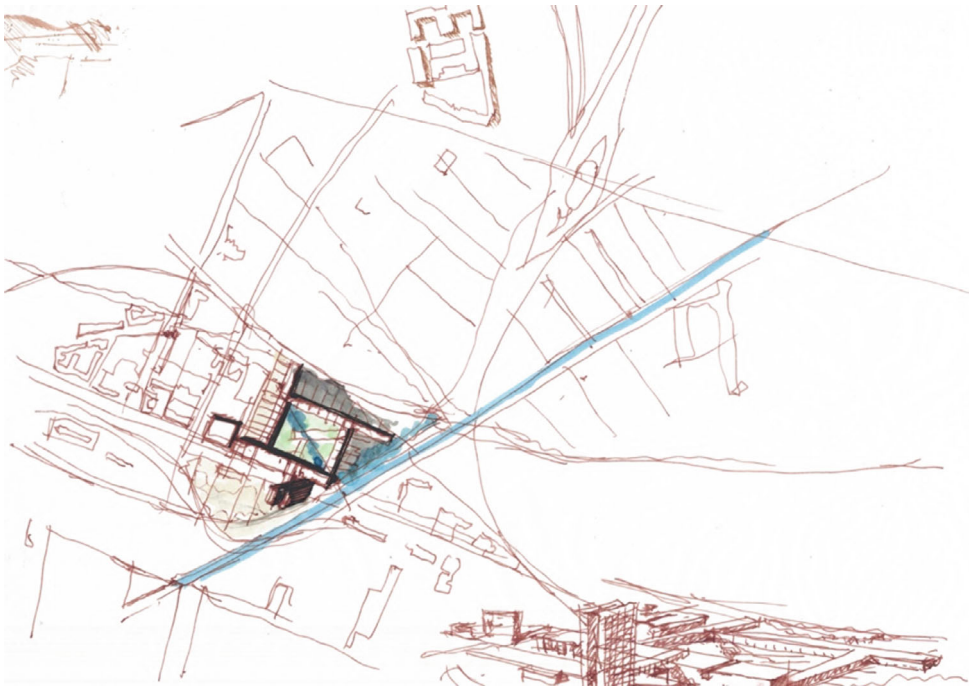


Fig. 3 Hypothesis of the migrant settlement unit—architectonic level (drawing by R. Capozzi)

4 Conclusions

The research aims to show a pilot project of a settlement for migrants (Sansò 2022) that is not only limited to solving a housing problem but poses other issues such as expansion to an urban and territorial scale that considers the inclusion of migrants in the labor market, the possibility of having collective and public spaces. In this way, the project becomes a way to redevelop a large area of the city of Naples, ranging from the center (port area) and extending into the eastern suburbs. This broader dimension of the project, which takes into account several factors, makes it possible to imagine the settlement for migrants from the perspective of integration and inclusiveness on the part of the host city.

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Technological Change and Food System: What Future for the Mediterranean Diet

Valeria Sodano

Abstract

Over the last years innovation patterns within the food system have concurred to align the food production and consumption activities to the current technological paradigm, i.e., the information and communication technology (ICT) paradigm. Shifts to new technological paradigms may produce a sudden disruption of pre-existing technological and cultural structures. The goal of the study is to assess the risks posed by the ICT paradigm to the preservation of the Mediterranean diet. The effects of technological change on the Mediterranean diet were investigated relying on four strands of literature: food regime approach; theories of technological change and innovation; food system digitalization; food sovereignty. Applications in the field of nanotechnology and AI were brought as emblematic examples of innovations affecting the Mediterranean diet. The results demonstrate that current technological changes may negatively affects the following features of the Mediterranean diet: eating habits, traditional production technologies, cultural heritage, environmental landscapes, food awareness and knowledge. Such negative effects depend upon the process of further food industrialization induced by ICT, with the weakening of rural communities and the loss of knowledge concerning traditional agricultural practices and food preparation and conservation.

Keywords

Technological change · Innovation · Digitalization · Nanotechnology · Mediterranean diet · Agroecology · Food sovereignty

V. Sodano (✉)
Department of Political Science, University of Naples Federico II, Naples, Italy
e-mail: vsodano@unina.it

1 Introduction

Over the last years innovation patterns within the food system have concurred to align the food production and consumption activities to the current technological paradigm, i.e., the information and communication technology (ICT) paradigm. Shifts to new technological paradigms may produce a sudden disruption of pre-existing technological and cultural structures and may radically change food consumption patterns. The goal of the study is to assess the risks posed by the ICT paradigm to the preservation of the Mediterranean diet (MD). The theory of technological innovation and the recent literature on the digitization of food systems were used to evaluate the possible survival of the MD.

2 Settings

The term "technological paradigm" refers to the concept introduced by Freeman and Perez (1988) within their theories of technology systems and technological revolutions. The latest revolution, which ushered the world economic system into the current ICT technological paradigm, has been determined by the propulsive force of ICTs, and follows the previous petrochemical technology-based revolution (Sodano 2019). The concept of technological paradigm is useful to understand three features of the innovation processes occurring in the food system: (1) current innovations are mainly "science pushed" instead of the demand pull innovation patterns experienced in the previous period; (2) innovations come as spillovers from innovation in other fields (such as military, energy, and computer science), which means that they need a strong positive narrative for being accepted as socially useful; (3) since they are the effect of a change of paradigm and therefore the concept of technological lock-in applies (David 1993), the ICTs-based innovations are likely to succeed and preclude alternative innovation trajectories,

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such as for example the possible ones based on agroecology and ecocentrism instead of techno-centrism-(Sodano 2019).

Food systems are surrendering to the ICT paradigm through the so-called process of digitalization of the system (Rejeb et al. 2022). Digital innovations include a wide array of applications (Digitalisation and Artificial Intelligence for sustainable food systems, 2022; Runck et al. 2022), spanning from the agricultural sector (genome edited seeds, smart tractors, farm management platforms) to the manufacturer (digital marketplaces, robotics, smart packaging) and distributive sector (quality sensors and analytics, automated warehouses, smart shopping, digital tools for commodity chain traceability and transparency). All such innovations are going to radically change not only the way in which food is produced and distributed but also the conception and perception of food and food habits by society.

3 Results

Historians recognize three major revolutions that affected agriculture. The first agricultural revolution took place around 10,000 B.C. and marked the transition from a hunting-and-gathering society to one based on stationary farming. The second agricultural revolution refer to a long period spanning from 1600s to 1900s, and partially overlapping with the first and second industrial revolution, that witnessed increasing agricultural yields due new farming techniques, such as crop rotation, improved livestock utilization, modern agricultural machinery. The third revolution, called the green revolution, which occurred from the 1940s till the late 1970s, was characterized by the widespread use of chemicals and new hybridized seed varieties. The green revolution went together with the rise of the food system, i.e., a system of food production and distribution based on a caesura between agricultural production and places and ways of food consumption, with the birth of food styles based on the prevailing consumption of processed foods instead of fresh and home-prepared foods.

The MD is a rich and nutritious diet that developed from the combination of economic and trade development in the period of the second agricultural revolution with the favorable environmental conditions and the peasant food culture of the Mediterranean area. The "discovery" of MD as a food model was due to the birth of the modern nutrition science and to the growing evidence in the field of medical research of the negative effects on human health of high-calorie diets rich in ultra-processed food. The definition and codification of the MD, which took place after the publication in the seventies of the thirty-year seven countries study (Trichopoulou and Lagiou 1997; Menotti and Puddu 2020), took place when the DM was on the way to disappearing as a real eating habit, as a result of the birth of modern food systems. Since the eighties many studies have demonstrated the beneficial effects of the MD (Mozaffarian 2020). Over time, three characterizations/uses of the diet have emerged: MD as a health policy tool for the definition of nutritional advice (food pyramids); MD as a research field of nutritional science for the study of individual nutrients and their effects on human health; MD as a cultural beyond nutritional model. UNESCO when declared the MD an "intangible cultural heritage of humanity" in 2010 endorsed the third definition/characterization, which is the one used in this study to assess the risks posed to MD by the ICT paradigm. According to UNESCO definition "the MD—from the Greek word díaita, lifestyle—is a social practice based on the set of skills, knowledge, practices and traditions ranging from the landscape to the cuisine, which in the countries of the Mediterranean culture concern the crops, harvesting, fishing, conservation, processing, preparation and, particularly, consumption." Such a definition endorses a holistic and socio-cultural approach to eating habits, opposed to the other two characterizations which lean toward the technologization and medicalization of food consumption.

Table 1 identifies the main features of the MD consistent with the UNESCO approach and assesses the likely disruptive effects (more crosses indicate a stronger effect) of four groups

Table 1 Examples of innovations negatively affecting the MD

	Examples of ICT innovation			
MD features	Nanotech. Smart packaging	Bioengineering Novel foods	Nanoencaps. Enriched/enhanced food	AI Eating applications
Traditional technologies	+	+++	+++	+
Holistic conception of diet	+++	+++	+++	+++
Tradition and cultural heritage	+++	+++	+++	+++
Fresh/raw materials-based food	+++	+++	+++	+
Minimum processed food	+++	+++	+++	+
Free access to food technologies	+	+++	+++	+++
Food awareness and knowledge	+++	+++	++	+++
Rural landscape preservation	++	+++	++	++

of ICT paradigm-related innovations. Two examples are taken from the long list of nano-innovations that are entering the food market.

The first refers to smart packaging, used to signal the freshness of a food product, extend its shelf life or to enable AI supported traceability systems. The second refers to the nanoencapsulation techniques used for enriched and nutraceutical food products. The other two examples refer to the wide field of bioengineering technologies that are allowing the development of novel foods, such as plant meat, and to the field of artificial intelligence (AI), which is producing innovations such as the eating applications used as virtual nutritionist assistants (Devecchi et al. 2023). All these innovations push toward food habits very far from the MD, based on: a hyper technologization of the food system; a wider consumption of ultra processed foods (Katidi et al. 2023); the transfer of food knowledge from people to the algorithms created by multinationals controlling the digital market (Zuboff 2019).

4 Discussion

The ongoing process of food system digitization within the ICT technological paradigm hampers the survival of the MD as a food pattern possibly followed by a large portion of population at least in the Mediterranean area. The current wave of innovation is disrupting some of the basic features of the MD: the prevalence of fresh and raw products instead of ultra processed food; the link between agriculture, rural communities and food consumption; the control of individuals on their diet, in term of affordability and knowledge (this latter in term not only of nutrients but also in terms of production and preparation processes); food behavior as a simple, relaxing activity, and not some kind of fitness/health race based on the best algorithm. Critical literature on technological change helps to highlight the risks of the high-tech, lab-made food offered by the ICT paradigm. While agribusinesses are selling their innovations under the umbrella of the sound science-based sustainability narrative, scholars like Noble (1997), questioning the myth of technological determinism, have clearly showed that there is not one best technological trajectory and that the scientific work depends on the same profit and power-driven motivations that shape actions and behaviors in capitalistic systems. Literature on food regimes (Friedmann 1987) has described how different technological systems shape power relations within the food system giving rise to food regimes, which are hierarchical production structures scoring low with respect to fairness and equality. Advocates of more democratic food systems, such as food sovereignty activists, recognize the non-neutrality of technological innovations and urge a case-by-case evaluation of innovations strongly based on criteria of social justice. Supporting the MD as a viable alternative to the rising ICT food regime may be a reasonable way to attain true sustainable food systems, where social sustainability, in terms of equity and democratic control is taken into the due account. In order to protect the MD as a public good available for the entire community, the following suggestions should be taken into account: developers of new technologies should consider their adaptability to rural environments and small farms; education policies should promote a widespread knowledge of food production, preservation and preparation techniques; public research for innovation should be directed towards technological paradigms, such as agroecology, which are more compatible with the MD; the concept of food sovereignty, which is in line with the features of the MD, should be the basis of agricultural and food policies.

5 Conclusion

The food sector has enormous social importance (in terms of impact on environment, health, human rights, national security, and democracy). It is also of great economic importance, in terms of contribution to GDP and determination of the cost of living. Together with other sectors involving the use of natural resources and with a high demand price inelasticity, it fosters the extraction of monopolistic extra-profits and exerts a very strong attraction for large multinational investors seeking profits and power. People's eating habits can follow patterns that help food to perform its important social functions. Or, alternatively, they can follow patterns useful only to multiply the exploitation opportunities on the behalf of powerful economic actors. The MD in its holistic conception proposed by UNESCO can help the system move towards the first direction. The new technological paradigm instead pushes in a completely different direction. The greatest risk is that the new paradigm will relaunch a "digital" version of MD where "novel" foods that claim to reproduce the beneficial effects of MD are offered to a public robbed of traditional food knowledge and pushed toward eating behaviors controlled by fancy algorithms, chef influencers, and the agribusiness' sustainability narrative used as greenwashing.

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Hygiene Monitoring of Water Intended for Human Consumption Employing Environmental-Omics: Metagenomic Applications for a Sustainable Use of Internal Drinking Water Sources

Federica Carraturo, Michela Salamone, Antonio Nappo, Michela Morelli, Sureyya Meric, Nello Carraturo, Marco Trifuoggi, and Marco Guida

Abstract

Multiple targets of the Agenda 2030 aim at enhancing the water quality through the integrated management of water sources. The scope of the present study was to evaluate the potability of the main natural water sources located on the island of Ischia (Naples, Regione Campania). The classification of such natural basins as drinking water may allow the disposal of internal supply sources, complementary to the drinking water provided by the peninsular distribution system. The methodological approach involved either the assessment of the parameters required by legislations, and environmental-omics techniques, consenting to deepen the microbiological risk assessment, implementing the proper human health risk prevention strategies. Collected samples additionally underwent chemical-physical analyses (according to Italian legislation) and ecotoxicological evaluations (employing *Daphnia magna* and *Aliivibrio fischeri*). Hygiene monitoring highlighted the presence, slightly over the Italian D. Lgs. 18/2023 and EU Directive 2020/2184 threshold values, of *Escherichia coli* and fecal Enterococci in most of the analyzed natural sources: results confirm the initial hypothesis of the study, considering the lack of water sources' treatment systems in the water sources' distribution system. With regard to chemical parameters, the derogation foreseen by the Regione Campania Water Protection Plan on specific compounds would allow the classification as sources exploitable for human consumption. The same applies to ecotoxicological findings, taking into account the absence of toxicity. Molecular outcomes were associated to microbiological, chemical, and ecotoxicological metadata, employing metagenomic analysis: the microbiota of the five water sources is mainly composed of strains of *Acinetobacter* spp., *Enterococcus* spp., *Micrococcus* spp., *Pseudomonas* spp. It can be hypothesized that the presence of potential pathogenic microorganisms at the distribution phase may rely on the biofilm formation at the pipes level: periodic maintenance treatments, complementary to the adequate disinfection interventions, would substantially reduce the health risk. The implementation of treatments to provide potable water from the available internal sources would be essential to improve the water supply chain of the island of Ischia, also considering the set-up of the Water Safety Plan required by EU Directive 2020/2184, pointing at reducing citizens' health risks, beyond increasing the drinking water availability supporting the sustainable use of resources.

Keywords

Environmental-omics · Ischia · Drinking water · Metagenomic · Hygiene monitoring

1 Introduction

Italian territory is rich of drinking water springs, and worldwide its peculiar morphology leads to consider the heritage of national spring waters among the most significant in terms of number of springs and diversity and quality of such resources. The purpose of the present research was to evaluate the drinking water requirements of the main springs located in Ischia (Naples). The entire island is characterized by a stream

F. Carraturo (✉) · M. Salamone · A. Nappo · M. Morelli · M. Guida
Hygiene Laboratories, Department of Biology, University of Naples Federico II, Naples, Italy
e-mail: federica.carraturo@unina.it

S. Meric
Environmental Engineering Department, Çorlu Engineering Faculty, Namik Kemal University, Çorlu, Tekirdağ, Türkiye

N. Carraturo
ASL Napoli2Nord, Ischia, Naples, Italy

M. Trifuoggi
Department of Chemical Sciences, University of Naples Federico II, Naples, Italy

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of drinking water and is rich in natural springs. Nevertheless, the most up-to-date literature on the subject dates back to the late 1800s: the most complete study reports that the perennial springs present on the island would be able to meet the needs of a population of 28,000 inhabitants, providing not less than 1800 m^3 of water per day (Morgera 1890). The verification of the potability of island water sources would therefore open up the possibility of having sources of internal supply, complementary to those supplied from the mainland. The research activity allowed to evaluate whether the sources still active on the island, currently available to the population—Ervaniello, Piellero, Buceto, Ciglio e Mirtina—comply with chemical, microbiological, and ecotoxicological threshold values required by regulations characterizing water sources intended for human consumption, in particular, Italian D. Lgs. 18/2023 (former D. Lgs. 31/2001), D. Lgs. 152/2006 and EU Directive 2020/2184 (European Parliament 2020).

2 Materials and Methods

The sampling points were selected aiming at identifying sources in a representative manner in each of the municipalities of the island of Ischia: Ervaniello (Casamicciola); Piellero (Forio d'Ischia); Buceto (Barano d'Ischia); Ciglio (Serrara Fontana); Mirtina (Ischia).

In addition to microbiological analysis required by current legislation, it was also possible to identify, employing molecular analysis (in particular, Sanger Sequencing and Next Generation Sequencing, NGS, with Illumina technology) the microbial communities of each of the sources under investigation, pointing at characterizing their microbiota and assessing possible health risks to the population, with the main purpose to implement strategies for the prevention and mitigation of microbiological and chemical risks related to the consumption of the analyzed sources. Water samples for the identification of microbial communities underwent total DNA extraction using CTAB extraction protocol (Doyle 1990); extracted DNA samples were amplified employing PCR, utilizing primers complementary to the V3-V4 variable region of 16S rRNA bacterial gene and then subjected to sequenced NGS analysis (Carraturo et al. 2021).

3 Results

The performed hygiene monitoring allowed to highlight the presence, slightly beyond the limits provided by D. Lgs. 18/2023 and by EU Directive 2184/2020, of *Escherichia coli* and fecal Enterococci in almost all the examined sources (Table 1): data confirm the initial hypothesis of the study, especially considering the absence of water treatment systems in the pre-distribution phase. However, the low level of contamination indicators opens up the possibility of using mild drinking water treatment strategies. As for chemical parameters, although some parameters are above the limits provided by D. Lgs. 18/2023, the derogation for certain chemical parameters (in particular, arsenic, chlorides, electrical conductivity, fluorides and sulphate) considered in the Plan for the Protection of Waters of the Campania Region (Regione Campania 2020), would consent to consider the sources as potable, whereas, being located in a hydrothermal basin, the exceeding of the chemical limits for specific parameters in the sources under evaluation could be attributable to possible connections to underground thermal springs. Also from the ecotoxicological point of view, the evaluation of potability for the five sources can be confirmed. As regards the exceeding of microbiological limits, Article 80, Part III, of D. Lgs. 152/2006, established that whereas the parameters *E. coli*" or Fecal Enterococci do not exceed values of 100 CFU/100 mL, the application of mild treatments foreseen by the first category (A1), additionally taking into accounts the needs of the municipalities responsible for managing each source. Molecular microbiology analysis consented the characterization of the spring water sources microbiota. Collected data were associated with microbiological, chemical, and ecotoxicological results exploiting metagenomic and association analysis (Fig. 1).

Table 1 Results of the microbiological analysis conducted on the five spring water sources analyzed on the island of Ischia

	Sample name (Source identification)				
Microbiological parameter	01—Ervaniello	02—Piellero	03—Buceto	04—Ciglio	05—Mirtina
Total bacterial count at 22 °C	95	820	218	7060	256,600
Total bacterial count at 37 °C	32	328	205	5020	198,500
Coliforms	38	43	28	57	65
E. coli	6	2	6	5	198
Fecal enterococci	31	26	52	9	97
Pseudomonas aeruginosa	2	0	3	0	0
Staphylococcus spp.	10	55	37	4	1076
Legionella pneumophila	0	0	0	0	0
Molds and yeasts	18	3	8	0	1

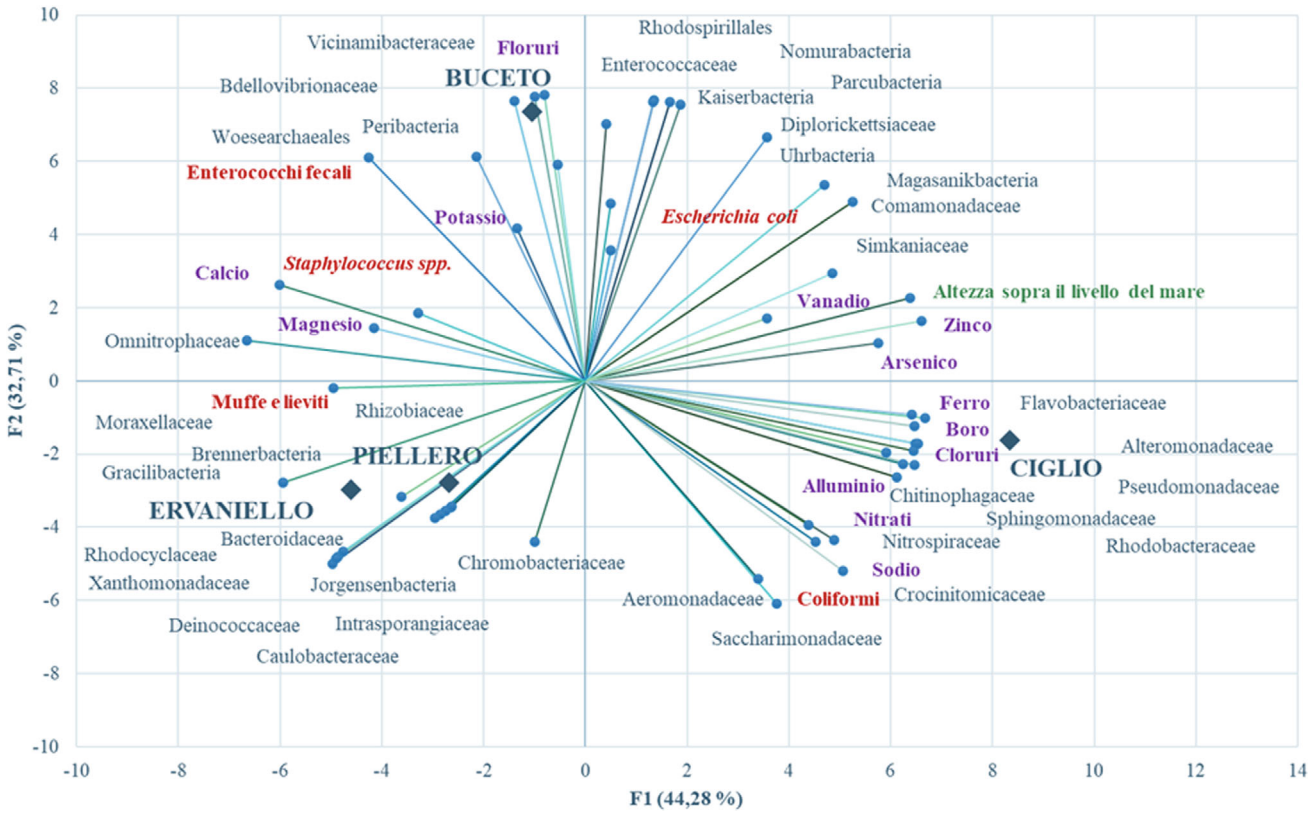


Fig. 1 Principal component analysis (PCA) associating results from next generation sequencing with chemical, physical, and microbiological metadata. For a better comprehension, samples are indicated in blue color, chemical data in violet, microbiological data in red

4 Discussion

The molecular analysis, employing Sanger sequencing analysis, evidenced that the microbiota composition at distribution phase is mainly represented by *Acinetobacter* spp. strains, *Enterococcus* spp. (confirming the microbiological isolation of fecal Enterococci) *Micrococcus* spp., *Pseudomonas* spp., *E. coli*, *Aeromonas* spp. and *Citrobacter* spp. The results of the Sanger sequencing were largely confirmed by the findings of Next Generation Sequencing, whose predominant genera for most sources are *Acinetobacter* spp., *Aeromonas* spp., *Pseudomonas* spp., and *Enterococcus* spp. I can be hypothesized that the presence of potential pathogens at the distribution and not at the source is due to contamination (e.g., biofilm formation), at the pipes level: periodic maintenance treatments would substantially reduce this health risk connected to the isolated microorganisms. The treatment of spring sources intended for human consumption located in Ischia would be essential to improve the strategies of water supply of the island that, supplying drinking water from the mainland, is easily subject to frequent failures in the water pipes, with consequent interruptions of the supply, and periodic shortage of drinking water. This may represent a major problem especially in the summer season, where the massive increase in tourist income leads to the doubling of the population on the island.

5 Conclusions

In a territory like that of Ischia, the concept of circular economy therefore assumes considerable importance in the perspective of a more adequate management of the resources of the territory: the strategies of potabilization of internal drinking water sources, also according to the Water Safety Plan (WSP) requirements established by EU Directive 2184/2020, would reduce the health risk for citizens and increase the availability of water to support the island's territory.

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Histological and Molecular Features Provide Insights to Consider *Ciona robusta* Gut a Suitable Model to Study Gut Physiology and Evolution

Marco Gerdol, Valerio De Felice, Sicong Yao, Rita Marino, Anna Capaldo, Michelina Plateroti, Annamaria Locascio, and Maria Sirakov

Abstract

This work proposes an overview of the anatomy and the molecular features of the *Ciona robusta* gut, focusing on the adult stage. This protochordate shares fundamental functional and morphogenetic molecules with vertebrates and, importantly, possess a non-duplicated and fully sequenced genome. While several similarities in the compartmentalization of the digestive system in *Ciona* and mouse have already been shown, the detailed mechanisms at the basis of this regionalization and its associated functionalities remain poorly understood. We investigated at the histological level tissue architecture along the intestinal antero-posterior axis of this ascidian. The RNAseq analysis was performed to identify and to reconstruct key signaling pathways and molecular component to elucidate both evolutionary and functional features of the digestive tract of this protochordate. Moreover, we applied a systemic approach to compare the ascidian anatomical and molecular features with a mammalian model. Understanding the conservation and evolution of the molecular mechanisms acting to establish cell types and their function is of pivotal importance in defining major aspects of animal evolution. Within this context, our results highlight some aspects of gut evolution and physiology that may be also relevant for vertebrate and human biology, with consequent biomedical implications.

Keywords

Ciona robusta · Gut · Protochordates · RNAseq · Digestive tract

M. Gerdol
Department of Life Sciences, Università degli Studi di Trieste, Trieste, Italy
e-mail: mgerdol@unitis.it

V. De Felice · S. Yao · R. Marino · A. Locascio · M. Sirakov (✉)
Department of Biology and Evolution of Marine Organisms, Stazione Zoologica Anton Dohrn, Naples, Italy
e-mail: maria.sirakov@szn.it

V. De Felice
e-mail: vdefelice@hotmail.it

S. Yao
e-mail: Sicong.Yao@unina.it

R. Marino
e-mail: rita.marino@szn.it

A. Locascio
e-mail: annamaria.locascio@szn.it

A. Capaldo
Department of Biology, Università degli Studi di Napoli "Federico II", Naples, Italy
e-mail: anna.capaldo@unina.it

M. Plateroti
Inserm, UMR-S1113/IRFAC, FHU ARRIMAGE, FMTS, University of Strasbourg, Strasbourg, France

1 Introduction

In the animal kingdom, the uptake of nutrients occurs via an alimentary canal that usually extends from mouth to anus. Indeed, animals are heterotrophic organisms in which the alimentary canal (i.e., gut) diverged in shape relative to the phylogeny and/or varying feeding strategies. Although animals of neighboring taxonomic ranks may show different gut morphologies, they tend to display similar functional features in their digestive systems. For example, the sequential steps of the digestive system are shared by all bilaterians. The gut and the associated digestive system have diverged in parallel with other traits in some species, and the corresponding traits are usually comparable at several levels (e.g., morphology, function, and molecular evolution). Such considerations are also valid while comparing different animal taxa, where shared gut traits, often masked by highly divergent morphologies, can be often pinpointed

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by the conservation of molecular features. In addition, the evolution of the gut function is related to the presence and the localization of specialized cell types (i.e., secretory and absorptive cells) and their progenitors. Finally, these different lineages can be either characterized morphologically, or by using specific histological markers, whose expression allows the identification of the cell type and function.

Most of the knowledge about vertebrate gut derives from research carried out on mammalian species (including human). A comparative approach can play a pivotal role in tracking the evolution or the conservation of gut traits during vertebrate evolution. This is the case for the model system proposed for this work, *Ciona robusta* (also known as *Ciona intestinalis* (Linnaeus, 1767) sp. A)**,** which belongs to a major clade of marine filter-feeders—the tunicates (or ascidians); this organism belongs to the sister group to vertebrates, and has a fully sequenced, high-quality chromosome-scale genome assembly available (Brunetti et al. 2015). Their phylogenetic position makes them ideally placed to study the evolution of the gut. Indeed, the low complexity of the *Ciona* gut, coupled with some anatomical and cellular similarities to the human and murine guts (Nakayama and Ogasawara 2017; Nakayama et al. 2019; Zhang et al. 2023; Matsubara et al. 2021), as well as a growing awareness of the broad physiological significance of microbiota that colonize the gut of healthy organisms (Liberti et al. 2021), underscore the value of this species as a suitable model to study gut development and physiology.

Here we present the preliminary results of studies carried out in the frame of an ongoing project, which aims to investigate in depth the anatomy, the cytotypes and the molecular features of the *C. robusta* gut. This work, focused on the adult stage, uses mouse as a comparative model species (Fig. 1), with the aim to evaluate the suitability of this tunicate to study both the evolution and the physiopathology of the gut.

2 Materials and Methods

For histological analysis, the digestive tract samples were immediately fixed in 4% paraformaldehyde (PFA), dehydrated in graded alcohols and stored at 4 °C. For sectioning, samples were cleared with xylene and embedded in paraffin. After dewaxing and re-hydration, 7 μm thick sections were stained with Hematoxylin-Eosin or Alkalin Phosphatase. The total RNA of *C. robusta* adult intestines and stomach were extracted using TRIZOL. cDNA libraries of biological triplicates for each tissue were prepared using TruSeq stranded mRNA kits and sequenced on an Illumina NextSeq550 platform. Following quality-based trimming, reads were mapped against the reference genome, obtaining digital count-based expression levels for all annotated genes. Statistically significant differences in gene expression levels among the different regions of the digestive tract were identified though EDGEr, based on combined FDR-corrected *p*-value (<1x10–5) and fold change (+/−2) thresholds.

3 Results

3.1 Gross Anatomy

Using histochemical approaches, we appreciate the specific cellular architecture of the stomach and the intestine, both composed of simple columnar epithelial cells (Fig. 2a). In order to identify differentiated adsorptive cells type (i.e., enterocyte) we performed alkaline phosphatase staining, which is likely expressed all over the digestive tract in adult animals (Fig. 2b).

3.2 RNAseq and Bioinformatics Approaches

The number of paired-end reads obtained though Illumina sequencing for each sample (23–48M) largely exceeds the target sequencing depth, leading to a uniform average mapping rate, close to 75%, against the reference genome. 14,655 out of 16,672 (87.9%) out of the annotated protein-coding genes displayed a biologically significant expression level in at least one of the nine sequenced samples, based on an arbitrary threshold (i.e., TPM = 1).

Overall, *S* sampled clearly displayed a distinct expression profile compared with PI and DI, which had nearly overlapping transcriptional landscapes, characterized by minor differences affecting only a small number of genes. In detail, as highlighted by Fig. 3a, b, the stomach displayed the expression at high levels of a subset of genes that were nearly not expressed neither in PI, nor in DI. This was supported by the detection of 290 and 204 differentially expressed genes (DEGs) in the *S* versus PI and *S* versus DI comparisons, respectively. The overwhelming majority of these (> 95%) were overexpressed in *S*, with several cases characterized by fold change values exceeding 100 folds. On the other hand, the scarce differences between PI and DI were supported by the lack of significant clustering among biological replicates (Fig. 3b), as well as by the low number of DEGs identified in the pairwise comparison, i.e., only 18, 17 of which were expressed at higher levels in DI. However, although the number of DEGs was low, a few of these genes displayed remarkable differences between the two intestine regions.

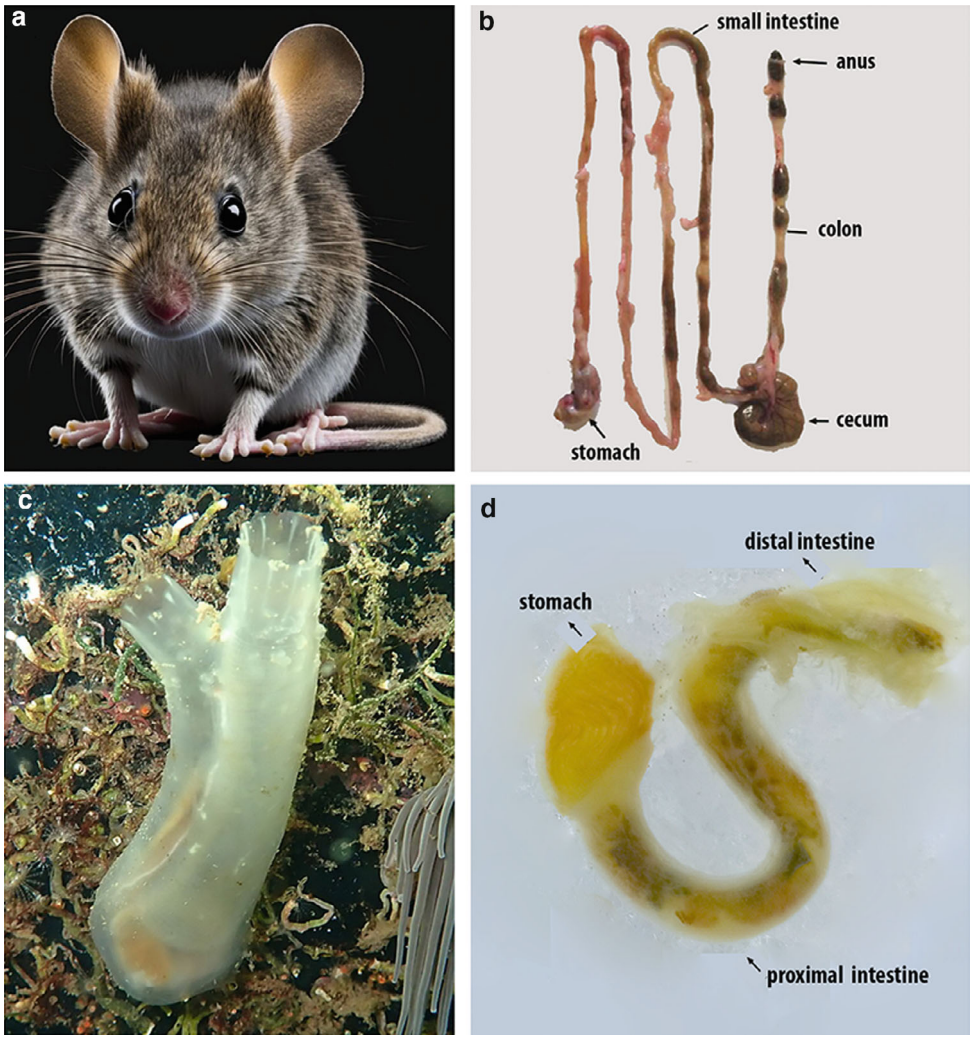


Fig. 1 Mouse and tunicate gastrointestinal tract. a Adult mouse *Mus musculs*. **b** Dissected mouse digestive tract labeled with stomach, small intestine, cecum, colon, and anus. **c** Adult vase tunicate *Ciona robusta*. **d** Dissected tunicate digestive tract labeled with stomach, proximal intestine and distal intestine

4 Discussion

According to Fig. 2, the *Ciona* gastrointestinal tract (GI) corresponds to the general description of this organ in tunicate (Cloney and RA 1997). In particular, we observed a specific cellular architecture and DEGs according to the different anatomical parts (Figs. 2a, 3). These results need further validation and confirmation through the analysis of molecular markers. Comparative approaches will allow us to define biological processes and molecular functions related to genes specifically expressed in the different part of the *Ciona* GI, including genes of pivotal developmental and physiological importance in vertebrate gut (i.e., Hox and para-Hox genes).

5 Conclusions

Our preliminary investigations show specific histological and molecular features if *Ciona* GI. Next steps will be to characterize the different cell types and their molecular signature comparing to vertebrate gut. For instance, identify signaling pathways such as Wnt, Notch, and TGFβ-BMP along *C. robusta* gut can confirm that this tunicate is a reliable model system for comparative studies aimed at clarifying major aspects of animal evolution, supporting it as a novel model to study gut physiology with valuable impact to vertebrate and human biology and possible medical implications.

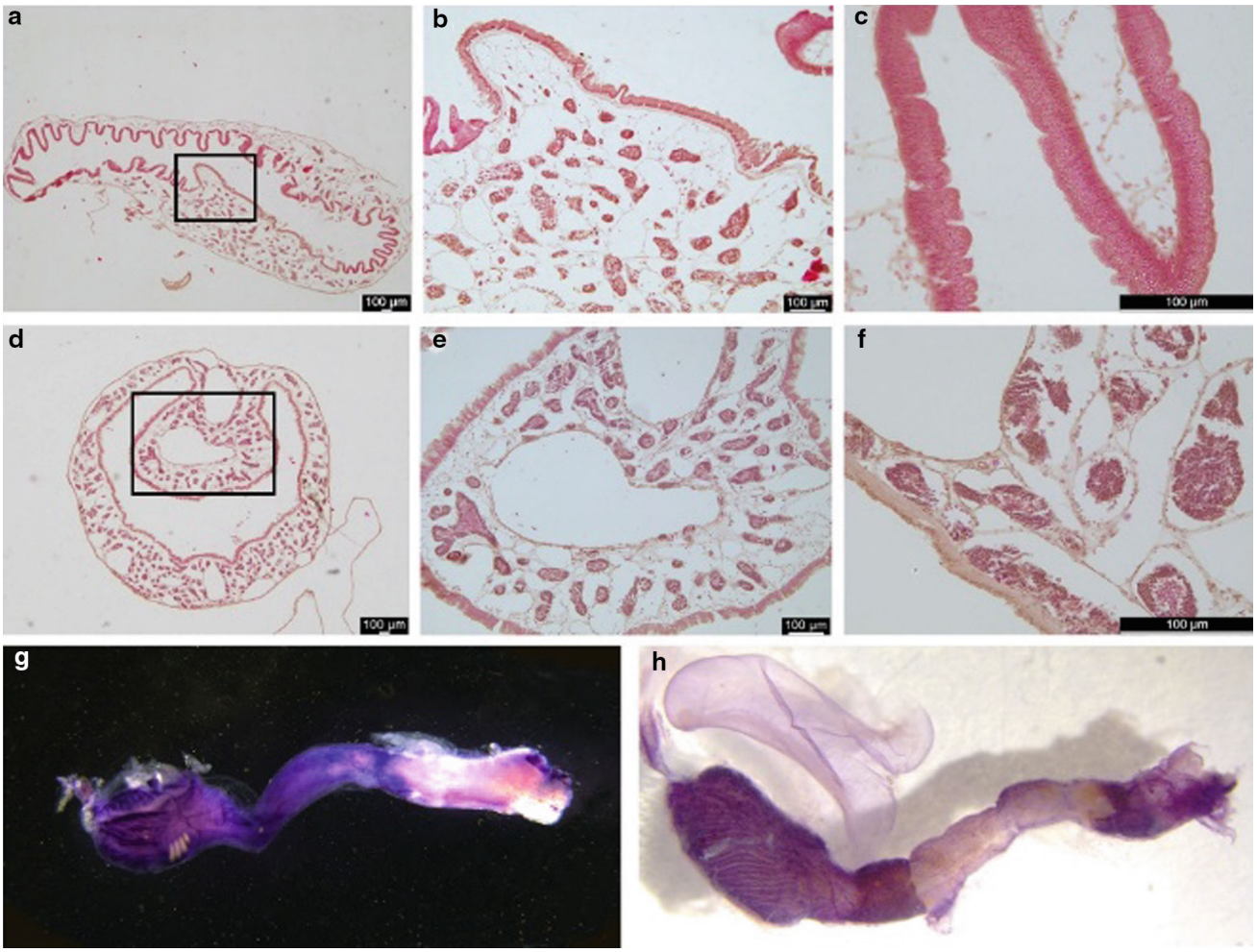


Fig. 2 **Images of *C. robusta* gut. a–f** Transversal sections of *Ciona* gut colored with haematoxylin-eosin: **a–c** Sections of the stomach at 2.5x (**a**), 10x (**b**), and 40x (**c**) magnifications. **d–f** Sections of the intestine at 2.5x (**a**), 10x (**b**), and 40x (**c**) magnifications. **g**, **h** Alkaline phosphatase staining of whole mount *Ciona* gut

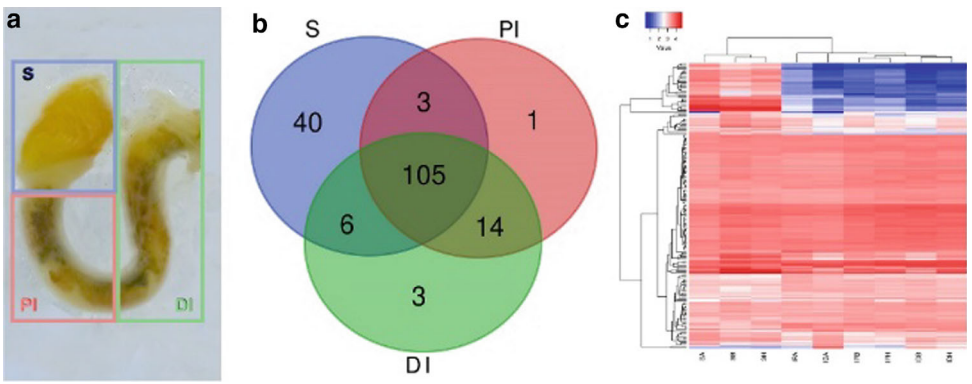


Fig. 3 **RNAseq approach and preliminary results. a** tunicate gut divided into three sections each highlithed with different colored boxes. **b** Venn diagram displaying the genes whose average expression level across the three biological replicates exceeded 1,000 TPMs in at least one of the three regions analyzed. **c** Heat map summarizing the expression levels of all genes showing an average expression level higher than 1,000 TPM in at least one of the three regions analyzed. "A", "B" and "H" indicate the three biological replicates. Both genes and samples were hierarchically clustered based on Euclidean distance and an average linkage clustering method. Gene expression levels are reported as log(TPM+1). S = Stomach, blue. PI = Proximal Intestine, red. DI = Distal Intestine, green

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From Sites of Community Interest to Special Areas of Conservation (SCI/SAC) and Special Protection Area (SPA): Three Years of Observations on Management Plans and Biodiversity

Nadia Piscopo, Luigi Sacchettino, Vincenzo Esposito, Danila d'Angelo, Francesca Ciani, and Luigi Esposito

Abstract

Humans' changes wrought on ecosystems have reduced the natural habitats of many animal and plant species that are not always sufficient to guarantee the survival of populations. For their protection, since 1979 EU has proposed a transnational instrument and, subsequently, other directives. Natura 2000 is the main political instrument of EU which aims to implement strategies for the conservation of biodiversity and with it has established the "Charter of Nature" in which all planning actions have been summarized. The census of the habitats and species of a territory is the first step to take but, in some regions, this phase has slowed down somewhat. This study aims to be a solicitation to local administrations to set up permanent territorial monitoring bodies. The presence/absence of the animal species listed in the Standard Data Form of SCI/SAC IT8010010 Lago Carinola; IT8010028 Foce Volturno-Variconi; IT8030018 Lago Patria and SPA IT8010018 Variconi was verified. The comparison of the biodiversity described between the date of first compilation (May 1995); the update (December 2019) and the census carried out by the research group (2020–2022) showed that 830 hectares of a coastal aquatic ecosystem have from time to time once hosted an animal biodiversity made up of 157 species of different Classes: Birds (112 species); Mammals (13 species); Fishes (10 species); Invertebrates (10 species); Reptiles (7 species); Amphibians (5 species). Eight allochthonous species have been reported belonging to the Classes: Mammals (3 species); Fish (1 species); Invertebrates (2 species); Reptiles (2 species). From these surveys it is possible to affirm the presence of non-native species for which the Campania Region must take measures. However, the Campanian environments express a large component of biodiversity which, to be conserved, requires particular precautions and specialized operators.

Keywords

Natura 2000 sites · Biodiversity · Local census · Camera trap · Endangered species · Pest animals

1 Introduction

The changes wrought by humans on ecosystems have reduced the natural habitats of many animal and plant species by confining them to small spaces which are not always sufficient to ensure the survival of populations (Adla et al. 2022; Piscopo et al. 2021; Piscopo et al. 2023). For their protection, the European Union has proposed a transnational instrument since 1979 and, subsequently, other directives. Natura 2000 (Habitats Directive (92/43/EEC) n.d.; Birds Directive (2009/147/EC) n.d.) is the main political instrument of the European Union which aims to implement strategies for the conservation of biodiversity through the establishment of the "Nature Charter." In this, all the planning actions (territorial planning, implementation of political choices) were summarized. The census of the habitats and species of a territory is the first step to be taken but, in some regions, this phase has slowed down a bit. This study was therefore created to highlight the need to identify permanent territorial monitoring bodies and focused on 4 sites, three of which are Sites of Community Interest/

Francesca Ciani and Luigi Esposito have contributed equally to this work and share last authorship.

N. Piscopo · L. Sacchettino · V. Esposito · D. d'Angelo (✉) · F. Ciani (✉) · L. Esposito
Department of Veterinary Medicine and Animal Production, UNINA, Naples, Italy
e-mail: danila.dangelo@unina.it

F. Ciani
e-mail: ciani@unina.it

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Special Areas of Conservation (SCI/SAC) and one Special Protection Area (SPA).

2 Materials and Methods

The study was conducted in Southern Italy in the Mediterranean Biogeographical Region. Three SCI/SAC (IT8010010, IT8010028, IT8030018; Fig. 1a–c) and one SPA (IT8010018 Fig. 1d) EU Natura 2000 official maps of were considered in this study (UN Homepage n.d.).

Biodiversity list, described on Standard Data Form of each studied Area Natura 2000 site was put on a data store. The date of first compilation (May 1995) and the update (December 2019) was compared with the census carried out by the research group from 2020 to 2022. Depending on the species, for the census operations of the three SCI/SAC and for the SPA, direct and indirect methods were used (Piscopo et al. 2023). "Direct observation" was based on the direct observation of animals by an operator and the use of camera traps (Spromise Full HD). For each sampling area, 9 camera traps were installed in strategic points. The "Indirect observation" was based on the detection of signs and tracks left by animals during their movements.

3 Results

The comparison of the biodiversity described between the date of first compilation (May 1995), the update (December 2019) and the census carried out by the research group (2020–2022) showed that 830 hectares of a coastal aquatic ecosystem (river mouth; natural lakes; sea coast; ecotonal dune belts; agroecosystem) have from time to time once hosted an animal biodiversity made up of 157 species of different Classes of which 8 alien species (pests). From these surveys, it is possible to state that there is the presence of non-native species, and the Region administration must take charge of both these species and those that need specific conservation actions (Table 1).

The identified birds within the four areas of the Natura 2000 network studied are part of the 14 orders, 35 families, and 112 species. The comparison between the periods shows the constant recurrence of 27 species. Between 1995 and 2019, 12 species were reported which did not reappear in the last period while 3 species reported in 1995 reappeared in 2020/2022. Sixteen species reported in 2019 are also present in 2020/2022. Reports of individual species were 0 in 1995; 52 in 2019 and 2 in 2020/2022. The total number of species reported in the 2020/2022 period is 48 so that our work indicates that only 43% of the species reported in the standard data form are confirmed to be present in the recent period.

The identified mammals within the four areas of the Natura 2000 network studied are part of the 6 orders, 8 families, and 13 species. The comparison between the periods shows the constant recurrence of 3 species while in the period 2020/2022 10 different species were reported. The total number of species reported in the 2020/2022 period is 13 so our work reports 333% more than the species reported in the standard data form. Three pest mammals were described into the studied areas: *Myocastor coypus; Rattus norvegicus*; *Sus scrofa.*

The identified fishes within the four areas of the Natura 2000 network studied are part of the 5 orders, 6 families, and



Fig. 1 **a** SAC IT8010010 Lago di Carinola; **b** SAC IT8010028 Foce Volturno-Variconi; **c** SAC IT8030018 Lago Patria; **d** SPA IT8010018 Variconi. *Source* https://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT8010010

Table 1 Chronological comparison of biodiversity in the Natura 2000 areas studied

Class	All	1995	2019	2020/2022	Pest species
Birds	112	42	107	48	0
Mammals	13	4	4	12	3
Fishes	10	3	7	5	1
Invertebrates	10	5	6	7	2
Reptiles	7	5	5	5	2
Amphibians	5	4	5	2	0
Animal biodiversity	157	59	133	80	8

10 species. The comparison between the periods shows the constant recurrence of 1 species. Between 1995 and 2019, 2 species were reported which did not reappear in the last period. Two species reported in 2019 are also present in 2020/2022. There were 2 reports of single species in 2020/2022. The total number of species reported in the 2020/2022 period is 5 so our work indicates that 40% of the species reported in the standard data form are confirmed to be present in the recent period. One pest fish was described into the studied areas: *Gambusia attinis.*

The identified invertebrates within the four areas of the Natura 2000 network studied are part of the 5 orders, 9 families, and 10 species. The comparison between the periods shows the constant recurrence of 4 species. Reports of single species were 1 in 1995, 2 in 2019 and 3 in 2020/2022. The total number of species reported in the 2020/2022 period is 7. Our work indicates that out of 7 species reported in the standard data form, 57% are confirmed to be present in the recent period. Added to these are a species of native crustacean and 2 invertebrates pest (one crustacean and one arthropod).

The identified reptiles within the four areas of the Natura 2000 network studied are part of the 2 orders, 3 families, and 7 species. The comparison between the periods shows the constant recurrence of 3 species. Between 1995 and 2019, 2 species were reported which did not reappear in the last period. There were 2 reports of individual species in 2020/2022, both belonging to alien species (*Trachemys scripta scripta* and *Trachemys scripta elegans*). The total number of species reported in the 2020/2022 period is 5 so that our work indicates that 60% of the species reported in the standard data form are confirmed to be present in the recent period.

The identified amphibians within the four areas of the Natura 2000 network studied are part of the 2 orders, 4 families, and 5 species. The comparison between the periods shows the constant repetition of 2 species. Between 1995 and 2019, 2 species were reported which did not reappear in the last period. A species reported in 2019 is also present in 2020/2022. The total number of species reported in the 2020/2022 period is 3 so our work indicates that 60% of the species reported in the standard data form are confirmed to be present in the recent period. No alien species have been reported for this class.

4 Discussion

The Convention on Biological Diversity (https://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT8010010;=IT8010028;=IT8030018;=IT8010018) establishes the need to preserve biodiversity and, above all, to reduce the loss of habitats and species. The first act to obtain these results was to establish protected areas. The European Union has amplified conservation actions with the Habitats (92/43/EEC) and Birds (2009/147/EC) directives. The establishment of protected areas, however, fails in the absence of adequate "monitoring," i.e., short and medium distance controlling by gradually making the changes that become appropriate. Our study aims to highlight the species present, over time, in the protected areas of the Campania Region and in the Natura 2000 areas. The results obtained highlight the importance of monitoring, indispensable for understanding the state of coexistence between the species present in each habitat. In the chronological analysis, the results highlighted the presence of 159 species among which the most represented class was that of Birds, followed by Mammals, Fish, Invertebrates (very under-estimated), reptiles, and amphibians. Among the identified species, 8 non-native species were reported belonging to the Classes Mammals, Fish, Invertebrates, Reptiles. The analysis of the single sample sites in the three observation periods in which lake and marshy environments are present demonstrated the constant presence of species of invertebrates, fish, amphibians, reptiles, birds, and mammals. Interestingly, some species have been reported in two consecutive periods or occasionally present. Particular attention was paid to endangered species. In the ZSC/SCI IT8010028 Foce Volturno—Variconi were detected Reptiles (*Emys orbicularis* and *Elaphe quatuorlineata*), Invertebrates (*Potamon fluviatile*), Fish (*Rutilius rubilio*).

5 Conclusions

The present study demonstrates that, in the absence of monitoring, the list of reported species present in protected areas is not sufficient to establish their degree of conservation or concern. The Standard Data Forms of the Natura 2000

sites require a periodic official update which took place after twenty-four years, a period which is too long to evaluate the biological cycles. In conclusion, it is possible to state that, to obtain concrete data that can be transferred to the biological needs of the species, the observation periods must not be neither too long nor too short.

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Possibilities to Control the Aggressive Invasive Plant *Solanum elaeagnifolium* (Solanaceae), by Revealing Its Medicinal Potential Against Skin Disorders

Ekaterina Kozuharova, Giuseppe Antonio Malfa, Rosaria Aquaviva, Yancho Zarev, and Iliana Ionkova

Abstract

Solanum elaeagnifolium Cav., (Solanaceae), is alien invasive plant in several Mediterranean countries, Australia, Africa, and South America. Recently its expansion has increased by 1750% in Greece.

- Purpose: The aim of this research is to spot the valuable bioactive compounds of *S. elaeagnifolium* with prospective medicinal application.
- Methods: We used the search string: "*Solanum elaeagnifolium,*" "pharmacological effects," and "bioactive compounds" to identify publications in Google Scholar, Web of Science, and PubMed database.
- Results: *S. elaeagnifolium* contains different secondary metabolites including alkaloids and glycoalkaloids (for example, solasodine), solamargine, as well as flavonoids, phytosterols, etc. responsible for interesting biological activities in several diseases. They possess anti-bacterial, anti-inflammatory activities and alleviate skin disorders and cancer. The solamargine in vitro inhibits the growth of metastatic and primary melanoma cells WM239 and WM115. At the same time, the harm on normal and benign WM35 cells is minimal. This effect is rapid, selective, and efficient. Also, the purified solasodine glycoalkaloids mixture is effective against non-malignant skin lesions (keratoses and keratoacanthomas) and malignant skin lesions (basal cell carcinomas and squamous cell carcinomas). The solasodine glycoalkaloids mixture is the active substance of the cream formulation Curaderm—BEC5.
- Interpretation: Our brief search reveals that *S. elaeagnifolium* has a promising potential for medicinal application, particularly against melanoma as well as non-melanoma skin cancer and psoriasis. Its bioactive compounds and pharmacological activities deserve further researchers' attention.
- Conclusion: *S. elaeagnifolium* could be a good source of solasodine, solamargine, and other compounds. The industrial exploitation of the populations of *S. elaeagnifolium* is a possibility to control its expansion.

Keywords

Invasive alien plant · Antibacterial · Antitumor · Anti-inflammatory activity · Glycoalkaloids and saponins

1 Introduction

It is well known that invasive alien plant species harm the natural ecosystems and biodiversity. *Solanum elaeagnifolium* Cav., (silverleaf nightshade, Solanaceae), is native to North and South America. It was spread as ornamental but turned into very aggressive invasive plant. It invaded a number of Mediterranean countries as well as Australia, South Africa, India, etc. (Roberts and Singarayer 2022; Balah and Hassany 2023). For instance, it has been reported that in Greece the presence of *S. elaegnifolium* has increased by more than 1700%, expanding its distribution centers. It gets to higher altitudes as well (Krigas et al. 2021). The biodiversity conservation and sustainable agricultural management require urgent activities to control its expansion. Revealing its medical potential is crucial. Collecting the plant substance industrially for the pharmaceutical practice may suppress its populations.

E. Kozuharova (✉) · Y. Zarev · I. Ionkova
Faculty of Pharmacy, Medical University of Sofia, Sofia, Bulgaria
e-mail: ina_kozuharova@yahoo.co.uk

G. A. Malfa · R. Aquaviva
Department of Drug and Health Sciences, University of Catania, CT, Italy

Research Centre on Nutraceuticals and Health Products (CERNUT), University of Catania, CT, Italy

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2 Methods

We used the search string: "*Solanum elaeagnifolium,*" "pharmacological effects," and "bioactive compounds" to identify publications in Google Scholar, Web of Science, and PubMed database. We focused mainly on alkaloids as well as few other compounds that can be used to alleviate skin diseases.

3 Results

3.1 Brief Overview of *Solanum elaeagnifolium* Phytochemical Compounds

The total phytosterol content in *S. elaeagnifolium* was found to be 11.34%, with γ-sitosterol being the most abundant at 5.36%, followed by campesterol at 3.72%, and stigmasta-5,24(28)-dien-3-ol at 2.25% (Badawy et al. 2013). The oil obtained from the seeds of *S. elaeagnifolium* consists mainly of *β*-sitosterol, *β*-sitosterol-3-*O*-*β*–D-glucoside, campesterol, stigmasterol, Δ-5-avenasterol, and small amounts of cholesterol, Δ-7- stigmastenol, clerosterol, and Δ-5–24 stigmastadienol. The most important fatty acids in seed oil are linoleic, oleic, palmitic, stearic, myristic, etc. although their quantitates vary a lot (Badawy et al. 2013; Feki et al. 2013).

Various flavonoids have been identified in *S. elaeagnifolium* such as kaempferol derivates, quercetin derivates, and apigenin derivates as well as rutin, mangiferin, coumaroyl glucosides, coumaroylquinic acids, dicaffeoylquinic acids, etc. Several kaempferol derivates were reported for the first time from the silverleaf nightshade (Badawy et al. 2013; Hawas et al. 2013; Radwan et al. 2015; Elabbar et al. 2014; Balah 2015).

As a member of the Solanaceae family, it contains spirosolane type of alkaloids. For example, the fruits (berries) of *S. elaeagnifolium* contain solasodine and its corresponding glycoalkaloids, solasonine and solamargine (Keeler et al. 1990; Cherkaoui et al. 2001; Lagoudakis et al. 2002). The solasodine content in the *S. elaeagnifolium* berries varies between 1.5% and 3.2% (Bothma 2006), in relation to ecological and geographical specifics. Therefore, the silverleaf nightshade can be inexpensive source of solasodine (Bradley et al. 1978). This compound is commercially important because steroidal hormones are produced out of it (Boyd et al. 1984).

Another identified compound from the plant is *β*-Solamarine (Njeh et al. 2016).

3.2 In Vitro Tests of *Solanum elaeagnifolium* Compounds against Skin Cancer

Solamargine exhibits potent and selective antitumor activity against primary and metastatic melanoma cells (WM115 and WM239). At the same time, it affects slightly the normal and benign melanoma WM35 cells. The experiment is performed with purified glycoalkaloid Solamargine obtained from Glycomix Ltd. The cell line WM35, WM239 and WM115 are treated with different concentrations (between 2 and 10 μM) of Solamargine. This compound induces cellular necrosis in the malignant melanoma cell lines (Al Sinani et al. 2016).

3.3 Toxicity

S. elaeagnifolium is poisonous for livestock due to the toxic glycoalkaloids (alkaloids bonded with sugars, e.g., solanine, solasonine, and solamargine). These glycoalkaloids irritate the gastrointestinal tract. They may be hydrolyzed within the gastrointestinal tract. In result they release toxic alkaloids or alkamines that are neurotoxic. Poisonings are documented due to consumption of the ripe berries (Njeh et al. 2016).

4 Discussion

Solasodine and its glycosides (glycoalkaloids) are constituents of the cream formulation Curaderm^{BEC5} (also known as Zycure in the U.K.). The mixture of glycoalkaloids is as follows: solasodine glycosides—triglycosides solasonine (*β*-solatriose) (33%), solamargine (*β*-chacotriose) (33%), and di-and-monoglycosides (34%). The aglycone of all glycosides is solasodine. This formulation is utilized as a topical therapy for non-melanoma skin cancers. Studies indicate that this treatment specifically targets cancer cells while sparing normal cells, resulting in excellent cosmetic outcomes. The therapy has shown positive results in a diverse range of basal cell carcinomas (BCCs) and squamous cell carcinomas (SCCs) with varying sizes and locations, eliminating the need for reconstructive surgery (Cham 2013; Robyn 2011). The mixture of purified solasodine glycoalkaloids has been shown to be effective also against non-malignant skin lesions (keratoses and keratoacanthomas) (Cham et al. 1987). Experimental clinical research evaluates the efficacy and safety of a 0.005% mixture of solasodine glycosides (Zycure—a novel treatment for non-melanoma skin cancer) for the basal cell carcinoma treatment. The study involved 94 patients from ten medical centers in the U.K.

The procedure took 8 weeks. The patients were treated twice daily with Zycure/Curaderm^{BEC5}. At the end of this period a histological test should confirm that the basal cell carcinoma was cleared. The results showed that the Zycure group had a significantly higher efficacy rate (66%) compared to the vehicle group (25%). Of the Zycure-treated patients, 78% had no recurrence during the one-year follow-up. Additionally, there were practically no side effects. These findings suggest that Zycure is a safe and effective treatment option for basal cell carcinoma (Punjabi et al. 2007). Also, a topical cream formulation PsorendBEC, containing solasodine glycosides is effective in psoriasis, as demonstrate a case study. It reports a complete resolution of cutaneous lesions after 4 weeks of treatment with no recurrence post 1 year after therapy (Chase et al. 2019).

5 Conclusions

This brief review has clarified that the research on *S. elaeagnifolium* bioactive compounds (extracted from the seed, fruit or the whole plant) is at initial stage and yet rather prospective. It also demonstrates an important medicinal potential of this invasive plant. *S. elaeagnifolium* contains a wide range of bioactive metabolites such as alkaloids, phytosterols and flavonoids. These compounds are well known to exhibit remarkable anti-inflammatory, antioxidant, and anticancer properties. *S. elaeagnifolium* is promising candidate as a source of alkaloids treating skin disorders such as melanoma, atopic dermatitis and psoriasis. Formulations containing solasodine and its glycosides (found in *S. elaeagnifolium*) demonstrate capacity to improve skin conditions, enhance wound healing, and inhibit tumor growth. Furthermore, the presence of solasonine and solamargine in this plant has a potential for commercial production of steroid hormones. These findings underscore the therapeutic versatility of *S. elaeagnifolium*, justifying further in-depth investigation for its pharmaceutical use.

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Exploring the Therapeutic Potential of Plant-Based Natural Products Against Resistant Human Pathogens

Samira R. Mansour, Mohamed Soliman, Stacey Ellen Pane, Abdelraouf A. Moustafa, and Giulia Guerriero

Abstract

The emergence of drug-resistant human pathogens poses a significant challenge to global healthcare systems. In the search for novel therapeutic strategies, attention has turned towards plant-based natural products due to their rich chemical diversity and potential antimicrobial properties. This study aims to explore the therapeutic potential of plant-based natural products against resistant human pathogens. The study was conducted in Jabal Ras Ghareb, located in the Hurghada area of Egypt, which is known for its diverse plant species. A total of thirteen medicinal plants were carefully collected and subjected to extraction using methyl alcohol as the solvent. The resulting methanolic extracts were then concentrated using a rotary evaporator. Subsequently, the condensed extracts from *Cleome droserifolia, Calligonum comosum, Crotalaria aegyptiaca, Zygophllum cocinum, Noaea mucronate, Verbascum sinaiticum, Salvadora per-sica,Astragalus spinosus,Capparis decidua, Fagonia indica, Arnebia hispidis-sima, Montia dichotoma*, and *Forestiera segregate* underwent evaluation to determine their efficacy in inhibiting human pathogens. These include Gram-negative bacterium and Gram-positive bacteria as well as *Candia albicans,* as pathogenic unicellular fungi. Among the tested plant extracts, *Cleome droserifolia*, *Crotalaria aegyptiaca*, and *Calligonum comosum* demonstrated significant potency against both Gram-negative and Gram-positive human pathogens, as well as unicellular fungi. Notably, *Helicobacter pylori*, *Escherichia coli,* and *Candida* albicans exhibited higher susceptibility towards these particular plant extracts. In conclusion, the exploration of plant-based natural products has demonstrated promising therapeutic potential in combating resistant human pathogens.

Keywords

Bioactive compounds · Human pathogenic organisms · Medicinal plants · Plant extract · Traditional medicine

1 Introduction

In recent years, antibiotic-resistant human pathogens have become a global health concern. To address this challenge, researchers are exploring plant-based natural products as potential alternatives to conventional antibiotics. Plants contain diverse bioactive compounds with antimicrobial properties that play a vital role in defending against pathogens and pests (Allemailem 2021). Plant-based natural products offer several advantages over synthetic drugs, including structural diversity that makes it difficult for resistance mechanisms to develop rapidly (Serwecińska 2020). Additionally, many of these compounds exhibit synergistic effects when combined with existing antibiotics, enhancing their effectiveness against resistant strains (Atanasov et al. 2020).

Utilizing nature's pharmacy provides sustainable and environmentally friendly solutions while promoting biodiversity conservation. Therefore, our study was focused on investi-

S. R. Mansour (✉) · M. Soliman · A. A. Moustafa
Department of Botany and Microbiology, Faculty of Science, Suez Canal University, Ismailia, Egypt
e-mail: samirarmansour@yahoo.com

M. Soliman
e-mail: mohamedsoliman2312@yahoo.com

A. A. Moustafa
e-mail: raoufmoustafa2@hotmail.com

S. E. Pane
EClab, Department of Biology, Federico II University, Naples, Italy
e-mail: Pane.eclab@gmail.com

G. Guerriero
The Interdepartmental Research Center for Environment (CIRAm), University of Naples Federico II, Naples, Italy
e-mail: guerrier@unina.it

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gation some of medicinal plants for their biological activity like antimicrobial activity, and contribute towards discovering new leads for developing alternative treatments that can overcome challenges posed by antibiotic resistance in human pathogens.

2 Materials and Methods

Study Area

The distinctive geographic location of Egypt results in a notable prevalence of xerophytic plant species within the country's flora composition. This is primarily due to the diverse range of plant species that have adapted to thrive in arid and dry environments. Considering the limited knowledge regarding medicinal plants in Gabal Ras Ghareb, located in Hurghada area of Egypt, our research aims to explore and document the presence of unique medicinal plant species that thrive under challenging environmental conditions in this area.

Gabal Ras Ghareb is situated approximately 30 kilometres south of the city of Hurghada, along the eastern coast of the Red Sea. In this unique location, medicinal plants were collected and carefully preserved in clean plastic bags until they were transported to the lab for identification and subsequent extraction processes.

Plant Extract

The extraction process typically involves maceration of the plant material in methanol followed by filtration and concentration under reduced pressure using rotary evaporator. Methanol-based extractions have been favoured for their efficiency in extracting diverse classes of secondary metabolites with potential therapeutic properties.

Propagation of Human Bacterial Pathogen

The human bacterial pathogen is inoculated onto suitable growth media and incubated for 24–48 h prior to use. Continuous monitoring of colony morphology, biochemical tests, and microscopic examination are conducted to ensure the purity of the pathogen culture throughout the entire duration of the experiment (Toukam et al. 2019).

Evaluation of Antimicrobial Activity

The antimicrobial activity of plant extracts (0.25 mg/ml) was assessed using the method described by (Toukam et al. 2019) with a standardized gold concentration of microbial pathogens according to McFland 0.5 turbidity standard.

Statistical Analyses

All data presented are expressed as mean ± standard error (SE) and were subjected to statistical analyses using ANOVA test, followed by Duncan's multiple range test. These analyses aimed to assess the plant extracts' highest inhibitory efficacy.

Results

2.1 Antimicrobial Activity of Different Plant Extract

The data obtained highlight the potential use of plant-based natural products as alternative sources for developing novel therapeutics targeting drug-resistant human pathogens. The measured inhibition zone (in mm) indicates the extent of antimicrobial activity exhibited by each plant extract against specific bacteria and fungi.

Zygophyllum cocinum showed significant inhibitory activity against *M. luteus*, *Shigella flexneri*, and *Candida albicans* with measured inhibition zones of 13, 14, and 16 mm, respectively. *Astragalus spinosus* exhibited a moderate inhibitory effect with a measured inhibition zone of 9 mm against Gram-positive bacteria.

However, *Verbascum sinaiticum* demonstrated an inhibitory effect against *E. coli* and unicellular fungi, with measured inhibition zones of 11 mm and 6 mm, respectively. On the other hand, *Cleome droserifolia* exhibited a broad range of inhibitory effects against both Gram-positive (G^+) and Gram-negative (G^-) bacteria. *Crotalaria aegyptiaca* also displayed inhibitory effects on five out of nine pathogens tested, with the highest observed inhibition recorded against *Candida albicans* at 17 mm. *Calligonum comosum* exhibited a significant inhibitory effect on six microbial pathogens tested, with the highest efficacy observed against the Gram-positive bacterium *E. faecalis.* The remaining plant extracts tested demonstrated only inhibitory effects on *Shigella flexneri.*

2.2 Minimal Inhibitory Effect

The MIC (Minimum Inhibitory Concentration) of *Cleom* plant extract was determined using an initial dose of 100 ml. The results showed that at this concentration, the extract exhibited inhibitory activity against the tested microorganisms. Further analysis is required to determine the specific MIC values for each microorganism and their susceptibility levels to *Cleome* plant extract.

2.3 Potent Plant Extract and Susceptible Human Pathogens

Cleome droserifolia, *Crotalaria aegyptiaca*, and *Calligonum comosum* demonstrated significant potency against both Gram-negative and Gram-positive human pathogens and unicellular fungi as well. The percentage of their extract efficacy was demonstrated as in Fig. 1 in which *Cleome*-extracted is most potent (27%), followed by *Crotalaria aegyptiaca* and *Calligonum comosum* (23%).

Meanwhile, among human microbial pathogens, Gram-negative bacteria including *Shigella flexneri*, *Helicobacter pylori*, and *Escherichia coli*, as well as unicellular fungi such as *Candida albicans*, exhibited higher susceptibility towards specific plant extracts (Fig. 2). In parallel, *Zygophyllum coccineum, Crotalaria aegyptiaca*, and *Cleome droserifolia* exhibited a potent inhibitory effect against *H. pylori*, a highly resistant stomach bacterium, as well as against bloodstream infections, pneumonia, and bone and joint infections caused by S. aureus (Fig. 3).

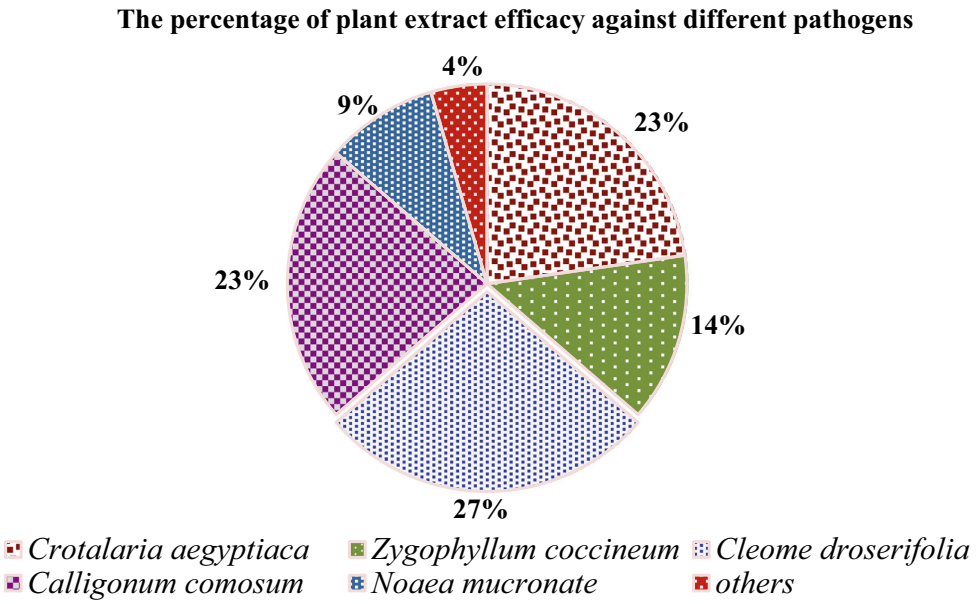


Fig. 1 Percentage of plant extract efficacy against different human pathogens

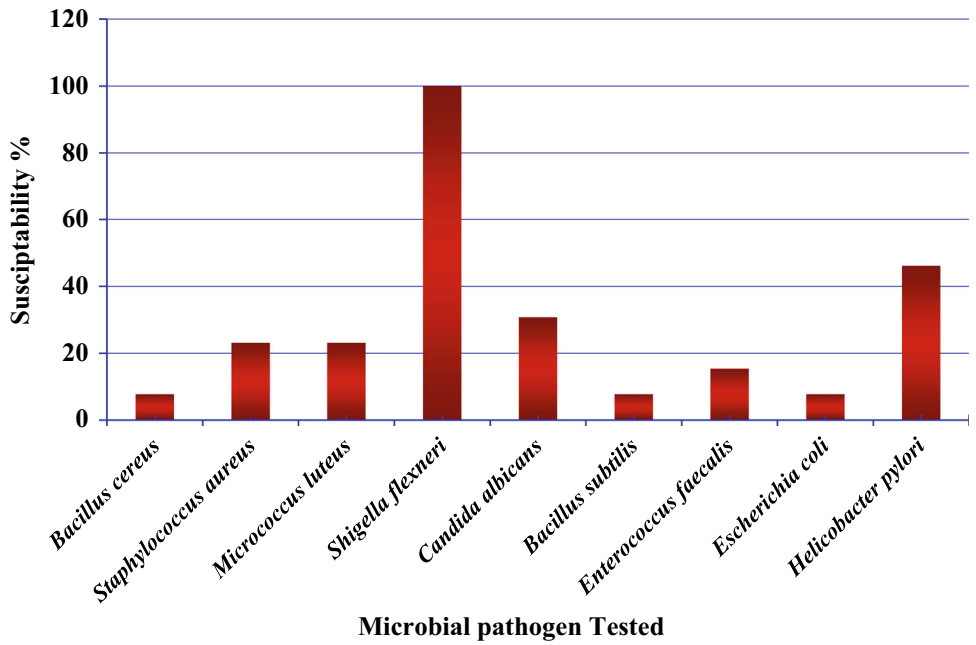


Fig. 2 Assessment of susceptibility percentage of various human pathogens to methanolic extracts from medicinal plants

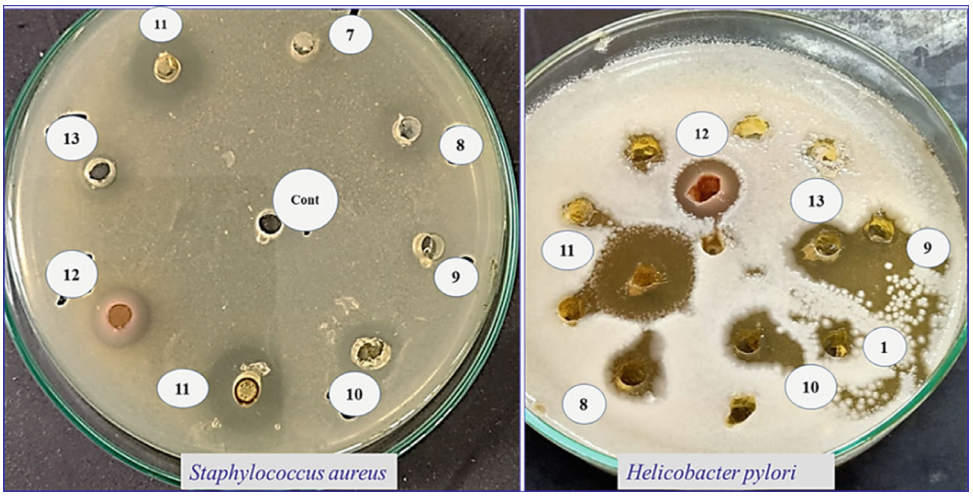


Fig. 3 Antimicrobial activity of methanolic extract of different medicinal plants against *Staphylococcus aureus and Helicobacter pylori* human pathogens. Medicinal plants tested*:* 1, *Noaea mucronate;*2, *Salvadora persica;* 3, *Astragalus spinosus;* 4, *Capparis decidua;* 5, *Verbascum sinaiticum;* 6, *Fagonia indica;* 7, *Noaea mucronate*; 8, *Zygophyllum coccineum*; 9, *Crotalaria aegyptiaca*; 10, *Crotalaria aegyptiaca*; 11, *Cleome droserifolia;* 12, *Calligonum comosum;* and 13, *Forestiera segregate*

3 Discussion

The present study evaluated the antimicrobial activity of several plant extracts against a diverse range of human pathogens including Gram-negative bacteria (*E. coli, Shigella flexneri, Helicobacter pylori),* Gram-positive bacteria (*Micrococcus luteus*, *Bacillus cereus, Bacillus subtilis, Staphylococcus aureus, Enterococcus faecalis*), and unicellular fungi (*Candida albicans*). The obtained data clearly demonstrated that the methanolic extract of *Cleome* exhibited exceptional potency as an inhibitory agent against a majority of these human pathogens. These findings are in line with the research conducted by (Hashem and Shehata 2021), which highlighted the potential application of *Cleome* extract as an innovative source of secondary metabolites for alternative antibiotics in both livestock farming and human pharmaceuticals. In another study conducted by (Zarghami Moghaddam et al. 2021) using a different species of *Cleome* (*C. coluteoides*) and utilizing different parts of the plant, it was found that the flower extract exhibited the most pronounced inhibitory effects, particularly when methanol was employed as the extraction solvent. It is noteworthy to mention that this specific methanolic extract showcased remarkable effectiveness against *Helicobacter pylori*, one of the most prevalent pathogenic bacteria responsible for stomach infections worldwide. Meanwhile, our study aligns with the results from the research conducted by (Gupta and Rao 2014) on a different *Cleome* species, *C. viscosa*, which exhibited notable gastroprotective effects attributed to its free radical scavenging activity, thereby validating traditional claims. Since *Helicobacter pylori* is widely recognized as the first formally acknowledged bacterial carcinogen and ranks among the most prevalent human pathogens (Kusters et al. 2006) discovery of a natural medicinal plant extract with antimicrobial properties against this bacterium may hold promising potential in reducing infection rates caused by such organisms.

Based on our knowledge, the methanolic extract of *Crotalaria aegyptiaca* was tested for its antimicrobial activity for the first time in this study. However, other independent studies have demonstrated its anti-inflammatory, antioxidant, and analgesic activities (Mamdouh et al. 2004). Additionally, another species of *Crotalaria*, namely *Crotalaria pallida*, has been tested and shown to possess inhibitory potential against certain microbial pathogens (Ukil et al. 2016). The biological activities observed in these studies have been attributed to the presence of flavonoids and phenolic compounds within the constituents of *Crotalaria aegyptiaca* extract. These bioactive compounds are believed to play a significant role in its medicinal properties as an herbal remedy (Speroni et al. n.d.).

Among the tested plants, *Calligonum comosum* exhibited notable antimicrobial potency. This finding aligns with previous research conducted in 2021 (Alghamdi et al. 2023), which demonstrated that this plant has been traditionally used for treating skin infections and possesses antibacterial properties. In another study done by Soliman et al., (2021), Abdullah et al., (2024), consistent with our result, they found that the aqueous extract of *C. comosum* displayed significant antibacterial activity against *S. aureus* and *E. coli*. The antibacterial activity of *Calligonum comosum* is believed to be attributed to various phytochemicals with different polarities; however, the specific compounds responsible for this activity have not yet been fully identified. Additionally, another study revealed that this plant displayed cytotoxic activity and holds potential as an anticancer agent against liver cancer cell line (HepG2 cell line).

4 Conclusions

In conclusion, the present study highlights the antimicrobial activity of various plant extracts against a diverse range of human pathogens, including Gram-negative bacteria,

Gram-positive bacteria, and unicellular fungi. Among these extracts, the methanolic extract of *Cleome* demonstrated exceptional potency as an inhibitory agent against most of the tested pathogens. *Crotalaria aegyptiaca* and *Calligonum comosum* exhibited notable antimicrobial potency but less than methanolic extract of *Cleome*. Overall, these findings may highlight the potential utility of plant extracts as alternative sources for developing new antibiotics or herbal remedies. Further research is needed to identify specific bioactive compounds within these plants that contribute to their medicinal properties. Additionally, mechanisms of action of these active compounds need to be explored that could pave the way for developing novel therapeutic strategies against these pathogens and potentially even cancer.

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Characterization of the Plastisphere of Microplastics Isolated from Marine Environments in the Gulf of Naples and Development of Plastics Bioremediation Technologies

Michela Salamone, Federica Carraturo, Carlo Donadio, Ioannis Kalavrouziotis, Marco Guida, and Giovanni Libralato

Abstract

Environmental pollution caused by plastic debris is estimated in millions of tons, mostly fragmented into micro- and nano-plastics. The BioPlast4Safe project aims at studying the chemical–physical characteristics, environmental and human fate, and potential toxic effects of micro- and nano-plastics derived from biodegradable polymers. In the marine environment, microplastic fragments act as a new ecological niche and are often colonized by bacterial species: The microbial communities of the marine "Plastisphere" generally differ from those constituting the marine environment, as plastic has a longer time of decay than most naturally fluctuating marine substrates, as well as a hydrophobic surface that can promote microbial colonization and biofilm formation. For the characterization of marine biofouling, experiments were carried out on the microbial composition of the substrate formed on two different materials, one typical of ships and one newly composed, placed at different geographical locations. During 2022, sampling was also carried out along the Neapolitan coastline, with the manta net, to collect fragments of microplastics, on which the microbiota that colonizes them, constituting true biofilms, was characterized through total DNA extraction and sequencing of the bacterial 16S gene using Next Generation Sequencing (NGS) techniques. The results of the preliminary study of the composition of the biofouling formed on the different materials allowed to hypothesize that there were no differences in the number of adhered microorganisms, but rather diversities in the site-specific species composition. By comparing the results with the Next Generation Sequencing analyses on the free materials in the marine area of interest, it was possible to highlight that certain genera, such as *Vibrio* and *Shewanella*, also part of the marine water microbiota, appear to be often part of the Plastisphere. Employing NGS analyses, it was possible to obtain more specific insights into the composition of the plastic biofilm and genera such as *Oceanoserpentilla*, *Pseudomonas,* and *Neptunomonas* were characterized, among which species capable of biodegrading plastic materials are comprised. The subsequent step will consist of utilizing specific consortia of microorganisms to test the effective degradative activity on biopolymers present in plastic materials, in the marine environment, employing both lab-scale and on-field experimental protocols.

Keywords

Microplastics · Plastisphere · Microorganisms · Biodegradation

1 Introduction

One of the biggest challenges of the ongoing environmental crisis of recent decades is the pollution caused by plastic waste. Plastics have been found in various types of environments, even in human tissues. It therefore represents a growing threat to both ecosystems and humans. Currently in Europe and in Italy, the main treatment for plastic waste is landfill. A recent report analyses trend in the cross-border trade of plastic waste, both within and outside the EU. Approximately 50% of plastics are exported to countries that often lack adequate management infras-

M. Salamone (✉) · F. Carraturo · M. Guida · G. Libralato
Hygiene Laboratories, Department of Biology, University of Naples "Federico II", Naples, Italy
e-mail: michela.salamone@unina.it

C. Donadio
Department of Earth Science, Environment and Resources, University of Naples "Federico II", Naples, Italy

I. Kalavrouziotis
School of Science and Technology, Hellenic Open University, Patras, Greece

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tructures. This increases the estimated environmental impact (D'Amato et al. 2023). Globally, 70–80% of plastic debris is transported through rivers into the ocean. From there, it returns along coastlines and settles on the water surface and seabed (Horton et al. 2017). The microbial ecology of this new anthropogenic ecosystem, called the "*Plastisphere,*" is unique. It has different implications for freshwater and marine ecosystems. Early studies of the Plastisphere were based on microscopy; however, the advent of modern molecular methods, in particular high-throughput DNA sequencing, is gradually increasing our understanding of the different inhabiting microorganisms (Amaral-Zettler et al. 2020).

In marine settings, microplastic fragments provide new ecological niches: Microbial communities in marine Plastispheres tend to be distinct from those in marine settings, due to their longer half-lives than natural fluctuating marine substrates, and their hydrophobic surfaces, which may favor microbial colonization, harmful algal species, and subsequent biofilm formation, distinct from native marine surface substrates (Barros & Seena 2021). However, the functions, assembly processes, and interaction networks of the complex microbial community established on different types of plastics and in different aquatic ecosystems are still not fully understood, although it is known that it is a distinct microbial community with a significant proportion of unique species compared to the typical aquatic community, potentially disrupting the ecosystem community and causing microbial invasion (Li et al. 2021). The aim of this work was to carry out a preliminary characterization and comparison, using molecular techniques, of the microbial biofilm formed on specific marine plastic materials, fixed in the aquatic environment for a given period, and on microplastics collected directly from seawater in the Gulf of Naples using the manta net.

2 Materials and Methods

During the first months of the multidisciplinary BioPlast4Safe project, the University of Naples "Federico II" focused on studying the formation and characterizing of biofilms on samples taken from the marine environment, and on detailed field studies on the composition of marine biofilms on two different types of plastic in two different locations in the Gulf of Naples.

To characterize marine biofouling, experiments were carried out on the microbial composition of the substrate formed on two different materials, fiberglass (a typical ship material) and a new plastic-derived material, called Ecorcore. The analysis was performed on 12 samples, 6 of Ecorcore and 6 of fiberglass, kept in seawater (on-field experiment) for 20 days at different depths (25 cm, 100 cm, 250 cm) in two sites of the Port of Torre Annunziata, close (Capitaneria) and far (Molo Ponente) from the coast. Qualitative and quantitative microbiological analyses, enumeration (total bacterial count at 22 °C) and isolation of viable colonies and their subsequent characterization by Sanger sequencing, were carried out to describe the microbial facies on the newly composed material, and the data obtained were compared with those collected from samples of fiberglass, stored under the same conditions.

Conversely, in the laboratory experiments, samples were collected along the Neapolitan coast using a manta net to collect microplastic fragments on which the colonizing microbiota was characterized. The samples were divided into aliquots and pre-treated for 24 h at 3 different temperatures (4 °C—M09, 22 °C—M05, and 37 °C—M07). This was done in order to study microbial growth under different conditions. To perform the analyses, 200 μL seawater, including the plastics dispersed in it, was collected, and processed using the CTAB protocol (Doyle 1990) to extract total DNA in duplicate. This was followed by amplification of the V3-V4 hypervariable region of the 16S rRNA gene. Next Generation Sequencing analysis was performed based on the concentration of DNA present in the samples and the subsequent amplification.

3 Results

3.1 Preliminary Analyses for the Characterization of the Microbial Communities on Different Types of Plastics Used in the Marine Environment

Quantitative microbiological analysis showed that at the "Capitaneria" sampling point, Ecorcore was less rooted than fiberglass at all depths studied. However, the situation was reversed at the "Molo Ponente" sampling point, as shown in Table 1. Microorganisms from both test materials could be identified by molecular analysis. In particular, the microorganisms isolated from the new material on the "Capitaneria" pier belonged mainly to the genus *Vibrio* and *Photobacterium.* On the other hand, microorganisms isolated from the fiberglass material belonged mainly to the genus *Vibrio.* A higher microbial diversity was found at the "Molo Ponente" pier, where the genera isolated from fiberglass were *Vibrio*, *Photobacterium*, *Shewanella,* and *Bacillus,* and those isolated from the new material are *Vibrio*, *Photobacterium*, *Shewanella,* and *Oceanimonas.*

Table 1 Results of the microbiological analyses carried out at two different sites—"Capitaneria" and "Molo Ponente"—on two different types of plastic materials

Samples	Localization	
	Capitaneria	Molo Ponente
Fiberglass 25 cm	3,2E+06	6,33E+07
Ecorcore 25 cm	1,2E+06	7,08E+07
Fiberglass 100 cm	1,65E+06	2,03E+08
Ecorcore 100 cm	1,2E+06	3,03E+08
Fiberglass 250 cm	1,7E+07	1,18E+07
Ecorcore 250 cm	1,54E+07	2,03E+07

3.2 Preliminary Analyses to Tipify Microbial Communities on Micro- and Macroplastics Sampled from the Marine Environment

Next Generation Sequencing analysis of aliquots of microplastics pre-treated at different temperatures produced the barplot in Fig. 1. This shows the main families detected. The families most represented in the samples are *Alteromonadaceae*, *Pseudoalteromonadaceae, Flavobacteriaceae, Vibrionaceae, Saccharospirillaceae, Moraxellaceae, Rhodobacteraceae, Pseudomonadaceae, Shewanellaceae, Colwelliaceae, Marinomonadaceae.* The species with the highest relative abundance are *Vibrio fluvialis, Vibrio furnissii, Vibrio alfacsensis, Oceaniserpentilla haliotis, Pseudomonas alcaligenes, Psychrosphaera saromensis, Neptunomonas naphthovorans, Oceanospirillum sanctuarii,* and *Shewanella putrefaciens.*

4 Discussion

The total biomass in terms of microorganisms was at one point lower on the new material and at the other point higher on the fiberglass. Sanger sequencing allowed the characterization of the microbial species isolated from the test materials, with highly comparable results. From the preliminary analyses, it can be concluded that the microbial colonization of the new material is comparable to that of fiberglass and that the microbial communities are not substrate-specific, but certainly site-specific. It was noted that some genera, such as *Vibrio* and *Shewanella*, appear to be frequently part of the Plastisphere by comparing the results of Next Generation Sequencing analyses of free materials in the marine area of interest with those obtained from Sanger sequencing of colonies attached to materials commonly used in the marine environment described in Sect. 3.1. Bacteria of the genus *Vibrio* are ubiquitous in the marine ecosystem, often in association with other organisms such as algae or zooplankton. The role of microplastics as abiotic vectors for *Vibrio* sp. has been evaluated in several scientific papers, some of which hypothesize a positive correlation between salinity and the number of *Vibrio* on plastic. Recent studies have investigated

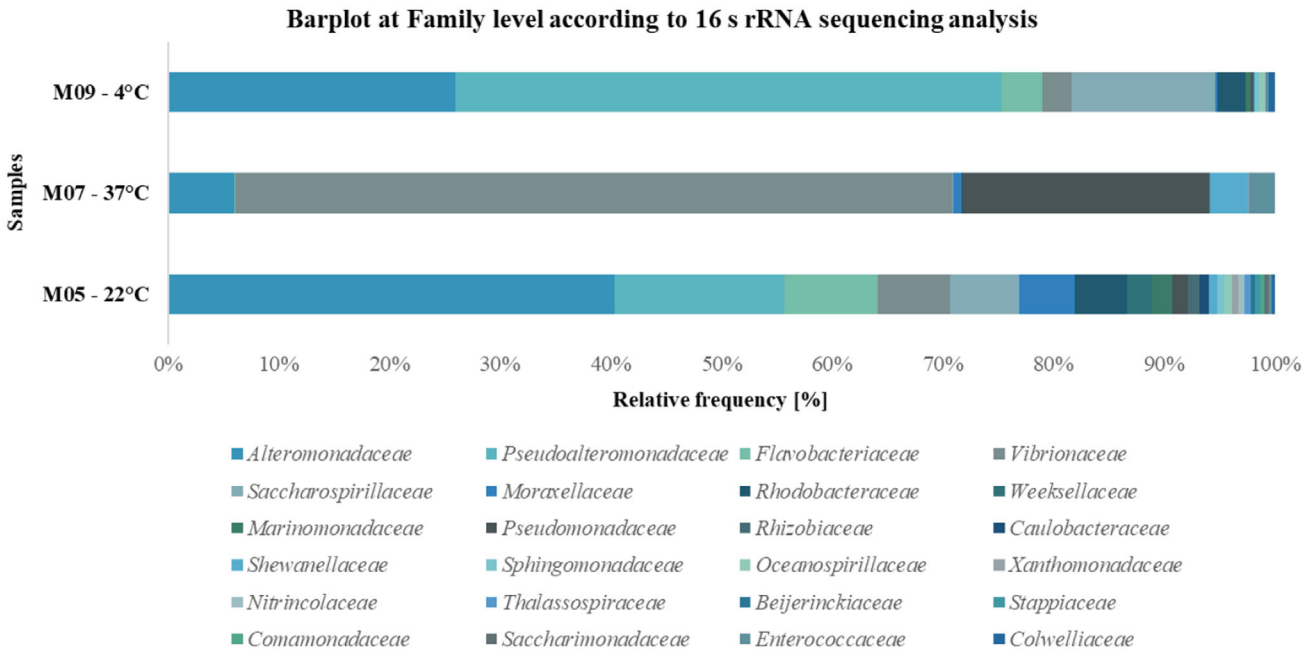


Fig. 1 Barplot at family level according to 16 s rRNA sequencing analysis. Results are expressed as relative abundance of reads

a consortium of strains of *Pseudomonas* and *Lysinibacillus* showed an increase in the production of extracellular matrix within the first 24 h to promote adhesion to HDPE surfaces, resulted in changes in the chemical structure of the polymer. This suggests the potential involvement of these strains in the biodegradation of plastic pollutants.

5 Conclusions

Overall, it can be assumed that the majority of the species that make up the biofilm found on microplastics, and plastics are common opportunistic colonizers. Next Generation Sequencing analyses have provided a better understanding of the composition of the plastic biofilm and genera such as *Oceanoserpentilla, Pseudomonas, and Neptunomonas* have been characterized, including species capable of biodegrading plastic materials. The next step will be the use of specific consortia of microorganisms to test the actual degradative activity on the biopolymers present in plastic materials in a marine environment using experimental protocols at both laboratory and field scale.

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Religious Tourism and Protection of Biodiversity

Fabio Balsamo

Abstract

The research will focus on the contribution of religious denominations in the implementation of sustainable forms of religious tourism, highlighting how religious tourism can become a tool for the protection of biodiversity and natural ecosystems. The paper will examine the legal instruments capable to support the effort of religious organisations in the management of protected natural areas and the most recent legal innovations concerning religious walks in the Italian legal system.

Keywords

Religious tourism · Religion and environmental · Environmental sustainability · Religious walks · Ecological transition

1 Introduction

Religious tourism is characterised by its intrinsic environmental sustainability compared to other forms of tourism.

It is no coincidence that the World Tourism Organisation (UNWTO) in 2017, during the International Fatima Conference on Religious Tourism and Pilgrimage, emphasised the environmental sustainability of religious tourism, which can even appear as a form of ecotourism also in view of its mode of travel, many times characterised by walking itineraries that take place in close contact with nature (see Lo Giacco 2020). In this sense, the experience of the European Green Pilgrimage Network (EGPN) is remarkable. Based on a synergy with the various 'pilgrimage towns', the Network promotes religious eco-tourism through the enhancement of small villages and the promotion of sustainable mobility.

The intrinsically eco-sustainable dimension of religious tourism does not mean, however, that with respect to these activities a further effort should not be made by religious actors to reduce its environmental impact.

2 Settings or Methods or Materials and Methods

The research will focus on the impact of the promotion of a 'green religious tourism' for the ecological challenges facing the planet with the aim to underline the importance of religious tourism as a tool for the protection of biodiversity.

It emerges by the doctrinal sources that religious denominations, as social actors engaged in the 'custody of creation', can contribute to the achievement of the Sustainable Development Goals, enunciated in the UN 2030 Agenda, also through the reduction of the environmental impact of religious tourism. Consider, for example that the *Green Guide for Haji and Umrah*—that develops guidelines for the implementation of green forms of pilgrimage—pays specific attention to the reduction of water waste through the pursuit of the need to contain the water footprint of the individual pilgrim.

Religion organisations can also promote forms of green religious tourism thanks to the establishment and management of biodiversity protection sites also in collaboration with public authorities and/or private foundations. Religious communities are also involved in the phenomena of 'legal anthromorphisation' of natural entities, especially rivers, as in the case of Whanganui River in New Zealand—sacred to the Maori and recognised as a living entity with full legal rights in 2017—and of Ganga and Yamuna rivers in India. Thus, thanks to this operation any damage done to the rivers recognised as legal entity can be penalised in the same way as damage brought to a person (Vazquez 2018).

F. Balsamo (✉)
Ecclesiastical and Canon Law, Department of Law, University Federico II of Naples, Naples, Italy
e-mail: fabio.balsamo@unina.it

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This research will examine some relevant experiences of 'green religious tourism' promoted by religious organisation and the legal instruments that can be used by religious actors to protect biodiversity and natural ecosystems. Finally, it will analyse the provisions concerning 'religious walks' in Italian legal system that can favour a further involvement of Third Sector religious entities in the promotion of eco-sustainable forms of religious tourism.

3 Results

The institution of protected natural areas managed by religious organisation can constitute a first instrument to protect natural ecosystems.

The institution of protected natural areas specifically dedicated to the protection of biodiversity, both animal and plant, is rooted, for example, in the Islamic context. In fact, the establishment of a protected natural area—*hima*—is very often justified precisely by the need to preserve the existence of specific animal or plant species. The first natural protected area in the Islamic context was established by the Prophet Muhammad himself near Medina, and today there are some emblematic examples of the revalorisation of the institution of the *hima* with the national network of protected areas in Lebanon (see Fronzoni 2023).

The management of protected natural areas can also involve religious denominations in collaboration with public authorities and/or private foundations. It's the case of the project 'A Garden to reconnect to the essential' of the Augustinian Nuns of Corigliano—Rossano for the creation of a park-garden at their Monastery thanks to Intesa San Paolo's ForFunding (see Gagliardi 2022). The initiative thus aims to concretely achieve a form of green religious tourism since the natural area is used to welcome tourists and pilgrims, attracted by the symbolic-religious and naturalistic value of the site. The park— designed and supervised by a team of agronomists—has in fact been created with a meticulous respect for biodiversity and native plant species, and it has been sponsored by ten private, public and religious bodies: the Archdiocese of Rossano-Cariati, the Municipality of Corigliano-Rossano, the Codex Diocesan Museum, the Sila and Pollino National Parks, the Italian Botanical Society, Unical—DiBest department, the Green Accord association of journalists, the Augustinian Monasteries of Italy Federation, the Order of Saint Augustine.

The sacred character of some natural sites can also be a prerequisite for their protection through their inclusion in the list of UNESCO sites. This is the case, for example, of what has happened in Italy with the nine *Sacri Monti of Piedmont and Lombardy*, whose recognition was established in 2003 also in consideration of their symbolic spiritual significance.

The recognition of natural sacred sites, as well as the search for adequate protection instruments, presupposes a necessary cooperation between public and religious authorities for the management of these sites, whose interests invest both state and religious orders also with regard to their touristic valorisation. For example, with regard to the *Sacri Monti of Piedmont and Lombardy,* this need for collaboration between religious and public bodies emerges from the institution of a special Permanent Conference, within which all the actors involved in management are represented (Mi-bac, Regions, Dioceses, Municipalities, religious bodies). The Permanent Conference has the task of expressing opinions and proposals on matters and topics that it considers of particular interest for the UNESCO site and for the context in which the Sacred Mounts are inserted; it examines, also for cognitive or reconnaissance purposes only, problems connected with the UNESCO site, its relations with third parties, the quality and type of services offered and the planning of interventions; it verifies the implementation of the activities envisaged by the Unitary Management Plan. The Permanent Conference carries out its activities in coordination with the Permanent Operational Working Group.

The sacred character of some natural sites can be also emphasised thanks to the institutions of UNESCO Biosphere Reserves. These Reserves are areas of terrestrial, coastal and marine ecosystems in which, through appropriate policies of management, the conservation of the biodiversity is associated with the sustainable use of natural resources for the benefit of local communities. Religious organisations can certainly contribute to the management of these areas too.

4 Discussion

The transformation of the religious tourism in an eco-sustainable way is now greatly encouraged in the current Italian legal system by the Italian Law no. 234 of 2021.

Its Article 1, paragraph 963 has established a special 'Fund for Religious Routes' for the relaunch and tourist promotion of the so-called religious walks and the recovery and enhancement of the properties that characterise them'. The Fund's resources are intended to finance 'actions for the relaunch and tourist promotion of religious walks, aimed at devising and implementing a coordinated communication strategy for the national religious walks tourism product'.

Among the subjects entitled to request the registration of an itinerary in the 'Catalogue of Italian Religious Routes', in addition to public bodies, there are also Third Sector bodies, including religious ones, and civilly recognised religious bodies that 'with reference to one or more religious routes, they carry out destination management activities, the promotion of the route and its maintenance, as well as the issuing and management of credentials and testimonium'.

It must be noted that the Italian legislator's choice to identify these routes as 'religious' paths is not without significance, unlike what happened in the Council of Europe in 2017, when many itineraries of an eminently religious nature were recognised as European 'Cultural' Itineraries.

A further aspect worthy of interest is represented by the possibility for the tourist/traveller/pilgrim to acquire and use one or more documents (also in digital form) certifying the pilgrimage for the whole or part of the route (so-called testimonium and pilgrim credential). On this point, it seems to be necessary to argue that the issuance of certifications must be recognised in the Third Sector religious entities or in the civilly recognised religious entities. The issue of certification, in fact, since it is aimed at satisfying a religious interest of the faithful themselves should be the prerogative of the religious bodies involved in the organisation and management of the religious paths. However, the forms attached to the decree seem to allow the issuing of credential and testimonium or other corresponding documents only to the body that has applied the request to register the itinerary in the Catalogue of Religious Walks. That's why it is particularly important that Third Sector religious bodies and civilly recognised ecclesiastical bodies, rather than public territorial bodies, take steps to request the registration of a specific religious walk in this Catalogue.

The most interesting aspect deriving from the implementing decree dated 23.06.2022, however, is the provision of a specific regulatory definition of the concept of 'religious path'. According to the definition of religious path contained in Article 1, paragraph 2 of the implementing Ministerial Decree religious walks are 'excursion itineraries with a religious or spiritual theme, which can be covered exclusively or prevalently on foot or with other forms of slow and sustainable tourism, at an interregional and regional level'.

A significant fact immediately emerges from reading this provision. It is evident how in this definition the religious character of the walk is inextricably intertwined with its necessary environmental sustainability. In other words, according to the legal definition, only that itinerary with a religious or spiritual theme that is realised on foot or with other forms of slow and sustainable tourism integrates the concept of a religious walk. Sustainability thus becomes an indefectible element of the very concept of 'religious walk', with the consequence that a walk with a spiritual theme that is realised in a manner different from those indicated, or in any case not sustainable, cannot be considered a 'religious walk' for the purposes of its registration in the 'Catalogue of Italian religious walks'. In this way, the regulatory intervention seems to further enhance the references to sustainable mobility or soft mobility contained in the various regional legislations and considered characteristic of this form of religious tourism.

5 Conclusions

This approach undoubtedly enhances the intrinsically eco-sustainable nature of religious walks and seems justified by the need to allocate these additional resources provided by the *Fund for Religious Walks* exclusively for those forms of religious tourism that are genuinely projected towards an environmental protection and a reduction in the environmental impact of human activities.

In conclusion, this provision may thus further stimulate religious denominations, and specifically Third Sector religious bodies, to continue their efforts towards the implementation of an increasingly eco-sustainable religious tourism, such as religious walks.

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The ESG Criteria of Islamic Finance Against Climate Change and Toward Sustainability. The Case of Green Sukuk

Vasco Fronzoni

Abstract

Tackling climate change has now become one of the top priorities for the international community, since the future of the next generations is increasingly threatened by production logics and market needs, typical of Western countries, characterized by greenwashing but without any scruples and ethical brake to protect the environment. Conversely, the Islamic financial system has been structured in an ethical way in order to guarantee all human beings wealth, productivity, development, poverty prevention, solidarity, and social justice, in line with ESG criteria. Thanks to its intrinsic ethical characteristics dictated by faith, Islamic finance offers its contribution to the global commitment against climate change in the era of the green transition.

The research method used is full qualitative, based on media and library research, with a comparative legal approach between traditional and Islamic financial system to investigate the stated problems.

The result of this research, investigating the stated problems, is that one of the goals of Islamic finance, is to develop sustainable programs and to find financial solutions in line with the Green economy. One of the most interesting products is represented by the green sukuk, which are aimed at eco-sustainable projects in compliance with the religious law of Islam and with respect for the environment.

The study highlights that there is therefore the possibility of implementing the global economy through the activation of some dedicated financial instruments, i.e. green sukuk, in line with ESG criteria and without having to further contribute to the climate change crisis.

Keywords

Climate change · Greenwashing · ESG criteria · Islamic finance · Green sukuk

1 Introduction

Climate change has a direct impact on the economy, with the emergence of opportunities but also and above all of crises, and is generating a significant transformation of the financial sector also due to the progressive distrust of investors in the system. Indeed, companies are vulnerable to the risks that derive from society's reaction to climate change, just think of the fluctuation of the markets that can increase the cost of business, threaten the profitability of existing assets and influence the value of consumer goods. Another example is provided by the increase in the price of energy due to the depletion of traditional energy resources, such as fossil fuels.

Tackling climate change has now become one of the top priorities for the international community, since the future of the next generations is increasingly threatened by production logics and market needs, typical of Western countries, characterized by greenwashing but without any scruples and ethical brake to protect the environment.[1] Conversely, the Islamic financial system has been structured in an ethical way in order to guarantee all human beings wealth, productivity, development, poverty prevention, solidarity, and social justice, in line with ESG criteria.[2]

V. Fronzoni (✉)
Pegaso Digital University, NA, Italy
e-mail: vasco.fronzoni@unipegaso.it

[1] Bowen (2014)

[2] Arbor (2021)

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2 Settings or Methods or Materials and Methods

By analyzing the economic data deriving from the markets and above all the academic literature and library research to investigate the stated problems, a great responsibility of the countries of the "Global North" in the dynamics of climate change and the resulting crises undoubtedly emerges. The cause is due to the production logic and financial speculations devoid of any ethical restraint of an increasingly industrialized West, progressively equipped with broad negotiating power on strategic fronts, but at the same time also less and less attentive to natural resources, despite a generic but hypocritical attitude characterized by greenwashing.

Indeed, many countries of the Global South, i.e., those states characterized by low income, high population density, and backwardness of industrial processes, are particularly exposed to climate change and environmental risk, especially concerning food safety and natural disasters.[3] Some of them, consequently, have launched specific programs to improve their production processes, develop alternative energies, and reduce emissions harmful to the environment, according to a more ethical path.[4]

It should immediately be noted that it is no coincidence that these initiatives were launched in social groups where religion and identity traditions still have an incisive weight, and where, consequently, the relationship between human beings and natural environment does not appear as unbalanced as elsewhere.[5]

Simplifying the analysis as much as possible, according to the dominant vision in the traditional finance system of the Western world, producing and producing profitably means not taking into account the ethical dimension of business and green needs since, otherwise, there would not be strong competitiveness and revenues would be too low.

3 Results

An important debate thus arose between financial service providers and the authorities that regulate the sector, aimed at studying concrete responses in compliance with the ESG criteria to face the current crisis, which threatens the survival of the financial system and the economic development.[6]

It must be emphasized that climate change also offers new business opportunities and research in the context of a sustainable financial sector is indispensable and even profitable. In fact, the "Green economy" or sustainable finance has gradually made its way into the financial market, which deals with encouraging investments that can generate environmental benefits.[7] The principles of the Green economy are the basis of Green banking practices whose aim is to provide innovative products to support activities that are not harmful to the environment and contribute to its conservation.[8]

As is known, Islamic finance is in line with the objectives of the Green economy aimed at guaranteeing an improvement in human well-being and social equity, significantly reducing environmental risks and the depletion of non-renewable resources.[9] It focuses on the equitable and sustainable use of natural resources, on eliminating direct and indirect negative aspects of commercial banking operations and on promoting the use of respectful business practices.[10] Islamic finance constitutes a sector of the world economy in great expansion, recipient of growing interest in the international financial panorama, so as to constitute a considerable segment of all financial markets and is a system endowed with specific distinct rules and, in some respects, even far from the financial rules and practices of the Western world.

4 Discussion

Islam leads to an economic policy that encourages profit and competition in business, inciting believers to work diligently for economic gain, to own private property, and to engage in business and commerce.

The religious principles of Islam and the ethical sense that pervades every financial transaction attract more and more consumers who perceive these essential values in this particular historical moment, who clearly perceive the link between Islamic finance and environmental sustainability.[11] Thanks to its intrinsic ethical characteristics dictated by faith, Islamic finance offers its contribution to the global commitment against climate change in the era of the Green transition. Indeed, one of the goals of Islamic finance is to develop sustainable programs and to find financial solutions in line with the Green economy.[12]

[3] Rigg (2007)

[4] Fronzoni (2023)

[5] Kouatli (2017)

[6] Cochran (1984)

[7] Islamic Relief (2018)

[8] Bril et al. (2023)

[9] Askari et al. (2009)

[10] Lahsasna (2013)

[11] Hassan et al. (2021)

[12] Asian Developemet Bank (2022)

A wide range of investment instruments have been introduced in recent years to meet the global demand for Green economy and have gained significant momentum as a growing number of major institutional funds and investors have increasingly adhered to broad investment principles, based on sustainable and responsible objectives, to protect the environment, economic ethics, and social impact.[13]

A concrete response to these needs came from Islamic finance and one of the most interesting products is represented by the "Green sukuk," which are aimed at eco-sustainable projects in compliance with the religious law of Islam and with respect for the environment.[14]

The Green sukuk are certificates representing undivided shares or properties involved in projects and investments compliant with Islamic religious law. They are negotiable and are backed by medium-term assets. Sometimes sukuk are defined as Islamic "bonds," even if this identification is incorrect since it tends to distort the intrinsic characteristics of these instruments.[15] These tools, mainly aimed at financing energy projects in compliance with the sustainability principles of the Shari'a, have thus become part of the various financial initiatives undertaken globally in support of the climate, to become in a short time the essential tools for the adoption of many large green economy projects.[16]

5 Conclusions

Green sukuk investments are based on projects focused on the Green economy, which leverage ESG criteria and which are decisive for the implementation of the United Nations 2030 Agenda.[17] Many objectives incorporated in the structure of the Green sukuk have convergent characteristics with the sustainable development goals, above all in consideration of their key characteristic of the so-called underlying asset, which frames them as asset-backed financial products.[18] These assets can be different, in particular a portion of land, a building, and other movable assets, and the underlying asset makes the financing instrument more attractive and an integral part of the real economy, rather than a simple debt-based commercial certificate.

We must also underline the intrinsic ethical nature of Green sukuk which makes them particularly suitable for the promotion of projects focused on environmental protection and energy efficiency from renewable sources.[19] In fact, from a theological point of view, these Islamic financial products have environmental protection as their main objective, because this is a commandment prescribed by Islam, given that Allah has entrusted nature and creation to men, who are accountable to Him. Furthermore, from a financial perspective, Green sukuks also offer a more diversified range of financing options for ESG-aligned projects, as they can be included in a pool of portfolio projects, making it possible to differentiate risk exposure of investors.[20] These tools also represent an opportunity for governments and large companies to increase the capital needed to establish a low-carbon economy, making it possible to meet the demand for green energy through renewable sources, as well as providing a virtuous source and advantageous long-term financing.

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