



Land cover dynamics in Cyprus: land use transitions between 2000 and 2020 across a coastal buffer zone

Dimitrios Koumoulidis^{a,*}, Dimitrios Mpormpoudakis^b, Ioannis Varvaris^a, Mariza Kaskara^b, Charalambos Kontoes^b, Diofantos Hadjimitsis^c

^a Eratosthenes Centre of Excellence, Environment & Climate Department, Limassol, Cyprus

^b BEYOND, Centre of EO Research & Satellite Remote Sensing, Athens, Greece

^c Cyprus University of Technology, Civil Engineering & Geomatics Department, Limassol, Cyprus

ARTICLE INFO

Keywords:

Mediterranean coastal environments
Cyprus – climate change hotspot
Land use change classification
GlobeLand30
ArcGIS
Focal statistics analysis algorithm

ABSTRACT

Coastal ecosystems hold critical economic value for local communities, national economies, and global markets, as they support livelihoods through tourism, natural resources and essential environmental services (e.g., protection from coastal erosion, climate change mitigation). However, anthropogenic drivers such as industrial expansion, loss of agricultural lands, excessive tourism, alongside natural disasters, place considerable pressure on coastal environments. The value of coastal ecosystems is recognized by a range of policy frameworks, ranging from the UN's Sustainable Development Goals (SDG-14) to the 2014/89/EU Directive, and in the Mediterranean basin, by the Barcelona Convention. In this paper, we conducted an analysis of land-cover change between 2000–2020, which presents valuable first-time available evidence on the evolution of coastal land dynamics in Cyprus. A 10-kilometer-wide coastal buffer zone was designated around the island to facilitate targeted land-use investigations. Land-cover data was derived from the GlobeLand30 2000 and 2020 datasets (Kappa coefficient: 0.78; accuracy level: 80.63%) and the analysis was conducted using the ArcGIS software employing spatial statistics (mainly focal statistics at a 10x10 pixel neighbourhood) and heatmap visualisations (incl. different bandwidth specifications). The results demonstrate an expansion of urban pressures, especially in the vicinity of the island's major tourist hotspots, including Larnaca, Paphos, and Limassol, and significant changes related to the rise of croplands. The major land-use transitions identified in this research are associated with the sparse vegetation and the croplands classes that transitioned into the built-up class. Significantly, the overall calculated areas of land conversions to the built-up class neared almost 5 km². By contributing new data on an environmental challenge that has not been previously examined by comparable studies in the context of Cyprus, this study aspires to serve as a future framework for analogous investigations across the Mediterranean basin.

1. Introduction

Coastal zones hold considerable importance from an ecological standpoint, given their variety of life forms and the richness of their geomorphological attributes [1]. They are fundamentally important in tackling the climate crisis, as they are often the first regions to confront the ramifications of climate change, primarily due to the increase in sea levels ([2,3]). As of now, nearly 40% of the global population inhabits coastal zones, equating to 2.4 billion individuals, with projections to rise in the forthcoming several decades [4]. Three-quarters of the world's metropolitan cities are located in coastal areas, thus designating them as a heavily populated segment of the globe, where there is a perpetual

interplay between economic and social development, environmental sustainability and resilience [5]. Coastal environments also provide essential ecosystem services, including shoreline stabilization and buffering, coastal defence, groundwater retention, and water purification.

However, those environments are facing increased rates of erosion and substratum depletion along rocky shores, primarily due to urbanization, and the growth of coastal infrastructure [6]. The enduring and escalating trend of human presence and activities is associated with the proliferation of urban coastal zones, thereby affecting the integrity of ecosystems on land and in the sea [7]. This phenomenon underscores the critical relationship between urban development and natural

* Corresponding author.

E-mail addresses: dimitrios.koumoulidis@eratosthenes.org.cy, dp.koumoulides@edu.cut.ac.cy (D. Koumoulidis).

<https://doi.org/10.1016/j.cacint.2026.100327>

Received 4 September 2025; Received in revised form 23 February 2026; Accepted 1 March 2026

Available online 2 March 2026

2590-2520/© 2026 The Author(s). Published by Elsevier Ltd. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

ecosystems [8].

Current projections indicate that coastal areas in Europe will encounter major threats and environmental challenges through 2050, stemming from modifications in land use dynamics [9], tourism-oriented coastal development, and intensified agricultural practices, which have synergistically led to soil erosion, biodiversity decline, and an elevated risk of desertification ([10], [6]). Climate change will intensify these threats [11], greatly affecting coastal regions that align with high-risk zones due to the significant aggregations of population and infrastructure in connection with hazard-enhancing conditions [12]. In the Mediterranean basin, these threats transpire within a territory already distinguished by semi-arid conditions and elevated climatic sensitivity, where the rates of warming exceed the global average and hydrological regimes are progressively disrupted by extended droughts, heatwaves, and rising sea levels [13].

Situated in the easternmost region of the basin, Cyprus encapsulates various intertwined dynamics related to Mediterranean land degradation and land-use transition. Accelerated urbanization spurred by tourism along the southern and eastern coastlines, has led to widespread coastal sprawl, soil sealing, and the conversion of agricultural and natural landscapes [6]. Conversely, the northern territories show a more scattered arrangement of agricultural intensification, vacant lands, and sporadic coastal development [14]. In related contexts, [15] emphasized that coastal wetlands in Apulia, Italy, are subject to ecosystem conversion, fragmentation, and hydrological shifts, which are influenced by intensified agricultural activities, water extraction, and modifications in land management approaches. Similarly, [16] conducted research on the comparative coastal vulnerability and socio-environmental pressures in the Eastern Mediterranean, with a specific focus on Greece, Cyprus, and Montenegro. Their study demonstrated a high to very high level of coastal vulnerability, particularly in Cyprus, when assessing biophysical factors such as erosion and sea-level rise in relation to socioeconomic and tourism pressures. Comparable processes are identified in various coastal regions across the globe, including the Odisha coast in India, which accommodates a densely populated demographic, primarily from lower socio-economic strata. Research by [2] suggests that the area is gradually being recognized as a coastal erosion hotspot, which can have devastating effects on livelihoods, resulting in landlessness, displacement, and a worsening of poverty levels.

Since 1974, Cyprus' political and strict territorial division has contributed to an increased level of governance complexity, leading to a lack of a unified and coherent policy framework for managing land. Crucially, Cyprus stands apart from other European and Mediterranean islands because of this sensitive territorial division. An unprecedented arrangement has required a unique internal-border regime built around Protocol 10's "line" concept to manage movement and economic activity without collapsing the coherence of EU law. The country entered the EU as a single member state while remaining territorially divided, with the EU *acquis* explicitly suspended in the areas where the Republic of Cyprus does not exercise effective control. This conditional application of EU laws and regulations creates asymmetries as well as the different legal, cultural, and governance arrangements make Cyprus a uniquely case in the Mediterranean ([17,18]).

The Mediterranean coastline has historically been aligned with the increasing growth of tourism and economic development. The area stands as the foremost tourist destination globally, serving as a vital source of national income and job opportunities [19]. As a result, the region serves as a focal point in numerous contexts related to climate change vulnerability [20] and increased occurrences of heat waves [21], heat stress [22], and air pollution. Along with the previous challenges that greatly strain the region, it is also classified as an urbanization hotspot. This region stands out as one of the most populated areas worldwide [23], reflecting a dynamic and growing trend in urbanization. Furthermore, the Mediterranean ranks among the most densely populated areas globally, exhibiting a pattern of urbanization that is both intensive and consistently on the rise [24].

Most economic activities in the Mediterranean, such as tourism, are concentrated on the coastline, which is inhabited by one-third of the region's population [25]. Of the ten European nations situated in the Mediterranean Basin, Malta stands out with an exceptional density rate of almost 1,700 inhabitants per km², while Cyprus along with Italy recorded the highest population densities in 2020, with 202 and 148 inhabitants per km², respectively. Projections for 2100 indicate that Cyprus will rise to the second position with 138 inhabitants, while France will occupy the third position with 124 inhabitants [26]. This trend is consistent with the total population indicator for Cyprus, anticipated to nearly reach 1.5 million by 2050, and thereafter demonstrates a downward trend through to 2100 (Fig. 1). Data from the UN Population Division suggests that by 2050, with an annual growth rate of approximately 0.45%, it is anticipated that about 75% of the island population will reside in urban areas (Fig. 2).

Referencing the data from the latest population census for 2021 as reported by the Cyprus Statistical Service [27], the major coastal urban agglomerations count a total population of about 225,000 individuals, with Limassol and Larnaca being the most densely populated coastal cities, having 107,970 and 52,046 inhabitants, respectively (Fig. 3).

This study presents a two-decade land use change analysis within a 10 km coastal buffer zone (CBZ). It quantifies land transitions for the period from 2000 to 2020 using GlobeLand30 land cover datasets along the entire coastline of Cyprus with a particular emphasis on uncovering patterns of land use conflict and the pressures that arise from competing human activities. We expect that urban growth would be spatially concentrated around the main coastal urban-tourism centres (e.g., Limassol, Larnaca, Paphos). We further expect that cropland gains would exhibit a different spatial footprint from built-up expansion, indicating potentially distinct processes of land conversion within the CBZ, and that forest cover would roughly remain constant, reflecting protection and conservation measures across the island. Finally, we explore the extent to which GlobeLand30 provides a consistent, island-scale representation of these broad transition patterns, while acknowledging that finer-grained changes may fall below the product's detection or temporal resolution limits.

The study holds considerable innovation and significance, offering a crucial spatial evaluation of land cover changes in Cyprus. Most importantly, ours is the first study to explore coastal land-use dynamics in Cyprus, and one of the few in the Mediterranean region, especially recently ([28–31]) – essentially tackling one crucial aspect of island [32] and coastal resilience ([2,33]). Furthermore, by illustrating the usability of analysis-ready land use / land cover dataset for national scale land transition analyses, we provide a relatively simple methodology that can be adapted for adoption in the capacity-challenged EMMENA region [34], complementing capacity building efforts in area. Furthermore, it provides an analysis of coastal land use change in a politically charged island, where territorial claims have an active role in land use management, including the coast. Finally, the manuscript directly addresses the urgent matter of sustainability in the Mediterranean coast as the expansion of urban zones, frequently driven by tourism, leads to a conflict between economic development and the maintenance of environmental sustainability. The findings uncover substantial built-up and artificial surfaces development at the expense of croplands and sparse vegetation classes. These changes not only bring to light the developing conflicts in land use but also emphasize the critical necessity for sustainable land management strategies that are adapted to bolster the resilience of coastal ecosystems.

2. Methodology

The manuscript relies on the GlobeLand30 dataset, which provides global land cover (GLC) data at a 30-meter resolution. GlobeLand30 was sourced from the Global Land Discovery & Analysis website (<http://glad.umd.edu/>, <https://doi.org/10.3389/frsen.2022.856903>) to portray the land cover characteristics of the area under investigation.

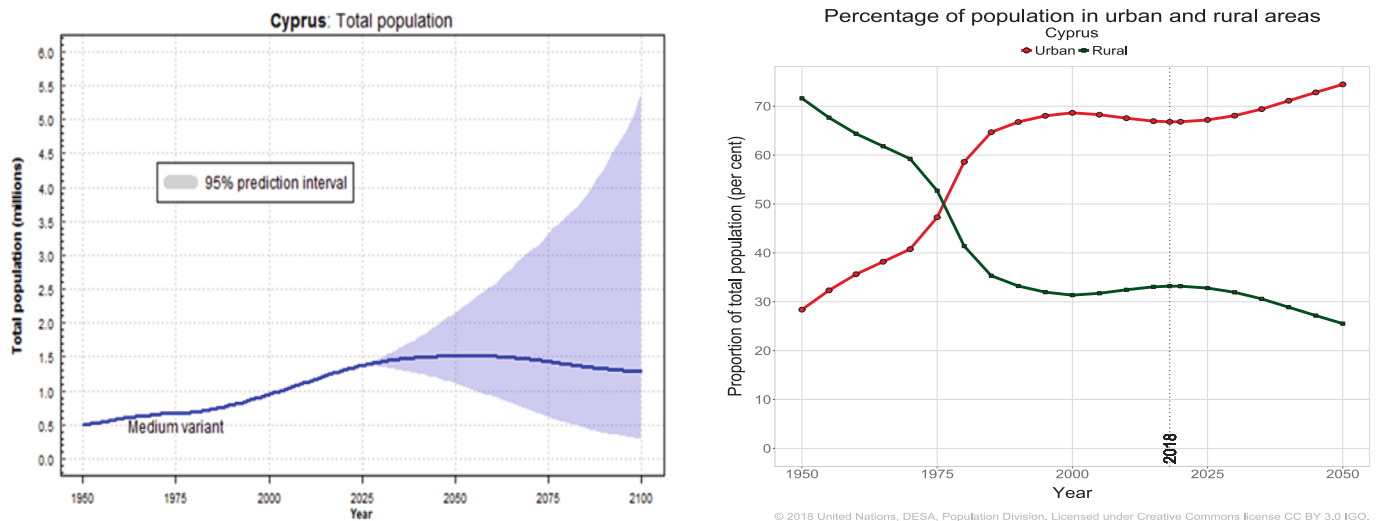


Fig. 1. Cyprus Total Population Projection.

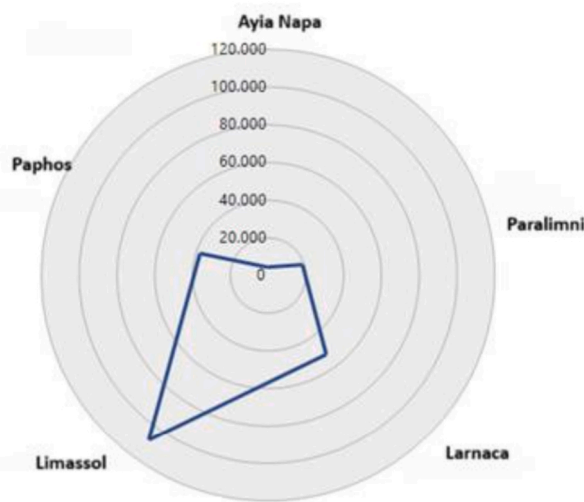
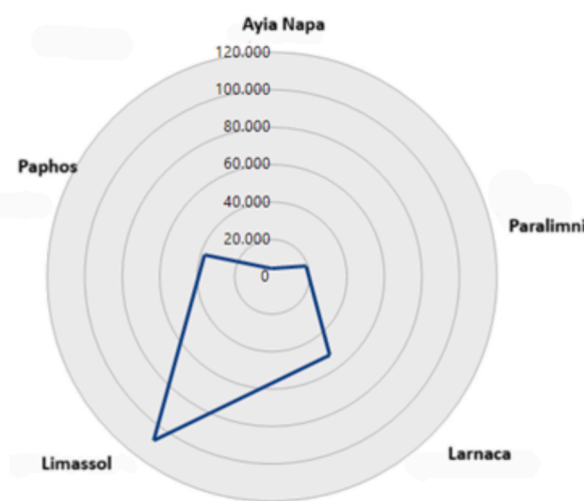
Fig. 2. Percentage of population in urban areas (%).
Source: UN DESA, Population Division

Fig. 3. Population of the main coastal urban cities in Cyprus (October 2021).

The GlobeLand30 dataset has been accessed by researchers and users in over 130 countries for conducting environmental change analyses, monitoring geographical conditions, managing urban and rural environments, modelling earth surface processes, and fostering sustainable development [35]. It is a vital geospatial dataset employed by several international entities, such as the UN Environment Programme [36]. Capturing timeframes from the year 2000 to 2020 via rectified imagery, data images sourced from Landsat Thematic Mapper (TM) – (active between 1982 and 2013), Enhanced Thematic Mapper plus (ETM+) on board on Landsat-7, (1999-present) and the Huan Jing-1: Environmental Protection & Disaster Monitoring Constellation [37].

Compared to other global or European satellite-derived maps, GlobeLand30 has some unique characteristics that make it suitable for mid-term (e.g., 20 years) land transition analysis [38]. For example, the Copernicus Climate Change Service gridded product [39] (an extension of ESA's CCI), while available for 1992 to 2022, has a spatial resolution of 300 m (compared to the 30 m of GlobeLand30). WorldCover [40], with a spatial resolution of 10 m, is currently only available for 2020, and 2021, making it unsuitable for land transition purposes. CORINE land cover data, while available for a longer period than GlobeLand30 (1990–2018), have thematic and spatial resolution inconsistencies that do not allow for direct transition matrix computations [41]. Finally, compared to Sentinel or other satellite-based land-cover classification ([42,43]), despite advantages in temporal or spatial resolution, using an analysis-ready dataset such as GlobeLand30 dataset makes the methodology much more user-friendly and transferable, especially for countries that often lack the capacity for national-scale satellite monitoring [34].

While GlobeLand30 provides a consistent 30 m global baseline, it can under-detect very small or narrow features, and its 2000/2010/2020 snapshots might not capture within-decade dynamics. Class confusions and or mixels can occur in heterogeneous Mediterranean mosaics (notably shrub/grass/bare classes), which may slightly change computations. Finally, because it is a global product, local performance can vary, but previous studies in the EMMENA region have shown its usefulness [44].

The GlobeLand30 dataset is formatted as raster data for storage, using the non-destructive GeoTIFF compression format and a 256-color, 8-bit indexed configuration. The dataset incorporates the WGS84 coordinate system, UTM projection, and a six-degree zoning system [38]. GlobeLand30 was created through a supervised classification approach that relies on the Pixel-Object-Knowledge (POK) method; around 38,000 validation samples from various global locations were utilized for ground truthing. GlobeLand30 includes 10 land-cover classes: cultivated

land, forest, grassland, shrubland, wetland, water body, tundra/bare land, artificial surfaces, glacier/snow, and sparse vegetation. Concerning the precision of the dataset, it boasts a Kappa coefficient of 0.78, positioning it among the most reliable GLC products accessible [45]. The dataset has been also reviewed by external researchers in several studies, including a notable one by [46], which assessed the accuracy of seven land cover products in China, concluding that GlobeLand30 (2010) demonstrated the highest overall accuracy of 82.4%. In a similar vein, [37] indicated that GlobeLand30 exhibits a strong correlation with CORINE (92.52%), Urban Atlas (85.43%), and OpenStreetMap (74.24%). Presented below in Fig. 4 is the methodological framework that has been adopted for the current study.

In the initial phase of this research, two separate land cover maps were acquired, corresponding to the years 2000 and the most recent update from 2020. The maps derived from the Global Land Discovery & Analysis website, were sufficiently geo-referenced, thus, no further geometric registration was required. All land use modifications were analyzed using the ArcGIS software. Prior to the preliminary stage of examining and processing alterations in land cover, the next step entailed merging the 255 colour map value classes from the two original raster maps that were acquired. The process involved reclassifying the data into ten new classes, as depicted in Table 1.

Within the above ten land cover classes, only a few are directly related, interconnected, and have a substantial impact on land degradation, croplands loss and transformations of natural landscapes. Furthermore, in the Cypriot context, some classes such as desert, open surface water, and snow have no or negligible footprint on the ground due to biogeographical reasons (i.e., no designated desert land cover type in Cyprus [44]). Therefore, we focused the analysis on four classes and their evolution over the past twenty years, namely: “Tree cover,” “Croplands,” “Sparse vegetation” and “Built-up”.

We followed a methodology predominantly reliant on the ArcGIS Spatial Analyst toolbox, consisting of the following steps. We first created four new raster layers (Raster Analysis tool), mapping the transitions to all four classes from each class between 2000 and 2020 (TreeCover → All_classes, Croplands → All_classes, Sparse Vegetation → All_classes and Builtup → All_classes). We then reclassified the raster layers and assigned a unique value for every type of change (13 types, e.g., cropland → urban, forest → cropland) in the newly created raster layers (Con tool). Afterwards, we generated a unified homogeneous layer product that integrated all 13 classes, along

Table 1

Re-classification scheme.

Classes	Colour Map Values
Desert	0–1
Low-Sparse Vegetation	2–24
Tree Cover	25–48
Wetlands	100–148
Open Surface Water	200–207
Snow	241–241
Croplands	244–244
Built-up	250–250
Ocean	254–254
No Data	255

with the ‘No-Change’ and ‘No-Data’ classes from the previous four layers (Con tool). This layer contains cells that delineate all changes between the four classes between 2000 and 2020, giving a unique number to each change (1–13). Based on this layer, we computed the transition matrix between the four classes using cross-tabulation.

In the subsequent step, we used a 10x10 cell rectangle grid to calculate the ratio of transitioned cells for each transition type (Focal Statistics tool, Mean statistics), including No Data values. We selected the 10x10 grid as trials with a 5x5 grid (150 m x 150 m) returned very sparse layers, particularly for layers with minimum amount of change such as sparse vegetation to forest (Table 2) while a 15x15 pixel grid (450 m x 450 m) stretches the limits of relations between land use transitions. Furthermore, the 10x10 pixel aligns with the 300 m resolution of existing and upcoming land cover products, such as ESA’s CCI Global Land Cover product or the Copernicus Climate Change Service gridded product. Thus, the adoption of a 10x10-pixel rectangle, by this study, reflected a methodological trade-off between spatial resolution and statistical stability. In the last step, all prior raster products were clipped to adjust them into the 10 km CBZ that was developed across the island of Cyprus, resulting in 13 raster maps of the coastal zone of Cyprus with a resolution of 30 m. Regarding clipping rules, on the sea side of the buffer, we excluded pixels classified as “ocean” in the GlobeLand30 dataset. For the inner, terrestrial clip, we used ArcGIS default setting and included those pixels whose centre falls in the coastal zone. Regarding the 10 km CBZ, globally, there is no universally accepted standard referring to delineation of CBZs. In the absence of a definitive universal definition for the CBZ, researchers across different fields of science, such as biology and physics, have suggested various interpretations of what constitutes the CBZ [47]. As an illustration, within the realm of marine physics, the CBZ is defined as the space that lies between the nearshore and ocean currents [48]. Some studies investigate coastal zones establishing buffer zones with a width of 100 km [49], while in others, the CBZ stretches from the waterline, which lies between the ocean and the land, to a depth of 20 or 30 m into the sea [50]. In this study, the designation of the 10 km zone is consistent with the Copernicus-Land Monitoring Service Product, which is the Coastal Zones Land Cover/Land Use 2018 (vector), Europe, 6-yearly, Feb. 2021 [51].

3. Results

The multifaceted interactions of socioeconomic, environmental, and natural disaster drivers shaped the composition and structure of the landscapes across the Mediterranean basin [52]. In the EU-Mediterranean region, intense land use in coastal zones is presently documented [53]. Despite this, the region stands at a crucial crossroads, facing profound socioeconomic and environmental shifts. The dynamics of these shifts in conjunction with the risks and vulnerabilities tied to climate change could lead to an increase in environmental degradation and pose risks to sustainability efforts at regional and national levels [54]. Nevertheless, this critical situation unfolds at a period in which the EU seems committed implementing more rigorous, stricter and concrete

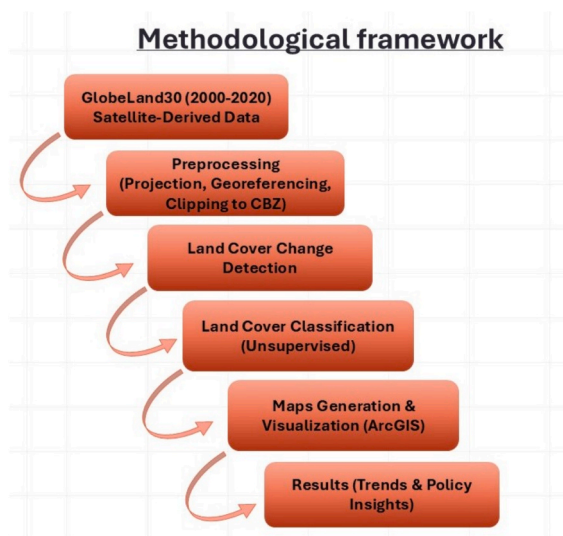
**Fig. 4.** Methodological framework.

Table 2
Land-use transition matrix in the 10 km CBZ of Cyprus / Area (m²) Converted per District.

Land Cover Class (From)	Land Cover Class (To)	Total Pixels Converted	Area (m ²) Converted	Area (m ²) Converted per District					
				LARNACA	FAMAGUSTA	LIMASSOL	PAPHOS	NICOSIA	KERYNIA
Croplands	Built-up	32,693	2043.31	978.31	529.43	81.87	109.75	13.62	330.06
Croplands	Sparse Vegetation	7698	481.12	39.18	203.87	157.62	42.37	27.37	10.68
Croplands	Tree Cover	0	0	0	0	0	0	0	0
Croplands	Open Surface	0	0	0	0	0	0	0	0
Water									
Sparse Vegetation	Croplands	38,579	2411.18	58.31	536.12	263.62	65.62	1427.93	59.56
Sparse Vegetation	Built-up	42,803	2675.18	318.87	383.50	573.75	646.12	175.87	577.06
Sparse Vegetation	Tree Cover	1415	88.43	0	0	0	0	51.75	36.68
Sparse Vegetation	Open Surface	324	20.25	13.00	0	7.25	0	0	0
Water									
Tree Cover	Built-up	19	1.18	0	0	0	0	0	1.18
Tree Cover	Sparse Vegetation	2181	136.31	0	0	0	132.12	4.18	0
Tree Cover	Croplands	428	26.75	0	0	0	0	26.75	0
Tree Cover	Open Surface	0	0	0	0	0	0	0	0
Water									

policies for the conservation and safeguarding of nature, alongside the no-land-take initiatives included as pivotal aspects at the European Green Deal and the Biodiversity Strategy for 2030 [55]. Historically, the EU has mandated and executed various policy frameworks and Directives aimed at addressing, conserving, and fostering sustainable development in marine and coastal environments, spearheaded by the Directive 2014/89/EU [56] for maritime spatial planning. That policy framework was further bolstered by the 2002/413/EC [57], encouraging an integrated management approach focused on environmental protection, as well as the consideration of social and economic

development, in conjunction with the Marine Strategy Framework Directive [58]. A significant component of the previously mentioned socioeconomic interactions is the ongoing economic development model of the Mediterranean coastal regions, associated with prolonged and excessive touristic influxes. The region is acknowledged as a quintessential example of a territory that is heavily burdened not solely by the overwhelming touristic activity, but also by the proliferation of secondary homes in these coastal regions ([59,60]). Distinctive areas of coastal urban rise associated with mass tourism have been pinpointed in Cyprus [61].

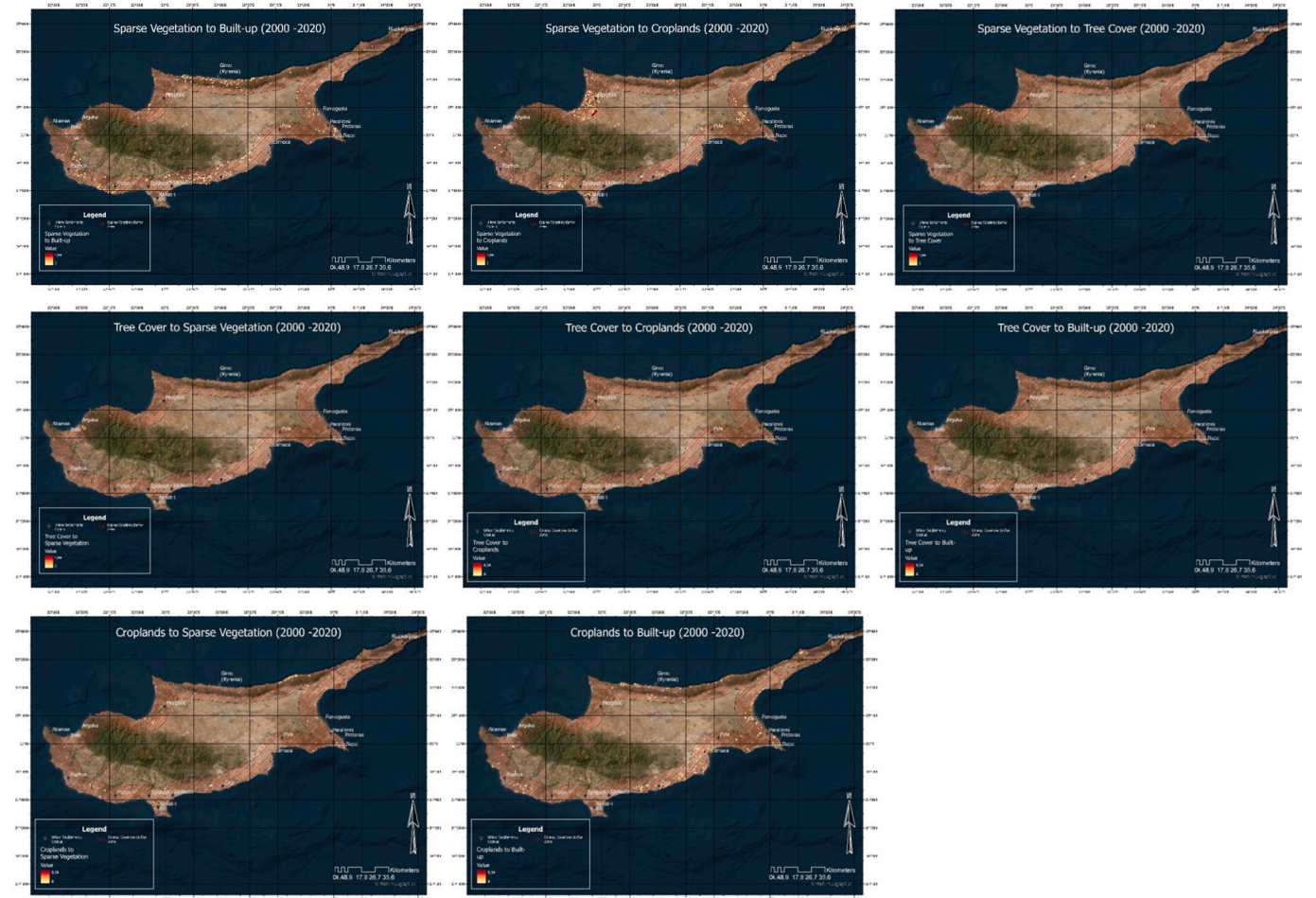


Fig. 5. All examined Land Use Classes and their Focal Statistics Analysis Classification.

Precisely, the outcomes of the current research demonstrate that regions that underwent considerable alterations over the two decades analyzed, especially concerning their evolution into built-up environments, located across the entire island's CBZ that has been developed. These regions reflect different levels and extent of transformations, which have significantly contributed to the coastal zone's overall landscape, underscoring the profound effect of these land use alterations on the coastline. Fig. 5 illustrates a more comprehensive analysis of the dynamics for each land use classification throughout the CBZ, subsequently implementing the Focal Statistics Analysis algorithm, which

synthesized the mean values associated with each individual land use original raster products. Specifically, the sparse vegetation class appears to have undergone the most profound and extensive modifications, either changing into a built-up class or into croplands. Notably, the land cover class in question underwent a substantial decrease in its land holdings throughout the twenty years, leading to its conversion into croplands. Exemplified is the development of large cropland areas on the eastern side of the island near Famagusta, along with those on the western and southwestern fronts of Morphou city. In Paphos district the same class, has undergone transformations to croplands in a dispersed

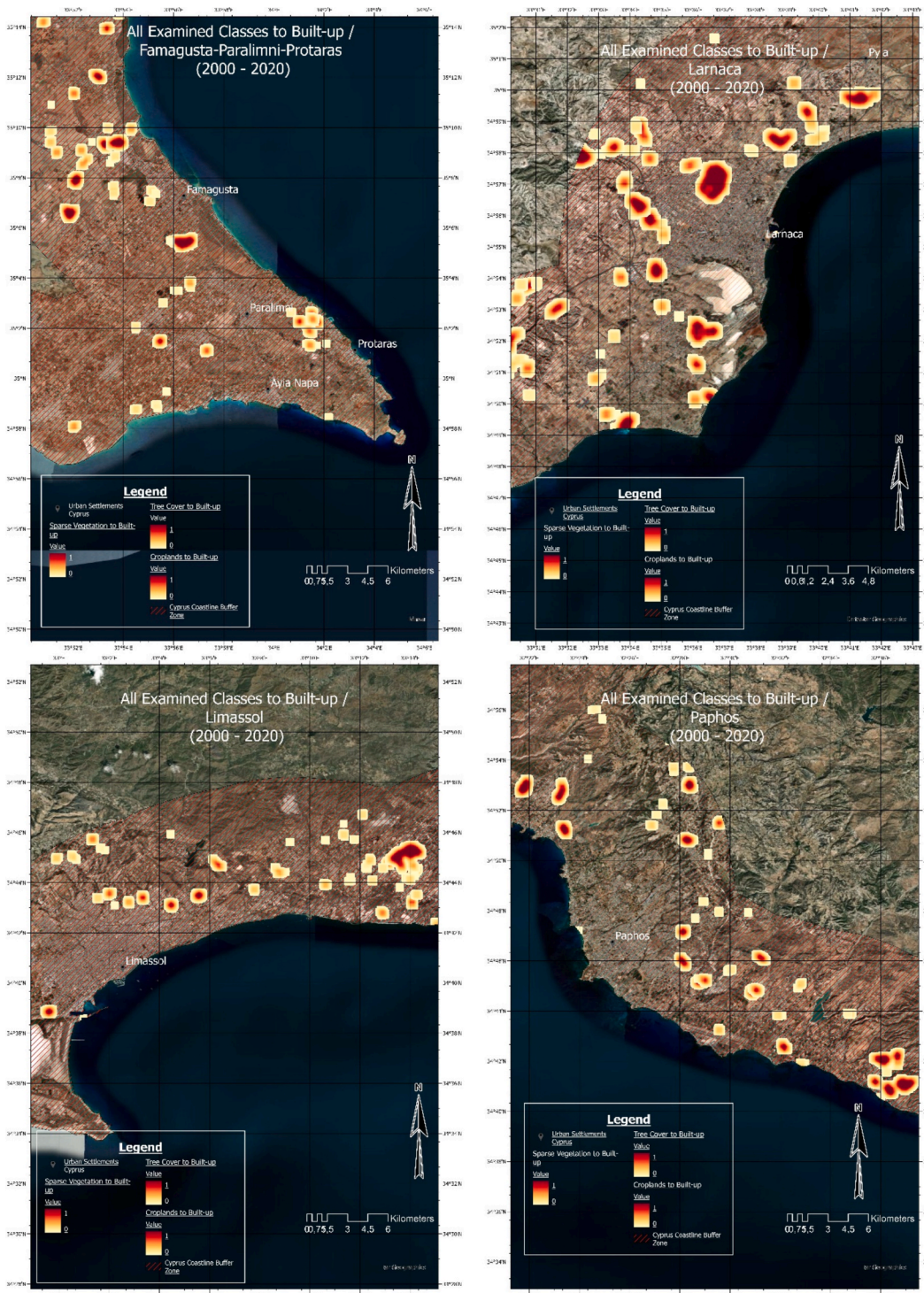


Fig. 6. Land Use Classes altered solely to Built-up Class for the major coastal urban centres in Cyprus.

manner, predominantly located within the northern aspect of the district, akin to the Limassol district, where analogous transformations occurred mainly in the western exposure and several in the adjacent urban network of the city.

The previously observed pattern remains consistent regarding the magnitude and severity of the modifications transitioning from the cropland class to the built-up environment. Specifically, within Paphos district CBZ, as demonstrated in Fig. 6, pronounced changes are noted mainly in the municipal region of Kouklia and across the wider part of the Pissouri municipality. Within Limassol district, pronounced and large-scale modifications resulting in the built-up classification exist, particularly in the neighbouring municipalities of Monagrouli and the northern side of Pentakomo locality. These changes might reflect a broader trend in urban development within these regions. The Larnaca district shows a similar status, but more intense. Significant changes are apparent in all municipalities near the city, especially around high-demand tourist areas like Voroklini and Pyla. In the eastern section of the island, the municipalities of Paralimni-Famagusta and Protaras reflect a similar scenario of croplands modifications into built-up spaces, with evident results documented in the northern aspect of Paralimni city, in addition to substantial transformations in the northern part of Famagusta. The flow of transitions among the examined land cover classes within the CBZ is visualized through a graph in Fig. 7, where all transitions are expressed in square meters (m^2). It is apparent that within a 20-year period (Table 2), the coastal region of Cyprus has experienced a conversion of approximately 5 km^2 of agricultural lands into urbanized spaces. The major portion of these areas emerged from the sparse vegetation class, accounting for approximately 2.8 km^2 . However, the polarized trend identified within the CBZ throughout the 20-year analysis period is similarly related to the expansion of cropland land cover by around 2.5 km^2 , again extracted from the sparse vegetation class. Conversely, vulnerable ecological zones, comprising tree

cover and open water surfaces, have been conserved with modifications in their land areas at 136 m^2 and 20 m^2 , respectively.

Analyzing the alterations from the perspective of the tree cover category reveals that it is the sole classification that was largely unscathed over the twenty-year span examined. Within the whole buffer zone investigated by this study, the land cover modifications associated with this class are trivial or almost non-existent, with a limited number of exceptions identified mainly in the north-western exposure of the island, limiting the pertinent variations to pertain among the interactions of this class with the sparse vegetation category. Prior investigations have also highlighted the slight rates of change in forested regions in Cyprus, revealing that the forests, including those identified as degraded or lush, have undergone minimal changes over the past one hundred and fifty years, regardless of human influence [62]. Correspondingly, the results from the Global Forest Watch platform reveal that from 2000 to 2020, Cyprus underwent a net change of 1.04 kha (0.72%) in tree cover emphasizing that the main factor of disturbance loss is attributed to the wildfires [63]. In alignment with this wavelength, the European Environment Agency (EEA) platform readily shows a tendency for the conservation and enhancement of forest numbers on the island, noting a rise in forest coverage of around 0.91% from 2000 to 2018 [64]. In relation to more recent legal changes, especially in the parts of the island under EU law, we could mention long-standing legal constraints on land-use change in state forests and subsequent strategic frameworks, including the National Forest Programme approved in February 2002 and the 2003 legal transposition that established the Natura 2000 framework in the government-controlled areas [65]. In the northern part of Cyprus, forest governance is conducted under a separate institutional and legislative setting, which may contribute to spatial heterogeneity in management and pressures. These timelines are offered as contextual background rather than evidence of policy-driven causation.

The data provided above correspond and align with the research conducted by [44], where the authors examined the same two decades across the entire island area, encapsulating the evolution of land use changes and transformations. A significant trend was noted, showcasing a positive transformation in Cyprus, with croplands percentages achieving a remarkable 80% . Meanwhile, the built-up classification for the same timeframe reached 70% .

To augment the visualization and interpretation of our research findings, a set of heatmaps was generated, with a specific focus on land cover classes that have been converted into the built-up class. These heatmaps present a spatially detailed illustration of the intensity and distribution of land cover transformations, which allows for a more accurate identification of areas undergoing considerable urban expansion. The determination of this specific conversion class to be depicted in Fig. 8, was influenced by the imperative to acknowledge and assess the rate and consequences of natural environment deterioration – such as sparse vegetation, cropland, and tree cover areas – as they evolve into urban settings. Through the visualization of these transformations, the heatmaps provide an enhanced comprehension of the soil sealing processes occurring in the coastal area of Cyprus. Our findings amplify and broaden the apprehension regarding the susceptibility of Mediterranean regions and urban centres concerning the climate crisis and the substantial anthropogenic modifications in land use intended to promote and fulfil the demand for urban development in coastal areas.

4. Discussion

When analyzed from a regional perspective, the trends evident in Cyprus's CBZ – distinguished by the growth of built-up surfaces at the expense of vegetation and agricultural land – epitomize a more extensive Mediterranean trend of tourism-driven urban sprawl, environmental degradation, and erosion associated with climate factors. The shift from sparse vegetation and cropland classes to urbanized areas resonates with wider Mediterranean trends. Across various locales in

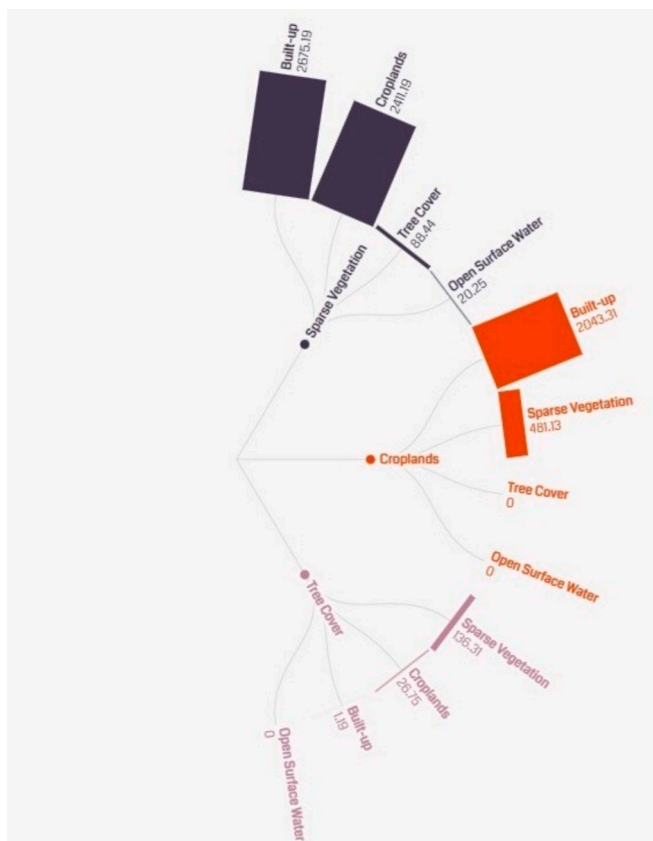


Fig. 7. Flow diagram of land use classes transitions in m^2 within the CBZ.

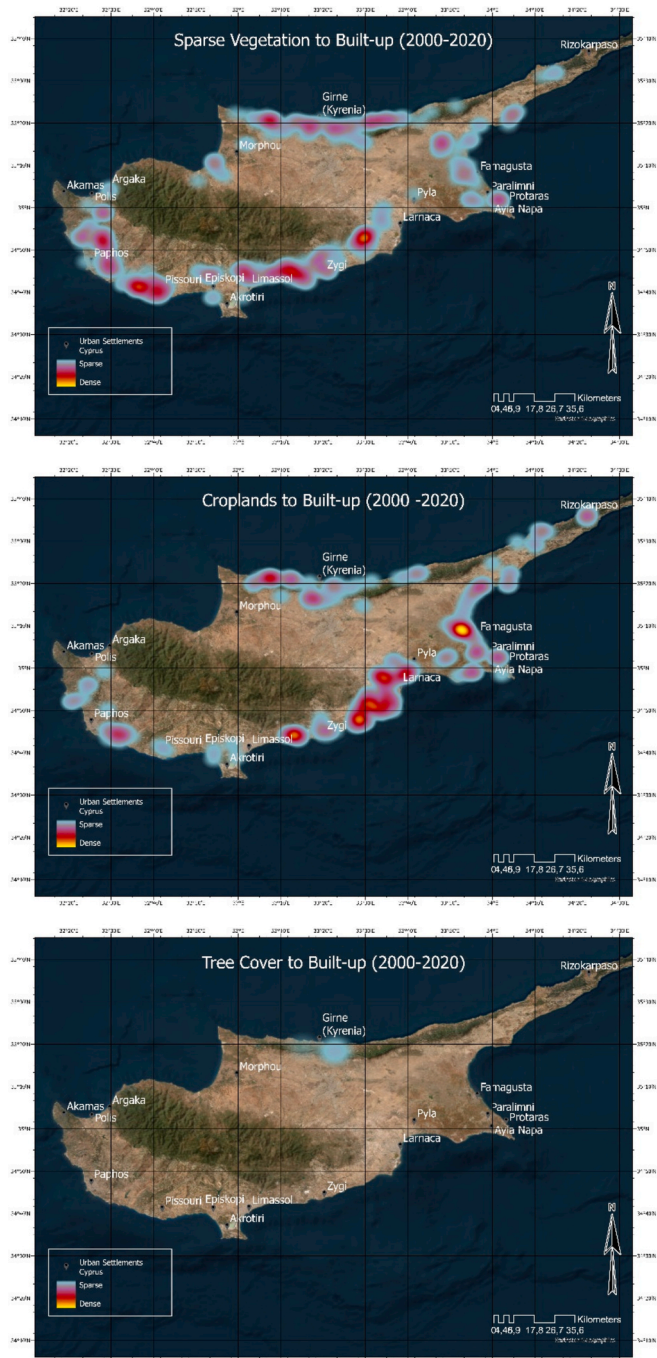


Fig. 8. Heatmaps – Land Classes conversions to the Built-up Class.

Italy, Spain, Greece, and Croatia, coastal areas have witnessed analogous expansions, at the cost of erstwhile agricultural and vegetated lands, mirroring the intensification of urbanization and land conversion motivated by tourism [66].

The insights derived from the study into the spatiotemporal changes of Cyprus's 10 km CBZ from 2000 to 2020, emphasize the overarching narrative of the ecological vulnerability, urbanization pressures, and the climate risks that are typical of Mediterranean coastal systems. The ecological vulnerability of these coastal ecosystems is primarily indicated by their ongoing erosion. The island's beaches have undergone both erosion and accretion in recent decades. A detailed analysis by [67] of the Famagusta coastline spanning from 1963 to 2024 has shown fluctuations in erosion, with some areas experiencing rates of up to -0.29 m/yr. In a similar vein, regional modelling suggests that the

increase in mean and extreme sea levels – presently rising at approximately 2.4–3.8 mm per year since the 1990 s – intensifies the risks of beach retreat in Cyprus across various climate scenarios [68]. Furthermore, given that Cyprus, as previously mentioned, experiences significant water stress, the results of this study, which detail the substitution of sparse vegetation and croplands classes with impervious surfaces, are intended to mathematically indicate a reduction in natural groundwater recharge and infiltration. This, in turn, exacerbates water scarcity, deteriorates the hydrological balance of the region and will further elevate the risk of surface runoff and flooding.

The ecological fragility of the island in relation to climate change is further complicated by two internal factors. The first factor relates to the increasing demographic trends and population projections for the island, as soil degradation is anticipated to escalate. Based on the World Population Review, by the end of 2070, the island will have almost 1.5 million citizens [69]. To satisfy the heightened demands of this rising population, extensive infrastructural development has occurred in recent years along the urban centres of the coastline, representing the most critical land degradation in the region and greatly influencing all ecosystem services. This is corroborated by the research conducted by [70], which indicated that a considerable area of Cyprus island (9.68%) is vulnerable to land degradation, with those hotspots located in Paphos, Limassol of the central and southern Famagusta districts. The second factor relates to the prevailing dominance of tourism, which introduces additional pressures that must be managed to fulfil its specific and rising demands. The role of tourism in the economic landscape is undeniable. In 2019, 94% of hotel capacity was along the coast, and nearly 91% of tourists resided in coastal resorts [68]. In 2022, the investment in tourism escalated to nearly €3.2 billion – constituting over 12% of the total capital investment in Cyprus [71]. Given the preceding point, it is to be expected that coastal cities like Limassol, Larnaca, and Paralimni reveal concentrated urban expansion, reflecting the pressures exerted by both the leisure and real estate markets.

Our results for Cyprus align with an observed Mediterranean pattern, where land-cover transitions concentrate in accessible lowland coastal areas where tourism, second homes, and service economies intensify land take. Yet the magnitudes vary across comparable islands. For example, in Mallorca, a post-1990 s shift from mass tourism to low-density “quality tourism” (second homes, gardens, pools, golf) is explicitly linked to sprawl around existing coastal centres and resource pressures (e.g., housing development outpacing tourist accommodation), illustrating how tourism restructuring can amplify dispersed coastal land conversion [28]. Sardinia, by contrast, shows (1990–2012) transition-matrix evidence that statutory protection can dampen urbanization pressures, suggesting a pathway that helps interpret why some Cypriot coastal change hotspots may sit outside stricter protection regimes [29]. In Corsica, coastal territories remain under strong tourism/real-estate pressure with agriculture struggling to resist coastal and near-inland expansion, while Crete's resort belts exhibit a staged progression toward high-density urbanized coastal forms shaped and difficulties integrating sea-land planning ([30,31]). These developments parallel our inferred Cyprus's tourism- and urban development-led coastal transformation but underscore how institutional arrangements and planning enforcement mediate observed transitions.

To ensure the protection of coastal ecological integrity alongside the preservation of socioeconomic viability, it is imperative that future research and policy efforts integrate geospatial, climatic, and socioeconomic analyses. Particularly, analyses that can incorporate environmental, economic, political, demographic, terrain and cultural spatial data to assess causal drivers of land transition would allow for the crucial extension of our work from the *where* to the *when* and *how* of land use change. Considering that Cyprus is a climate change hotspot, extending our results into the causal realm would allow researcher to model how land use might change under climate change scenarios, providing a crucial element in the decision-making toolbox at a variety

of scales.

5. Conclusions

Our 20-year analysis of land use change in the coastal zone of Cyprus revealed distinct patterns that align with patterns across the Mediterranean. Specifically, within the 10 km CBZ, conversions to built-up total $\sim 5 \text{ km}^2$ concentrated around the main coastal urban–tourism centres and sourced primarily from sparse vegetation ($\sim 2.8 \text{ km}^2$) with most of the remainder coming from croplands. Over the same period, croplands expand by $\sim 2.4\text{--}2.5 \text{ km}^2$, again mainly at the expense of sparse vegetation, with prominent clusters east of Famagusta and west/southwest of Morphou. By contrast, tree cover class shows only negligible net change, indicating that the robust pattern is a reallocation of sparse vegetation to cropland and built-up within the CBZ.

These patterns of socio-economic development, associated mainly with urban development and mass tourism, introduce a variety of risks and challenges. They encompass the need for infrastructure development, artificial space expansion, and the overwhelming demand for resources from the local primary agricultural sector, which collectively raise questions regarding the sustainability of the Mediterranean region's profile. This study presents a framework for monitoring land-use transitions in the politically sensitive CBZ in Cyprus by incorporating analysis-ready data and spatial statistics workflow within a coastal environment characterized by political disputes – an area that has rarely been explored through spatially explicit land-cover monitoring because of its complicated geopolitical context. The study evaluated the efficacy of employing GlobeLand30 satellite-derived imagery for the analysis of four land cover types (tree cover, sparse vegetation, croplands, and built-up) in Cyprus, over a timeframe of twenty years.

Despite the GlobeLand30 dataset being a valuable instrument for land cover analysis, its limitations in spatial and temporal resolution, the generalization of land use classes, and the accuracy of classification [38], introduce challenges when it comes to monitoring small-scale land use changes. Small-scale land use transitions, such as urban development at the neighbourhood scale, may be masked by this moderate resolution. An additional constraint of this study is that since the GlobeLand30 dataset presents global coverage for specific time intervals (e.g., 2000, 2010, and 2020), devoid of continuous temporal data, poses challenges in tracking the dynamics of land use over time [72]. Furthermore, confusion patterns for the GlobeLand30 dataset as reported by [73] imply that some of our dominant transitions involving sparse vegetation could be partly affected by mixing between shrub/grass/bare classes and by occasional cropland-impermeable or bare-impermeable errors, potentially inflating or dampening hotspot magnitudes at the margins. By contrast, the minor net changes we report for tree cover are more robust to classification error given the higher forest accuracies. Despite that, the results of this study are pivotal in understanding ecological changes occurring in Cyprus coastline. Furthermore, the insights obtained from the study on local planning procedures suggest that the preceding methodological framework may act as a significant tool for the advancement of effective spatial planning policies, the execution of effective monitoring, pertaining to the sensitive matter of land change, and the parallel escalating human demand for natural resources.

In terms of concrete policy recommendations, in the first instance we suggest prioritising stricter coastal zoning and development-control enforcement in the most affected districts (especially Limassol, Larnaca, and Paphos). We also propose the use of higher temporal and spatial resolution data, e.g. Sentinel-2 or Landsat monitoring, see for example [42] to track the built-up expansion hotspots identified here. A possibility would be to embed these indicators in national coastal management (e.g. Integrated Coastal Zone Management), so land-use change evidence routinely informs permitting, mitigation, and conservation decisions. Furthermore, while we note an amount of uncertainty regarding the use of the GlobeLand30 dataset because of classification

accuracy, cell size, mixel presence, and temporal resolution, we are confident that at a national scale the results accurately capture land-use change patterns across the coastal zone of Cyprus. The additional $\sim 5 \text{ km}^2$ of built-up within the CBZ (concentrated around Limassol, Larnaca and Paphos) points to local plans' zoning and development-control provisions as the most immediate lever to tighten permitting in the mapped hotspots. The nearshore component of these hotspots makes the integrated coastal zone management framework and the protection of the beach/foreshore controls directly relevant to prevent further coastal encroachment and to steer projects through an integrated coastal-management lens. Where hotspot areas intersect or adjoin protected coastlines, Natura 2000 appropriate assessments and management plans should be explicitly developed or triggered. The hotspot evidence can be carried into legally binding Maritime Spatial Plan processes to improve land–sea coordination. In terms of local- or city-scale practical recommendations, the use of higher resolution imagery is suggested to assess vulnerability or resilience implications [33,43].

From a resilience viewpoint, this research is significantly aligned with the Mediterranean land-use resilience frameworks, including the Integrated Coastal Zone Management [74] and the Mediterranean Strategy for Sustainable Development (MSSD) [75]. These frameworks stress the ability of coastal zones to adapt to pressures like urbanization, climate change, and economic development. In relation to the global Sustainable Development Goals (SDGs), this study is consistent with several key objectives, especially the SDG 11 (Sustainable Cities and Communities) [76] and the SDG-15 (Life on Land) [77]. The observed strain from the persistent urban growth along the coastline of the Republic of Cyprus accentuates the vital requirement to improve sustainable land-use planning and tourism practices that satisfy human development demands and preserve the fragile coastal ecosystems.

In the context of upcoming research, the rise of machine-learning strategies has illustrated that Artificial Neural Networks represent a transformative and remarkably effective solution for addressing unprecedented, large-scale, and significant issues within remote sensing data analysis. Consequently, an array of machine learning frameworks has been established to analyze land use and land cover change, with Deep Neural Networks and Convolutional Neural Networks being among the most prominent examples. These advancements could be used to produce higher temporal and spatial resolution products, e.g., taking advantage of the Sentinel constellation of satellites, thereby overcoming some of the limitations imposed by using derived products such as GlobeLand30. In relation to the future avenues of this current manuscript, it will involve strategies to assess projections for the same CBZ utilizing one of the most prevalent models in land use and land cover change, specifically the CLUE (Conversion of Land Use and its Effects) model. As one of the most widely adopted modelling frameworks for regional-scale analysis of land use change and scenario development, our ongoing research will benefit from this model's capacity to simultaneously simulate diverse land-use types and the potential to explore a range of scenarios. Finally, further research on land use change in coastal Cyprus, especially in the context of how it might influence coastal vulnerability to climate change and/or disaster resilience, could focus on how different terrain-aware delineations of the coastal zone (e.g., elevation/slope- or watershed-informed coastal zones) might affect assessments.

To conclude, our island-wide, fixed-width coastal zone workflow and transition typology are readily transferable to other Mediterranean islands as a transparent first-instance screening tool to identify where coastal land take is occurring and which land-cover classes are most affected. Inferring drivers or projecting impacts beyond Cyprus would require additional evidence, mainly related to topography- and watershed-aware coastal delineations, higher-resolution/denser time-series land-cover data, and locally validated policy, demographic, and development indicators to separate governance effects from broader Mediterranean development pressures.

CRediT authorship contribution statement

Dimitrios Koumoulidis: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis. **Dimitrios Mpormpoudakis:** Writing – review & editing, Validation, Supervision, Software, Resources, Methodology, Formal analysis, Data curation, Conceptualization. **Ioannis Varvaris:** Supervision, Project administration, Investigation, Data curation. **Mariza Kaskara:** Validation, Resources, Project administration. **Charalambos Kontoes:** Supervision, Resources. **Diofantos Hadjimitsis:** Supervision, Funding acquisition.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: [Dimitrios Koumoulidis reports a relationship with ERATOSTHENES Centre of Excellence that includes: employment. Ioannis Varvaris reports a relationship with ERATOSTHENES Centre of Excellence that includes: employment. Diofantos Hadjimitsis reports a relationship with ERATOSTHENES Centre of Excellence that includes: employment. Dimitrios Mpormpoudakis reports a relationship with National Observatory of Athens that includes: employment. Mariza Kaskara reports a relationship with National Observatory of Athens that includes: employment. Charalambos Kontoes reports a relationship with National Observatory of Athens that includes: employment. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper].

Acknowledgments

We acknowledge the ‘EXCELSIOR’: ERATOSTHENES: Excellence Research Centre, for Earth Surveillance and Space-Based Monitoring of the Environment H2020 Widespread Teaming project (www.excel-sior2020.eu), with funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 857510, from the Government of the Republic of Cyprus through the Directorate General for the European Programmes, Coordination and Development and the Cyprus University of Technology. We also acknowledge the ‘LANDSHIFT’: Community-Led Creation of Living Spaces in Shifting Landscapes for Climate-Resilient Land Use Management and Supporting the New European Bauhaus. The “LandShift” project has received funding from the European Union's Horizon Europe Research and Innovation Programme (HORIZON-CL6-2024-CLIMATE-01-4) under Grant Agreement No. 101182007. We extend our sincere appreciation to Mr. Christos Theocharidis from Eratosthenes Centre of Excellence for his contribution, advice and technical support in G.I.S software matters.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.cacint.2026.100327>.

Data availability

Data will be made available on request.

References

- [1] Masselink G, Lazarus ED. Defining coastal resilience. *Water* (Basel) 2019;11:2587. <https://doi.org/10.3390/w1122587>.
- [2] Mishra M, Chand P, Beja SK, Santos CAG, da Silva RM, Ahmed I, et al. Quantitative assessment of present and the future potential threat of coastal erosion along the Odisha coast using geospatial tools and statistical techniques. *Sci Total Environ* 2023;875:162488. <https://doi.org/10.1016/j.scitotenv.2023.162488>.
- [3] Pournara A, Sakellariadou F, Kitsiou D. Toward a sustainable blue economy in the coastal zone: case study of an industrialized coastal ecosystem in Greece. *Sustainability* (Switzerland) 2023;15:11333. <https://doi.org/10.3390/su151411333>.
- [4] OECD, Adapting to a changing climate in the management of coastal zones, OECD Environment Policy Papers (2021). DOI: 10.1787/b21083c5-en.
- [5] Fang X, Zou J, Wu Y, Zhang Y, Zhao Y, Zhang H. Evaluation of the sustainable development of an island “Blue Economy”: a case study of Hainan, China. *Sustain Cities Soc* 2021;66:102662. <https://doi.org/10.1016/j.scs.2020.102662>.
- [6] U.N.E. Programme, State of the Environment and Development in the Mediterranean (SoED) 2020, United Nations, Erscheinungsort nicht ermittelbar, 2021. https://planbleu.org/wp-content/uploads/2021/04/SoED_full-report.pdf.
- [7] Vogiatzakis I, Mannion AM, Pungetti G. Introduction to the mediterranean island landscapes. In: Vogiatzakis I, Pungetti G, Mannion AM, editors. *Mediterranean Island Landscapes: Natural and Cultural Approaches*. Netherlands, Dordrecht: Springer; 2008. p. 3–14. 10.1007/978-1-4020-5064-0_1.
- [8] Kefalas G, Poirazidis K, Xofis P, Kalogirou S, Chalkias C. Landscape dynamics on insular environments of South-east mediterranean Europe. *Geocarto Int* 2022;37:1813. <https://doi.org/10.1080/10106049.2020.1790677>.
- [9] C. Laval, C.R. Gomes, C. Baranzelli, Policy alternatives impacts on European Coastal Zones 2000 – 2050, (n.d.). <https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=e7a543af907c22030afca985f3e55b8bafcf8f95>.
- [10] European Environment Agency, Waste and resources in a circular economy (Chaper 9), The European Environment —State and Outlook 2020. Knowledge for Transition to a Sustainable Europe (2019) 211–229. <https://www.eea.europa.eu/en/analysis/publications/soer-2020> (accessed February 23, 2026).
- [11] Satta A, Puddu M, Venturini S, Giupponi C. Assessment of coastal risks to climate change related impacts at the regional scale: the case of the Mediterranean region. *Int J Disaster Risk Reduct* 2017;24:284–96. <https://doi.org/10.1016/j.ijdrr.2017.06.018>.
- [12] MedECC, W. Cramer, J. Guiot, K. Marini, Climate and Environmental Change in the Mediterranean Basin – Current Situation and Risks for the Future. First Mediterranean Assessment Report, MedECC Reports. MedECC Secretariat, Marseille, France., 2020. DOI: 10.5281/ZENODO.7224821.
- [13] UNCCD Library | Details | High-Level Dialogue on Desertification, Land Degradation and Drought -General Assembly, 75th session -14 June 2021- 2 July 2021. Summary by the President of the General Assembly, (n.d.). <https://library.unccd.int/Details/fullCatalogue/600000135> (accessed February 23, 2026).
- [14] Esendagli Ç, Selim S. Monitoring of land use/land cover change and statistical analysis of change within the scope of Urban Sprawl North Cyprus case. *Journal of Architectural Sciences and Applications* 2024;9:195–211. <https://doi.org/10.30785/mbud.1435714>.
- [15] Tomaselli V, Mantino F, Tarantino C, Albanese G, Adamo M. Changing landscapes: habitat monitoring and land transformation in a long-time used Mediterranean coastal wetland. *Wetl Ecol Manag* 2023;31:31–58. <https://doi.org/10.1007/s11273-022-09900-5>.
- [16] A. Gkaifyllia, S. Papasarafricanou, A.E. Chatzipavlis, N. Đorđević, I.N. Monioudi, O. Tzoraki, T. Hasiotis, Interaction between coastal socioeconomic and environmental activities for integrated management: case study East Mediterranean (Greece, Cyprus, and Montenegro), *Euro-Mediterranean Journal for Environmental Integration*. 2025 10:4 10 (2025) 2863–2881. DOI: 10.1007/s41207-025-00776-4.
- [17] Eminel Sülün E, Azizbeyli Z. The eu and environmental protection: cyprus at the crossroads of europe. *Ankara Avrupa Calismalari Dergisi* 2021;21:293–317. <https://doi.org/10.32450/aacd.995877>.
- [18] Skoutaris N. The application of the acquis communautaire in the areas not under the effective control of the Republic of Cyprus: the Green Line Regulation. *Common Market Law Review* 2008;45:727–55. <https://doi.org/10.54648/cola2008049>.
- [19] Alola AA, Alola UV. Agricultural land usage and tourism impact on renewable energy consumption among Coastline Mediterranean Countries. *Energy Environ* 2018;29:1438–54. <https://www.jstor.org/stable/26554641>.
- [20] Zittis G, Almazroui M, Alpert P, Ciais P, Cramer W, Dahdal Y, Fnaïs M, Francis D, Hadjinicolaou P, Howari F, Jrrar A, Kaskaoutis DG, Kulmala M, Lazoglou G, Mihalopoulos N, Lin X, Rudich Y, Sciare J, Stenchikov G, Xoplaki E, Lelieveld J. Climate change and weather extremes in the eastern mediterranean and middle east. *Rev Geophys* 2022;60. <https://doi.org/10.1029/2021RG000762>.
- [21] Mediterranean Region, in: *Climate Change 2022 – Impacts, Adaptation and Vulnerability*, 1st ed., Cambridge University Press, 2023: pp. 2233–2272. DOI: 10.1017/9781009325844.021.
- [22] Guerreiro SB, Dawson RJ, Kilsby C, Lewis E, Ford A. Future heat-waves, droughts and floods in 571 European cities. *Environ Res Lett* 2018;13:034009. <https://doi.org/10.1088/1748-9326/aaad3>.
- [23] Nastos P, Saaroni H. Living in mediterranean cities in the context of climate change: a review. *Int J Climatol* 2024;44:3169–90. <https://doi.org/10.1002/joc.8546>.
- [24] Stratigea A, Leka A, Nicolaidis C. Small and medium-sized cities and insular communities in the mediterranean: coping with sustainability challenges in the smart city context. *Progress in IS* 2017;3–29. https://doi.org/10.1007/978-3-319-54558-5_1.
- [25] Discover our target regions: The Mediterranean Sea - SHORE, (n.d.). <https://shoreproject.eu/mediterranean-sea/> (accessed February 23, 2026).
- [26] Home Page | Data Portal, (n.d.). <https://population.un.org/dataportal/home?df=87cf1538-8045-468d-80ce-f8943fcc2989> (accessed February 23, 2026).
- [27] Statistical Service - Home, (n.d.). <https://www.cystat.gov.cy/en/default> (accessed February 23, 2026).

- [28] Hof A, Schmitt T. Urban and tourist land use patterns and water consumption: evidence from Mallorca, Balearic Islands. *Land Use Policy* 2011;28:792–804. <https://doi.org/10.1016/j.landusepol.2011.01.007>.
- [29] Lai S, Leone F, Zoppi C. Land cover changes and environmental protection: a study based on transition matrices concerning Sardinia (Italy). *Land Use Policy* 2017;67: 126–50. <https://doi.org/10.1016/j.landusepol.2017.05.030>.
- [30] Prévost A, Robert S. Local spatial planning practices in four French Mediterranean coastal territories under pressure. *Land Use Policy* 2016;56:68–80. <https://doi.org/10.1016/j.landusepol.2016.04.034>.
- [31] Tsilimigkas G, Rempis N. Marine uses, synergies and conflicts. evidence from Crete Island, Greece. *J Coast Conserv* 2018;22:235–45. <https://doi.org/10.1007/s11852-017-0568-7>.
- [32] Tzoraki O, Monioudi IN, Velegrakis AF, Moutafis N, Pavlogeorgatos G, Kitsiou D. Resilience of touristic island beaches under sea level rise: a methodological framework. *Coast Manag* 2018;46:78–102. <https://doi.org/10.1080/08920753.2018.1426376>.
- [33] Hasan MU, Drakou EG, Karymbalis E, Tragaki A, Gallousi C, Liqueste C. Modelling and mapping coastal protection: adapting an EU-wide model to national specificities. *Sustainability* 2023;15:260. <https://doi.org/10.3390/su15010260>.
- [34] Eliades M, Michaelides S, Evagorou E, Fotiou K, Fragkos K, Leventis G, et al. Earth observation in the EMMENA region: scoping review of current applications and knowledge gaps. *Remote Sens (Basel)* 2023;15:4202. <https://doi.org/10.3390/rs15174202>.
- [35] Chen J, Chen L, Chen F, Ban Y, Li S, Han G, et al. Collaborative validation of Globeland30: methodology and practices. *Geo-spatial Inf Sci* 2021;24:134–44. <https://doi.org/10.1080/10095020.2021.1894906>.
- [36] O'Connor B, Secades C, Penner J, Sonnenschein R, Skidmore A, Burgess ND, et al. Earth observation as a tool for tracking progress towards the Aichi Biodiversity Targets. *Remote Sens Ecol Conserv* 2015;1:19–28. <https://doi.org/10.1002/rse2.4>.
- [37] Jökar Arsanjani J, See L, Tayyebi A. Assessing the suitability of Globeland30 for mapping land cover in Germany. *Int J Digit Earth* 2016;8:73–91. <https://doi.org/10.1080/17538947.2016.1151956>.
- [38] Chen J, Cao X, Peng S, Ren H. Analysis and applications of globeland30: a review. *ISPRS Int J Geoinf* 2017;6:230. <https://doi.org/10.3390/ijgi6080230>.
- [39] Land cover classification gridded maps from 1992 to present derived from satellite observations, (n.d.). <https://cds.climate.copernicus.eu/datasets/satellite-land-cover?tab=overview> (accessed February 23, 2026).
- [40] D. Zanaga, R. Van De Kerchove, D. Daems, W. De Keersmaecker, C. Brockmann, G. Kirches, J. Wevers, O. Cartus, M. Santoro, S. Fritz, M. Lesiv, M. Herold, N.-E. Tsendbazar, P. Xu, F. Ramoino, O. Arino, ESA WorldCover 10 m 2021 v200, (2022). DOI: 10.5281/ZENODO.7254221.
- [41] Product user manual — CORINE Land Cover (from 1990 to 2018) and CORINE Land Cover Changes — Copernicus Land Monitoring Service, (n.d.). <https://land.copernicus.eu/en/technical-library/clc-product-user-manual> (accessed February 23, 2026).
- [42] Mishra M, Bhattacharyya D, Mondal B, Paul S, Da Silva RM, Santos CAG, et al. Forecasting shoreline dynamics and land use/land cover changes in Balukhand-Konark Wildlife Sanctuary (India) using geospatial techniques and machine learning. *Sci Total Environ* 2025;975:179207. <https://doi.org/10.1016/j.scitotenv.2025.179207>.
- [43] Santos CAG, do Nascimento GR, Freitas LMT, Batista LV, Zerouali B, Mishra M, da Silva RM. Coastal evolution and future projections in Conde County, Brazil: a multi-decadal assessment via remote sensing and sea-level rise scenarios. *Science of the Total Environment* 915 2024. <https://doi.org/10.1016/j.scitotenv.2023.169829>.
- [44] Koumoulidis D, Varvaris I, Theocharidis C, Hadjimitsis D, Kontoes C. Mapping land use transformations in the eastern part of the EMMENA region in the last two decades. addressing food security from a land use perspective. *Copernicus Meetings* 2025. <https://doi.org/10.5194/egusphere-egu25-2235>.
- [45] Chen J, Chen J, Liao A, Cao X, Chen L, Chen X, et al. Global land cover mapping at 30 m resolution: a POK-based operational approach. *ISPRS J Photogramm Remote Sens* 2015;103:7–27. <https://doi.org/10.1016/j.isprsjprs.2014.09.002>.
- [46] Yang Y, Xiao P, Feng X, Li H. Accuracy assessment of seven global land cover datasets over China. *ISPRS J Photogramm Remote Sens* 2017;125:156–73. <https://doi.org/10.1016/j.isprsjprs.2017.01.016>.
- [47] Lan Y-J, Hsu T-W. Planning and management of coastal buffer zones in Taiwan. *Water (Basel)* 2021;13:2925. <https://doi.org/10.3390/w13202925>.
- [48] H. Yagi, H. Hinata, K. Nadaoka, Velocity Field Measurements in a "Coastal Buffer Zone," (2015) 3431–3441. DOI: 10.1061/9780784402429.265.
- [49] Zuo J, Zhang L, Chen B, Zhang B, Ruan L, Hu Y, et al. A comprehensive coastal indicators database for global coastal sustainable development assessment. *Sci Data* 2025;12:1562. <https://doi.org/10.1038/s41597-025-05668-4>.
- [50] Lan YJ, Hsu TW. Planning and management of coastal buffer zones in taiwan. *Water (Switzerland)* 2021;13. <https://doi.org/10.3390/w13202925>.
- [51] Coastal Zones Land Cover/Land Use 2018 (vector), Europe, 6-yearly, Feb. 2021, (n. d.). <https://sdi.eea.europa.eu/catalogue/copernicus/api/records/205e2db2-4e35-4b1b-bf84-271c4a82248c?language=all> (accessed February 23, 2026).
- [52] Kefalas G, Kalogirou S, Poirazidis K, Lorilla RS. Landscape transition in Mediterranean islands: the case of Ionian islands, Greece 1985–2015. *Landsc Urban Plan* 2019;191:103641. <https://doi.org/10.1016/j.landurbplan.2019.103641>.
- [53] Smiraglia D, Cavalli A, Giuliani C, Assennato F. The increasing coastal urbanization in the mediterranean environment: the state of the art in Italy. *Land* 2023;12:1017. <https://doi.org/10.3390/land12051017>.
- [54] Leka A, Lagarias A, Panagiotopoulou M, Stratigea A. Development of a Tourism Carrying Capacity Index (TCCI) for sustainable management of coastal areas in Mediterranean islands - Case study Naxos, Greece. *Ocean Coast Manag* 2022;216: 105978. <https://doi.org/10.1016/j.ocecoaman.2021.105978>.
- [55] Biodiversity Strategy for 2030 - Environment - European Commission, (n.d.). https://environment.ec.europa.eu/strategy/biodiversity-strategy-2030_en (accessed February 23, 2026).
- [56] Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014 establishing a framework for maritime spatial planning, 2014. <http://data.europa.eu/ropa.eu/eli/dir/2014/89/oj>.
- [57] Recommendation of the European Parliament and of the Council of 30 May 2002 concerning the implementation of Integrated Coastal Zone Management in Europe, 2002. <http://data.europa.eu/eli/reco/2002/413/oj>.
- [58] Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive) (Text with EEA relevance), 2008. <http://data.europa.eu/eli/dir/2008/56/oj>.
- [59] Second homes and urban landscape patterns in Mediterranean coastal tourism destinations | Request PDF, ResearchGate (2025). DOI: 10.1016/j.landusepol.2017.07.018.
- [60] State of play of tourism in the Mediterranean - Blue Tourism Initiative, (n.d.). <https://bluetourisminitiative.org/publications/state-of-play-of-tourism-in-the-mediterranean-2/> (accessed February 23, 2026).
- [61] Vardopoulos I, Ioannides S, Georgiou M, Voukalli I, Salvati L, Doukas YE. Shaping sustainable cities: a long-term GIS-emanated spatial analysis of settlement growth and planning in a coastal mediterranean european city. *Sustainability* 2023;15: 1–24. <https://ideas.repec.org/a/gam/jsusta/v15y2023i14p11202-d1196814.html>.
- [62] Harris SE. Cyprus as a degraded landscape or resilient environment in the wake of colonial intrusion. *PNAS* 2012;109:3670–5. <https://doi.org/10.1073/pnas.1114085109>.
- [63] Cyprus Deforestation Rates & Statistics | GFW, (n.d.). <https://www.globalforestwatch.org/dashboards/country/CYP/> (accessed February 23, 2026).
- [64] Land cover country fact sheets 2000-2018 | Maps and charts | European Environment Agency (EEA), (n.d.). <https://www.eea.europa.eu/en/analysis/maps-and-charts/copy-of-land-cover-country-fact-sheets-2000-2018-land-cover-country-fact-sheets> (accessed February 23, 2026).
- [65] E. Stylianopoulou, Habitats directive: implementation in CYPRUS, (2017).
- [66] Salvati L, Smiraglia D, Bajocco S, Munafò M. Land use changes in two mediterranean coastal regions: do urban areas matter?, world academy of science, engineering and technology. *International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering* 2014.
- [67] Theocharidis C, Eliades M, Themistocleous K, Neocleous K, Kontoes C, Hadjimitsis D. Shoreline change assessment in varosha, famagusta, cyprus: a case study of a ghost town using aerial photographs and very high-resolution satellite data (1963–2024). *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences X-G-2025* 2025:879–84. <https://doi.org/10.5194/isprs-annals-X-G-2025-879-2025>.
- [68] Monioudi IN, Velegrakis AF, Chatzistratis D, Voudoukas MI, Savva C, Wang D, et al. Climate change - induced hazards on touristic island beaches: Cyprus, eastern mediterranean. *Front Mar Sci* 2023;10:1188896. <https://doi.org/10.3389/fmars.2023.1188896>.
- [69] Cyprus Population 2026, (n.d.). <https://worldpopulationreview.com/countries/cyprus> (accessed February 23, 2026).
- [70] Kolios S, Mitrakos S, Stylios C. Detection of areas susceptible to land degradation in Cyprus using remote sensed data and environmental quality indices. *Land Degrad Dev* 2018;29:2338–50. <https://doi.org/10.1002/ldr.3024>.
- [71] Tourism Boom: Cyprus Reaps €3.2 Billion In 2024 - The Future Media, (n.d.). <https://thefuturemedia.eu/tourism-boom-cyprus-reaps-e3-2-billion-in-2024/> (accessed February 23, 2026).
- [72] Zhu Z, Woodcock CE. Continuous change detection and classification of land cover using all available Landsat data. *Remote Sens Environ* 2014;144:152–71. <https://doi.org/10.1016/j.rse.2014.01.011>.
- [73] Zhang X, Liu L, Chen X, Gao Y, Xie S, Mi J. GLC_FCS30: global land-cover product with fine classification system at 30 m using time-series Landsat imagery. *Earth Syst Sci Data* 2021;13:2753–76. <https://doi.org/10.5194/essd-13-2753-2021>.
- [74] COP Decisions | UNEP MAP, (n.d.). <https://www.unep.org/unepmap/meetings/cop-decisions> (accessed February 23, 2026).
- [75] Mediterranean Strategy for Sustainable Development (MSSD) | UNEP MAP, (n.d.). <https://www.unep.org/unepmap/what-we-do/mediterranean-strategy-sustainable-development-mssd> (accessed February 23, 2026).
- [76] Goal 11: Sustainable cities and communities - The Global Goals, (n.d.). <https://globalgoals.org/goals/11-sustainable-cities-and-communities/> (accessed February 23, 2026).
- [77] Goal 15: Life on land - The Global Goals, (n.d.). <https://globalgoals.org/goals/15-life-on-land/> (accessed February 23, 2026).