This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 857510.

This project has received funding from the Government of the Republic of Cyprus through the Directorate General for the European Programmes, Coordination and Development as well as the Cyprus University of Technology.

EXCELSIOR Project

H2020-WIDESPREAD-2018-2020 | Grant Agreement No 857510	
Project full title:	**ERATOSTHENES: Excellence Research Centre for Earth Surveillance and Space-Based Monitoring of the Environment**
Project acronym:	**EXCELSIOR**
Work Package:	**WP8 ECoE Digital Innovation Hub in EMMENA**
Deliverable:	**D8.10 Report on the ECoE Living Labs Program and analysis of effectiveness**
Version:	**Final D8.10**
Dissemination level:	**Public**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 857510.

This project has received funding from the Government of the Republic of Cyprus through the Directorate General for the European Programmes, Coordination and Development as well as the Cyprus University of Technology.

	**H2020-WIDESPREAD-2018-2020/ H2020-WIDESPREAD-2018-01** **Grant Agreement No 857510** This project is funded by the **EUROPEAN COMMISSION** in the Framework Programme for Research and Innovation (2014-2020).
Call / Topic:	**H2020-WIDESPREAD-2018-01 /** **WIDESPREAD-01-2018-2019** **Teaming Phase 2**
Project full title:	**ERATOSTHENES: Excellence Research Centre for Earth Surveillance and Space-Based Monitoring of the Environment**
Project acronym:	**EXCELSIOR**
Work Package (WP): Task (T):	**WP8 ECoE Digital Innovation Hub in EMMENA** **T8.5 ECoE Living Labs Program**
Deliverable (D):	**D8.10 Report on the ECoE Living Labs Program and analysis of effectiveness**
Due date of deliverable:	**30 September 2022** **(Month 36 of the project)** / **Version: Final D8.10**
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Start date of project:	**1 October 2019** / Duration: **84 months**
Dissemination Level:	**Public**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 857510.

This project has received funding from the Government of the Republic of Cyprus through the Directorate General for the European Programmes, Coordination and Development as well as the Cyprus University of Technology.

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Work Package 8: ECoE Digital Innovation Hub in EMMENA

Deliverable D8.10: Report on the ECoE Living Labs Program and analysis of effectiveness

Sections to be protected	Description	Owner	Access Rights	
			Period	**Type***
None	-	-	-	**PD**

*PD: Public dissemination CA: Confidentiality Agreement required for disclosure

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EXECUTIVE SUMMARY

This document, entitled "D8.10 Report on the ECoE Living Labs Program and analysis of effectiveness" provides a detailed description of currently ongoing developments pertaining to the Living Labs Program of the ERATOSTHENES Centre of Excellence (ECoE). In specific, Living Labs in two of the scientific thematic areas of the centre are currently under development, namely in the thematic areas of "Agriculture" and "Atmosphere", both of which are presented in detail in this report. The role of each Living Lab and main End-user categories are discussed, along with infrastructure devoted to each Living Lab and the relative procedures that will enable access to interested parties.

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Abbreviations and Acronyms

CUT	Cyprus University of Technology
DIH	Digital Innovation Hub
ECoE	ERATOSTHENES Centre of Excellence
EO	Earth Observation
EMMENA	East Mediterranean/Middle East/North Africa
ESA	European Space Agency
GEO	Group on Earth Observation
TROPOS	Leibniz Institute for Tropospheric Research
UAV	Unmanned Aerial Vehicle

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1. INTRODUCTION

The ECoE Living Labs Program is a long-term plan for a combination of research infrastructure compilation and network for collaboration between academia and stakeholders as well as interested entities, leading to implementation of scientific principles in sectors other than academia, for the combined benefit of the society and the economy.

This document presents the development of an open innovation network between academics, students, stakeholders, researchers, and industries, with end-users having a key role in the participatory approach implemented in the Living Labs instead of just being passive receivers of innovation. The ongoing development of the ECoE Living Labs program follows the European Network of Living Labs guidelines for every case of thematic area Living Lab, providing the five essential elements of a Living Lab: (1) active user involvement, (2) real-life setting, (3) multi-stakeholder participation, (4) multi-method approach, and (5) co-creation among the main actors of a Quadruple Helix Model, namely citizens, government, industry, and academia[1].

The two Living Labs are currently proposed in the thematic areas of Atmosphere and Agriculture, which are further described in this report. Additional ideas for Living Labs in other thematic areas are under discussion but are not presented herein since their development is still in its initial stage, specifically under discussion with the local stakeholders in each area.

1.1 Goals and Objectives of the Living Labs Program

During the EXCELSIOR project, ECoE aims to develop a Living Labs Program in coordination with strategic partners. The ECoE Living Labs main objective is to enable ECoE staff and third parties the hands-on reuse of data generated by the ECoE, as well as measurements and tools, to experiment, test and maintain new value chains. Also, the Living Labs program will attempt to maximise the Open Innovation potential of the new Centre of Excellence.

The ECoE Living Labs programme will be an open innovation eco-system for big EO data innovation in the EMMENA region, where DIH academics, students, researchers, industry members, policy makers and end-users can come together to generate and validate ideas. The programme will involve close interaction with end-users of potential products/services in a user co-design, co-creation multi-actor approach. This programme will attempt to be an intermediate space in the DIH between academia, local/national Government, private companies and ECoE's Research Competence Centres, to test and study new solutions for real life problems with swift prototyping or validation.

A first draft timeframe for the two Living Labs under preparation is provided in Table 1, while detailed description of the proposed Atmospheric Research and Agricultural Research Living Labs are provided in Section 2 of this report.

[1] https://enoll.org/

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Table 1. Proposed Timeframe for the two Living Labs under preparation

AgriLab Schedule	
Action	**Results**
Experimental Implementation of recommended practices	• First Series by 31 March 2023 • Second Series by 31 March 2024 • Third Series by 31 March 2025 • Fourth Series by 31 March 2026
Evaluation/ Validation of recommended practices	• First Series by 31 July 2023 • Second Series by 31 July 2024 • Third Series by 31 July 2025 • Fourth Series by 31 July 2026
Suggestion of management practices and estimation models for biomass in agricultural lands	• First draft by 30 September 2023 • Second draft by 30 September 2024 • Third draft by 30 September 2025 • Final draft by 30 September 2026
ATMOLab Schedule	
Action	**Results**
Operation of CARO national facility	• Between June and December 2024
Scientific measurement campaigns	• First Series by 30 September 2025 • Second Series by 30 September 2026
Hands on training and high-level services	• First Series by 30 June 2025 • Second Series by 28 February 2026 • Third Series by 30 September 2026

The dates proposed in Table 1 are preliminary and subject to change, based on the availability of infrastructure, data acquisition, etc.

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2. Living Labs under preparation

2.1 AGRICULTURE thematic area

ERATOSTHENES AgriLab
ERATOSTHENES Centre of Excellence
Agricultural innovation Living Lab

Living Labs represent a user-centric, open innovation approach for sensing, prototyping, validating, and refining complex solutions in multiple and evolving multiple contexts with a cross-sector nexus approach and provide an open space for the dialog, co-creation, and experimentation in which traditional, experience, and specific knowledge are integrated for the research, education and awareness raise concerning food production and natural resources conservation[2,3].

The proposed synergies and end-users identified for the Agriculture thematic area Living Lab are presented in Figure 1.

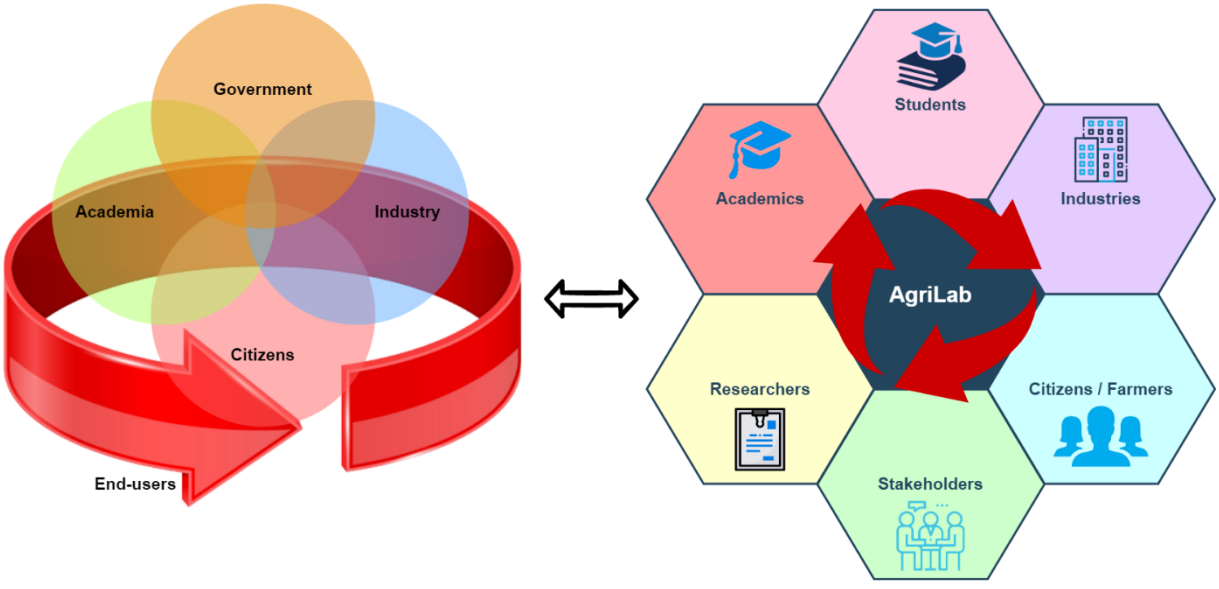

Figure 1. **AgriLab** synergies and End-users

[2] Wolfert J., Verdouw C.N., Verloop C.M., Beulens A.J.M. (2010) Organizing information integration in agri-food—A method based on a service-oriented architecture and living lab approach. Computers and Electronics in Agriculture 70:389-405. DOI: 10.1016/j.compag.2009.07.015.
[3] Zapata F., Barbieri G., Ardila Y., Akle V., Osma J. (2019) AgroLab: a living lab in Colombia for research and education in urban agriculture, Cumulus Conference Proceedings-The Design After.

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2.1.1 Role of ERATOSTHENES AgriLab

The Cyprus University of Technology (CUT) has provided the **ERATOSTHENES** Centre of Excellence (CoE) access and use to the CUT agricultural research facility, which will be utilized for establishing the first **Agr**icultural **i**nnovation **L**iving l**ab** (**AgriLab**) in Cyprus and one of the few in the EMMENA (East Mediterranean, Middle East & North Africa) region. **ERATOSTHENES AgriLab** will act as an experimental environment (test bed) where users can interact, as well as apply and test new agricultural management practices and technologies in a fully equipped and monitored environment to tackle the challenges of climate change, water scarcity, soil health degradation, and biodiversity loss, etc. based on their priorities and strategic goals.

2.1.1.1 Main Actors

a. Citizens

Citizens' and farmers' engagement mechanisms in agro-food systems governance have lagged due to their non-participation in the development chain. Similarly, policy-decision making lacks involving citizens during the development of the models built as tools for assessing the risk of environmental deterioration by the current agricultural management practices. Nowadays, the farmers and local citizens are not priority actors in the emergence of innovative technologies or ideas, which are perceived as exogenous[4]. Therefore, several activities will be held at ERATOSTHENES **AgriLab** to involve farmers and citizens and promote a participatory approach in developing policies and products under the regulations of protecting the integrity of the environment and public health. These activities will include organizing one-off events targeting citizens, and other actors of the agricultural sector (e.g., farmers), which will consist of regular visits to the ERATOSTHENES **AgriLab** followed by discussions, allowing for interaction between farmers, citizens, stakeholders, and researchers. Therefore, the visits of citizens and farmers to the ERATOSTHENES **AgriLab** and the briefing information about the innovative experiments taking place will enrich their knowledge, encourage their participation in the upgrade of agro-food systems and simultaneously transform them into promoters of initiatives and innovation projects.

b. Government

Living Labs appear to have the potential to accelerate co-creation and adoption throughout the value chain because of their user-centric approach used to develop and co-create innovative solutions in partnership with stakeholders and tested in the users' real-life context[5]. ERATOSTHENES **AgriLab** has the potential to be characterized by a high

[4] Toffolini Q., Capitaine M., Hannachi M., Cerf M. (2021) Implementing agricultural living labs that renew actors' roles within existing innovation systems: A case study in France. Journal of Rural Studies 88:157-168. DOI: 10.1016/j.jrurstud.2021.10.015.

[5] McPhee C., Bancerz M., Mambrini-Doudet M., Chrétien F., Huyghe C., Gracia-Garza J. (2021) The Defining Characteristics of Agroecosystem Living Labs. Sustainability 13. DOI: 10.3390/su13041718.

number and diversity of stakeholders involved and the capability to provide different services to different stakeholders. The planned objectives of ERATOSTHENES **AgriLab** are set based on the needs of several stakeholders from the public sector, e.g., the Department of Environment (DoE), Department of Agriculture (DoA), Agricultural Research Institute (ARI), Department of Forests (DoF), Water Development Department (WDD) of the Ministry of Agriculture, Rural Development and Environment (MARDE), Cyprus Civil Defence (CCD) of the Ministry of Interior of Cyprus, Farmers and Farmers' associations such as Panagrotikos and PEK, etc. One of the key objectives of ERATOSTHENES **AgriLab** is to produce data that meet country and EU policy needs and decision-making.

By 2020, EU member states are not allowed any free greenhouse gas emissions allowances. The Republic's revenues from auctioning GHG emissions allowances for 2021 stood at 120 million. The agricultural sector produces nearly 6% of its total GHG emissions in Cyprus. DoE has upgraded its strategic plan for reducing GHG emissions in 2017. ERATOSTHENES **AgriLab** will potentially provide all the data and quantitative information required for successfully implementing its strategic plan to reduce GHG emissions, particularly from the agricultural sector. Moreover, ERATOSTHENES **AgriLab** will provide all the required data that can be used to assess the risk of the contamination of coastal zone due to surface-applied agrochemicals, which is one of the key elements of the protocol on integrated coastal zone management in the Mediterranean that MARDE has adopted for developing the national strategy and action plan to manage the coastal zones of Cyprus.

At the ERATOSTHENES **AgriLab**, experimental studies will be continuously conducted to evaluate and assess the impacts of selected management practices on soil health restoration and crop yield optimization before their adoption and implementation in the agricultural fields in Cyprus and other countries with similar climates. The outcomes of these studies can also be used by DoA, ARI, farmers, and farmers' associations, since that will assist them in implementing their plans for restoring soil health. This in turn will decrease the intensive use of pesticides and fertilizers that adds additional cost to public authorities to regulate and monitor pesticide pollution and increases the operational costs for the farmers. In addition, the national funds to eliminate the hazards of pesticides will be diminished, and simultaneously, the environment's integrity and public health will be shielded. Moreover, ERATOSTHENES **AgriLab** will provide all the essential information to the farmers for greater resilience of crops and decreasing soil carbon losses from their agricultural lands. Furthermore, ERATOSTHENES **AgriLab** will promote and evaluate precision agriculture and circular economy practices, which also aligns with the National Waste Prevention Programmes carried out by DoE. In the ERATOSTHENES **AgriLab**, all the recommended practices for effectively utilizing waste and by-products produced from the agricultural sector will be implemented and evaluated, aiming to reduce energy demand by agricultural systems and encourage appropriate energy optimization approaches for evaluating systematic energy efficiencies, which is one of the main objectives of the research conducted in ARI.

Moreover, utilizing the data collected from the ERATOSTHENES **AgriLab**, suggestions for adopting new agricultural management practices will be provided, targeting the maximum

optimization of machinery and irrigation systems' operations in the farming lands (e.g., UAV-based plant protection/plant nutrition, precise irrigation, etc.) with significantly increased energy efficiency for the farmers, which is subject of interest for the stakeholders in the agricultural sector in Cyprus (e.g., ARI, DoA, WDD, etc.).

Two of the primary responsibilities of the WDD of MARDE are the study, design, operation, and maintenance of the infrastructure related to irrigation and water supply and to protect water resources from contamination and pollution of the environment. Within this framework, the proven solutions for reversing land degradation provided by utilizing the data from ERATOSTHENES **AgriLab** will also assist in promoting sustainable water resources management and water systems restoration. Limiting the current quantities of surface-applied agrochemicals will also reduce the energy consumption for water purification of Cyprus's nitrate-contaminated surface and groundwater systems, reducing the carbon footprint. Replenishment of soils through the blending of multi-scale Earth Observation, ground-measured data, and geospatial modeling is expected to financially empower farming communities and increase their profit margins by increasing water availability, thus achieving long-term conservation of the agricultural landscapes

Agriculture utilizes enormous resources, while 85% of global water consumption is used for irrigation. Solar photovoltaic (PV) systems require large surface areas because of the relatively diffuse nature of solar energy. PV farms will increase competition for land resources as food production and energy consumption are growing and vie for the limited land resources. Part of the area used for ERATOSTHENES **AgriLab** will be used for PV farming to study the various implementation opportunities for agrivoltaics, depending on the local climatic conditions, the facility's scale, and the compatibility with current agricultural management practices and to assess the financial viability for selected crops. These are aligned with the mission of the Energy Service of the Ministry of Energy, Commerce, and Industry of Cyprus and its strategic goals to create a sustainable and competitive energy market, the exploitation of the national energy savings potential, and the promotion of renewable energy sources.

Furthermore, ERATOSTHENES **AgriLab** will produce high-quality data for developing models to estimate the biomass in the agricultural lands. These data and models will provide essential information to DoF and CCD regarding dry biomass in the agricultural lands in Cyprus, which has been identified as a controlling factor for reducing the wildfire hazards and risks for public and biodiversity safety and for predicting the wildfire's propagation.

In addition, visits to the ERATOSTHENES **AgriLab** will connect young talent and regional businesses to support the retention of the next generation of researchers and innovators. That will assist in minimizing gender discrepancies and achieving gender balance in soil and water research and the agricultural sector, which is also a priority for the Department of Labour of the Ministry of Labour, Welfare and Social Insurance of Cyprus.

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c. Industry

Living labs are innovation infrastructures that have the capabilities to assist large agricultural and agri-food industries, SMEs, and start-ups in creating participative strategies to define, design, develop and validate new products and services that can cover the needs of a specific purpose and potentially maximize their profits through this partnership. However, one of the main obstacles facing the industries is that it is often difficult to deliver efficient standardized information to the farmers, which partly explains the low adoption rate of automated systems. Farmers also complain because the exchange is mainly one-way: from industry to farm, and the information they receive from industry is hampered by a poor level of information-integration and mostly on paper in a non-standardized data format, and their integration into their management system constitutes a major challenge. In addition, industries are also poor at reaching out to other organizations to develop strategic advice relating to the future[6]. ERATOSTHENES **AgriLab** could potentially enable information sharing and thus facilitate and improve knowledge-based production of innovative and applicable technologies that industries can adopt. Moreover, the collaboration that will be established between the ERATOSTHENES CoE and the enterprises through ERATOSTHENES **AgriLab** will initiate a close effective collaboration network with the national stakeholders and potential end-users in the agricultural sector, which will be the foundation to expunge their resistance to innovative solutions which in turn will increase their competitiveness and capacity for enriching their knowledge.

d. Academia

Living Labs is an increasingly popular component encompassing a range of strategies that engage students, faculty, staff, and/or community in campus sustainability activities[7]. ERATOSTHENES **AgriLab** will constitute an environment for multidisciplinary interaction for research and education in agriculture. In terms of education, new interdisciplinary courses and integration of experience-based learning activities within existing courses will be developed based on the activities implemented in ERATOSTHENES **AgriLab**. In addition, the lab will consist of a means to support mental restoration and student engagement in projects for carrying out pioneering research that ranges from management practices, soil health, and ecological restoration to food systems, energy, waste transformations, and water resources management in the agricultural sector. Moreover, ERATOSTHENES **AgriLab** can also be used as a teaching tool to challenge and stimulate students' creativity in finding innovative solutions to tackle problems related to agricultural management and to ensure that they will become innovative professionals instead of routine performers. Furthermore, the students engaging in the activities of ERATOSTHENES **AgriLab** will overcome the obstacle of "lack of experience" in gaining employment due to the links with work-

[6] Burbridge M. (2017) If Living Labs are the Answer – What's the Question? A Review of the Literature. Procedia Engineering 180:1725-1732. DOI: 10.1016/j.proeng.2017.04.335.

[7] Gomez T., Derr V. (2021) Landscapes as living laboratories for sustainable campus planning and stewardship: A scoping review of approaches and practices. Landscape and Urban Planning 216:104259. DOI: 10.1016/j.landurbplan.2021.104259.

life already during the education. Finally, the under-development agricultural living lab will create new academic knowledge for researchers through research publications and technical and technological recommendations. Eventually, the novelty and importance of the topic favours the generation of proposals for funding calls and will point out the importance of interdisciplinarity when tackling complex issues in the agriculture and agri-food system.

2.2 ATMOSPHERE thematic area

ERATOSTHENES Centre of Excellence
Atmospheric Research Living Lab (ATMOLab)

The Intergovernmental Panel on Climate Change (IPCC[8]) has shown clearly that collective, urgent action is needed to keep the planet's climate within tolerable levels of warming. A temperature increase beyond 2°C will put severe stress on human health, impact food production, disrupt water supplies and damage property/infrastructure. In addition, the resulting estimated annual economic loss could be between 0.2 % to 2 %, rising with further warming.

Furthermore, the report highlights that one of the highest projected risks, regarding climate change, is foreseen for small islands. The risks are determined by the increases in temperature, which will lead to more violent storm surges, droughts, changes in the precipitation patterns, and sea level rise. Thus, small islands present the most urgent need for investment in capacity building and adaptation strategies to reduce the impact of climate change. Moreover, EU identified four key risks caused by the climate change impacts: mortality and morbidity of people and changes in ecosystems due to heat, heat and drought stress on crops, water scarcity, and flooding and sea level rise.

Customized climate-related tools, products and information will enable climate-smart, strategic decisions to build resilience to climate change. The ERATOSTHENES Centre of Excellence (ECoE) responds to user needs for scientifically credible information for climate monitoring, evaluation and quality assurance of products and services through the creation of a Living Lab program dedicated to Atmospheric Observations.

[8] IPCC, 2022: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. In Press.

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2.2.1 Role of ERATOSTHENES ATMOLab

ATMOLab is the Atmospheric Remote Sensing Living Lab operating under the Department of Climate and Environment of the ERATOSTHENES Centre of Excellence. The overall mission of the **ATMOLab** (for short from now on) is to promote a world-class open innovation eco-system for big EO data in EMMENA, where academics, students, researchers, industry members, policymakers and end-users can come together to generate and validate ideas toward a better understanding of the Mediterranean climate and the regional processes that lead to extreme weather conditions.
More specifically, **ATMOLab** utilizes the synergy of ground-based and space-borne atmospheric remote sensing along to support the creation of new knowledge about the complex aerosol-cloud-radiation interactions met in the Mediterranean environment.

The programme involves close interaction with end-users of potential products/services in a user co-design, co-creation multi-actor approach dedicated but not limited to: (a) the development of new atmospheric remote sensing technologies, (b) the operation of observing facilities for continuously monitoring of the atmosphere, (c) the development of new retrievals from ground-based and spaceborne remote sensors.

The ERATOSTHENES **ATMOLab** is created with the purpose to bring several users to access observations of various atmospheric parameters to test and study new solutions for real-life problems with swift prototyping or validation.

One important component of the **ATMOLab** will be a web portal (designed and build in collaboration and support of the IT and the Big Data Analytics Department of ECoE) which will act as the central point for access to the Research infrastructure observations. Through the portal the different classes of users will have access to the ACTRIS and Cloudnet databases and to the atmospheric observations beyond the ACTRIS, available in ECoE.

ATMOLab will be a facility open to all external users, including users from SMEs, users from the European or the EMMENA region, and also those outside these regions. Users refer to any researcher, student, engineer, technician, officer or citizen who needs the support of an observational platform to carry out a scientific study, or to design, test, proof and study new solutions.

The staff of ECoE will act as trainers of the users who want to access **ATMOLab**, explaining the basic concepts of the instruments and the retrieved observations, and describing the basic routine to access the data and the processing routine for generating products. For end-users not from the academia sector, an introduction to the basic concepts of performing a scientific study will be given.

From the moment of developing the idea, the ECoE staff and the end user will work together on a collaborative design of the study. Using this approach, the ECoE staff will understand better the needs of the end user and will have a better image of every day financial demands.

2.2.2 ACCESS to ATMOLab

Through **ATMOLab**, the ECoE will offer access to the research infrastructures and observational facilities of the Cyprus Atmospheric Research Observatory (CARO).

The observations that will be collected by CARO requires impressive processing and storage resources. The resources could be made available by ECoE, together with processing tools, thus the end-users, either these are students, researchers, academics, representatives from the industry, or policymakers, will have at their disposal all the tools they need to follow the experiment.

Through **ATMOLab** the end-users will have access to:

- Comprehensive measurement applications using state-of-the-art equipment and expertise within the domains: aerosol vertical profiles, cloud-aerosol-radiation observations, atmospheric dynamics, wind fields, aerosol-cloud interaction;
- Scientific measurement campaigns, calibration and intercomparisons, instrument testing, data analysis;
- Hands-on training on the use of research infrastructures and observation platforms;
- High level services and support to users including training for young scientists and new users.

One of the advantages of the concept of **ATMOLab** is that the user will make use of the IT capabilities and virtual machines available at ECoE and not be requested to make a mirror of the data but access it instead using cloud processing tools.

The users will have access to infrastructure with direct connection to CARO data. Software tools to access, read, and visualize the data will be available on this infrastructure, with the support of the IT and the Big Data Analytics Department of ECoE. Several packages[9] will be developed based on open-source repositories and will be available to the community of atmospheric sciences.

2.2.3 ATMOLab Infrastructures

ECoE will run the Cyprus Atmospheric Remote Sensing Observatory [CARO] National facility, which will consist mainly of the Aerosol Remote Sensing and the Cloud Remote Sensing Observational Platforms.

Both Operational platforms will include the optimum instruments required by ACTRIS European Research Infrastructure and will be operated by the Cyprus Atmospheric Remote Sensing Observatory (CARO; https://excelsior2020.eu/infrastructure/) of ECoE. The CARO infrastructure comprises two high-tech containers housing state-of-the-art lidar, radar and radiometric equipment that are used for:

[9] Packages like pyLarda, parsivel2tools, polly4cloudnet, Pollynet_processing_Chain, polly2earlinetDB, polylog, PollyNET-EARLINET-SCC, cloudnetpy, CloudnetPy-QC, cloudnet-processing, mrr2c (the list is not mandatory or exhaustive, and it will be updated when CARO will be fully operational and the packages will become available).

- The investigation of the processes that determine the life cycle of dust and its interactions with clouds and radiation;
- The development of new remote sensing-based methodologies/tools for dedicated studies (e.g. evaluation of space-borne lidar missions);
- The investigation of key atmospheric parameters (e.g. optical and physical properties of aerosols, clouds, water vapour, temperature, wind) above the Mediterranean region;
- 24/7 monitoring of the atmosphere, from the ground up to the stratosphere, supporting governmental and European infrastructures regulating aviation and air quality hazards (e.g. volcano eruptions, fires).

Currently[10], CARO National Facility, located in the center of Limassol, Cyprus, operates the state-of-the-art multiwavelength Raman lidar PollyXT-Cyp for aerosol profiling and the sun/sky photometer of the Aerosol Robotic Network (AERONET, CUT–TEPAK site, Limassol, Cyprus, http://aeronet.gsfc.nasa.gov) (Holben et al., 1998). The site is in the center of the city and in close proximity to the sea. Additionally, it is at a distance of 500m from the PollyXT-CYP lidar system.

In the near future CARO facility will operate a 35 GHz cloud radar, microwave radiometer, scanning Doppler lidar, wind lidar, a disdrometer and a ceilometer. As soon as both observation platforms for aerosol and cloud vertical profiling will be operational, CARO will become one of the most advanced facilities placed in the region (East Mediterranean, Middle East & North Africa) with high interest concerning the atmospheric structure. In addition to the aerosol and cloud remote sensing observational platforms, CARO will probably include a solar radiation station and the Disdrometer networks of ECoE.

2.3.4 Main category of users of ATMOLab

a. Government

One category of living lab users is represented by the Cyprus Department of Meteorology. CARO's capabilities sample the troposphere, and in special conditions, also lower stratosphere. CARO will be able to identify layers of atmospheric particles (dust, smoke, volcanic ash) and provide information about the height of the layer. Thus, the Department of Meteorology can provide information to the airports, for safe operation, using real-time measured data, in addition to the Meteorological Aerodrome Reports (METAR), and the Terminal Area Forecasts (TAF) that are currently available. A special case of extreme conditions for navigation is represented by the presence of volcanic ash. An example is represented by the 2010 eruption of the Eyjafjallajökull volcano from Iceland, which led to a total stopping of civil aviation for more than 1 week in entire Europe. Using CARO capabilities, layers of volcanic ash can be identified, and based on this, timely issuing of alerts will follow. Thus, by accessing **ATMOLab**, users from the Department of Meteorology will be able to define their experiments of observation, based on their needs, for better services, and better information in

[10] September 2022

making decisions. Furthermore, given the wind profiling capabilities of CARO, a similar restriction can be taken in case of strong winds, the information provided in real-time by the wind lidar of the observatory, access through **ATMOLab**.

By determining the parameters needed for their operation, the Department of Meteorology can issue alerts for storms, based on the Skew-T stability diagram, that is delivered in real-time operation (using less than 1h measurements) by CARO. This comes in addition to the radio sounding performed by the Department of Meteorology once per day. Thus, CARO can provide a similar diagram, but with a temporal resolution of several minutes.

b. Industry

The **ATMOLab** will be open to SMS and industries offering ground truthing and quality assured observations of atmospheric parameters. Those observations could be used for the validation, calibration, and proof of concept of co-designed and co-developed sensors, models and products.

c. Academia

Atmospheric scientists will have the possibility to access the CARO facilities and to make studies with data collected by the observatory. The main advantage of CARO is represented by its geographic position, with air masses influenced by the East Mediterranean, Middle East, and North Africa. For example, dust intrusions from Sahara over Europe occur mostly during spring. As the air mass is transported towards Europe, it may also overpass Cyprus, and be detected by the remote sensing instruments of CARO. The dust overpasses different lidar stations, over which it is detected, and the changes of the dust particle properties can be studied. In recent years, several observation campaigns were made for this purpose, some examples being represented by the CyCARE, Pre-TECT, or ASKOS campaign.

By building the CARO infrastructure, the observations will not be limited to several weeks/ months per year, or one IOP for two consecutive years. Having permanent observations, the studies with data from multiple years can be made and changes in patterns or circulation from one season to another, or from one year to another can be detected.

Having remote access to CARO measurements, scientists can do their experiments, without the need to be physically present in Cyprus all the time or can monitor parameters online. Furthermore, by having infrastructure installed at ECoE, they will not need to clone the measurements (size of data can be in the order of magnitude of tens of TB), since the infrastructure of the living lab will have a direct connection to CARO measurements.

Being able to control the instruments, scientists will have the option to perform a specific experiment, without interfering with the regular measurements needed by CARO operation performed in the framework of ACTRIS. A further example is the Trans-National Access calls from the ATMO-ACCESS project. The ATMO-ACCESS TNA offers open physical and remote access to 43 operational European atmospheric research facilities, with some of the facilities being similar to CARO (for atmospheric

remote sensing). By creating **ATMOLab**, CARO aligns with the policies developed in the framework of ACTRIS.

d. Young Scientists

An important sector of users is represented by students. Whether these are from high schools or universities, they will have the chance for a first contact with research. They will understand the use of the basic principles learned from schools and how these are applied to everyday activities (for example how scattering works, or how the Doppler principle is applied). The students will find out how to properly structure different types of data, and different levels of data (from raw signals to variables with physical meaning), how to archive a large amount of data and how to structure it in a proper way for easier access. They will learn from ECoE experts how data from different instruments are used in a synergistic way to extract complementary information about atmospheric scene classification. Thus, students from different courses of the Cyprus Technical University can be users of the atmospheric living laboratory. Students from the Department of Informatics will be able to find out how the IT resources are used for research purposes, or even to establish algorithms than can handle real-time data. TStudents from the the Department of Electrical Engineering will be able to learn about the application of radars and lasers for everyday use, about collecting data and how this data can be used for real-time operation. Students from the Department of Civil Engineering will learn about the use of the ground-based station for the atmospheric sensing.

e. Space agencies

Given the resources of ECoE, and the potential development of CARO, **ATMOLab** can be used as a tool for the calibration and validation of ESA missions, from the Copernicus programme. The targeted active missions for this, are Sentinel-5P, ADM-Aeolus, or the future mission EarthCARE. The ground-based instruments, which are used for the cal/val of the space missions, together with the Big-Data cube from ECoE, which will have direct access to space measurements, will help **ATMOLab** to develop and become a partner of ESA_Lab[11].

f. Cyprus Ornithological societies

Using the synergy between CARO instruments, the particles detected above the station can be identified as aerosols, hydrometers, or insects. One possibility to use the living labs is to study the behaviour of insects, as these pass above CARO station, and are detected by the remote sensing instruments[12]. Having several years of measurements, users from the Cyprus Ornithological societies (for example BirdLife Cy) could analyse the activity of the insects by looking at the products delivered by CARO. Thus, a study regarding the change from one season to another, or one year to another

[11] https://www.esa.int/Space_in_Member_States/United_Kingdom/Setting_Up_an_ESA_LAB2

[12] K. R. Beerwinkle, J. D. Lopez, JR., J. A. Witz, P. G. Schleider, R. S. Eyster, P. D. Lingren, Seasonal Radar and Meteorological Observations Associated with Nocturnal Insect Flight at Altitudes to 900 Meters, Environmental Entomology, Volume 23, Issue 3, 1 June 1994, Pages 676–683, https://doi.org/10.1093/ee/23.3.676

insects behaviour can be done. Furthermore, by knowing what type of insects are passing above the station, more products can be developed, to further improve the classification schemes used by the scientific community. For now, there are two generic classes: insects, and aerosols and insects (for example, depending on the time of day, or day of the year, the linear depolarization ratio induced at the 35GHz radar data, the height of the target, the Doppler speed, or the number of targets).

g. Other users

Except from the users from the Met office and/or transportation, another group of users from the private sector can benefit from the CARO capabilities. Using the meteorological radar for precipitation sampling, CARO will be able to identify the type of particle during precipitation: snow, ice, hail, or liquid. Thus, insurance companies will have the option to see the type of precipitation[13] and in case of extreme events (e.g., hail) to compensate the beneficiaries (farmers, car owners etc) that are insured against damages caused by these extreme events.

[13] Information that is relevant for precipitation occurred above CARO

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 857510.

This project has received funding from the Government of the Republic of Cyprus through the Directorate General for the European Programmes, Coordination and Development as well as the Cyprus University of Technology.

3. CONCLUSIONS

The proposed development of the ERATOSTHENES Centre of Excellence (ECoE) Living Labs are examined in the thematic areas of Agriculture and Atmosphere, as described in this report. The ECoE researchers will work together with EXCELSIOR project advanced partners and local stakeholders towards the development of meaningful networking synergies in the scientific thematic areas of "Agriculture" and "Atmosphere", with specific goals aiming for evident societal and economic benefits.

The proposed ECoE Agricultural innovation Living Lab (**AgriLab**) plans to utilize its synergy with the Cyprus University of Technology (CUT) to establish the first Agricultural research infrastructure in Cyprus and one of the few in the EMMENA (East Mediterranean, Middle East & North Africa) region, aiming to act as an experimental test bed for various users, and apply new agricultural management practices and technologies with the goal of tackling the global challenges of climate change, water scarcity, soil health degradation, and biodiversity loss. The main objective of the proposed ECoE Atmospheric research Living Lab (**ATMOLab**) is to provide several users with access to observations regarding various atmospheric parameters, to test and study new solutions for real-life problems with swift prototyping or validation.

The two Living Labs that are proposed will be under development based on the objectives described in this report. However, other Living Lab proposals will be evaluated during the lifetime of the project. The main concept of the Living Labs is to be able to evolve, change and adapt their applications and content during and after the EXCELSIOR project to provide an open innovation network between academics, students, stakeholders, researchers and industries.