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Temporary Salt Lakes: Ecosystem Services Shift in a Ramsar Site Over a 50-Year Period

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Changes in land use/land cover (LULC) are the key factors driving biodiversity and ecosystem services decline globally. This study examines spatiotemporal LULC changes in a Ramsar coastal temporary wetland (Larnaca Salt Lake) on the island of Cyprus between 1963 and 2015. LULC changes in the area are related to variations in the provision of ecosystem services (ES) namely food provision, climate regulation, avifauna support and landscape aesthetics. LULC mapping was performed based on the interpretation of aerial photos taken in 1963, while 2015 mapping was based on CORINE classification validated by satellite image analysis and fieldwork. We used the following indicators for the ES examined: (1) crops' yield for the estimation of food supply, (2) carbon storage potential for climate regulation, (3) land cover potential to support avifauna richness and (4) naturalness as a proxy for landscape aesthetics. Quantifications were based on a mixed-methods approach with the use of statistical data, expert opinion and bibliography. Estimates for every service were assigned to CORINE land use classes (CLC) present in the area. Landscape structure was measured using a suite of commonly employed landscape metrics. The results showed that between 1963 and 2015 there has been a significant reduction in food provisioning service by 75%, a 37% reduction in carbon storage capacity, an 11% reduction in the capacity to support avifauna, and a 13% reduction in landscape aesthetics. Increased soil surface sealing, mainly with the construction of the international airport, which resulted in the conversion of natural or semi-natural to artificial surfaces, has been the main reason for the decrease in ES supply over the last fifty years in the study area. The character of the area in terms of land use types richness and diversity remains fairly stable but the dominant land use types have experienced fragmentation. The study sets the basis for a monitoring scheme to evaluate the state of the temporary wetlands with emphasis placed on spatial processes as a link to ES provision.

Keywords: Cyprus, climate regulation, Natura 2000, food supply, habitat maintenance, landscape aesthetics, wetlands

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INTRODUCTION

Temporary wetlands are generally small and shallow aquatic ecosystems, characterised by frequent drying (Boix et al., 2020) and can be found in a variety of landscape settings worldwide (Calhoun et al., 2017). Their intermittent character makes these ecosystems an ecotone between terrestrial and aquatic environments. The cyclical nature between phases of inundation and drought creates a unique and highly dynamic environment that supports a specialised assemblage of plant and animal species (Williams, 2002). Temporary wetlands are ecologically significant landscape elements especially in regions where water sources are limited, through the insertion of the aquatic feature into the terrestrial matrix (Boix et al., 2020). They are remarkably diverse ecosystems exhibiting variances based on their genesis, their regional characteristics and their hydroregime (Vanschoenwinkel et al., 2009; Sim et al., 2013).

Salt lakes is a special type of temporary wetlands (Dungan , 1990; Britton and Crivelli, 1993; Tiner, 2003). They occur throughout the arid (25–200 mm annual precipitation) and semi-arid (200–500 mm) regions of the world (Jellison et al., 2004; Oren et al., 2009). They include a vast array of different sizes, ages, salinity, ionic composition, flora and fauna; from ephemeral playa lakes to ancient lakes (Hammer, 1986; Williams, 1996). The global volume of inland saline water (85,000 km^3) is only slightly less than that of freshwater (105,000 km^3) (Shiklomanov, 1990). Locally they may be more abundant than freshwater, and they often dominate the landscape and provide critical habitat for endemic species, and breeding and migratory birds (Jellison et al., 2004).

Temporary wetlands are ecologically important given their role to global biochemical cycles and the provision of habitats for a high number of species, disproportionate to their size (Deil, 2005). In addition to their ecological value, temporary wetlands provide important ecosystem services, some of which are exclusive to these ecosystems, owing to their unique functions and biodiversity. They perform important economic (fisheries, livestock and forestry), social (water supply, spiritual, educational, visual), and ecological functions (groundwater recharge, nutrient recycling, and biodiversity maintenance) with significant values (Williams, 2002). Although their benefits to society are not as easily monetised, their economic value is estimated at around US$15 trillion a year (Millennium Ecosystem Assessment, 2005).

Salt lakes can accumulate and recycle nutrients better than freshwater systems (Blomqvist et al., 2004). They produce high quantities of food for fish which in turn sustain bird populations. Even when salinity levels are too high for fish to survive, invertebrates can still support birds' diets. Millions of migratory shorebirds and waterfowl utilize saline lakes for nesting and to fuel long migrations with abundant food resources such as brine shrimp (*Artemia* spp.) and brine flies (*Ephedra* spp.). When saline lakes are desiccated, the amount of habitat decreases and salinities can rise beyond the tolerance of these invertebrates, limiting both food and habitat for birds. Due to their importance for avifauna, many salt lakes in Europe are, in addition to Ramsar sites, part of the Natura 2000 network of protected areas (Zadereev et al., 2020).

Despite their valuable ecological and economic functions, many temporary salt lakes are often seen as "wastelands" by the local communities, particularly during the dry season (Williams, 2006). As a result, they are threatened and already degraded or lost due to urbanisation, population growth, and increased economic activities (Central Pollution Control Board, 2008). Proximity to urban areas has increased their vulnerability to pollution, eutrophication and other human pressures (Gedan et al., 2009). Land use/land cover (LULC) changes within the lakes' catchments may also have adverse effects leading to a reduction in inflows and deteriorating quality of the "runoff" traversing through agricultural fields and urban areas. Additionally, the tight relationship between their hydroregime and hydrology makes temporary salt lakes extremely vulnerable to changes in climate (Boix et al., 2020). Due to their small size and their cyclical inundation nature, temporary salt lakes are very responsive to changes in temperature and precipitation patterns (Boix et al., 2020).

Identifying and mapping the ecosystem services (ES) provided by temporary salt lakes is essential for highlighting their importance and the need for further protection, given that they have been relatively neglected, compared to other wetland ecosystems. Mapping of ecosystem services supply and demand is a critical step in spatial planning with a plethora of mapping methods now at hand (Crossman et al., 2013). The use of LULC as a proxy for broad ecosystem type delineation, is often applied to large geographic areas where the dominant ES are directly linked to land cover and where data availability is limited (Burkhard et al., 2012; Maes et al., 2015). LULC modifications in an area could lead directly or indirectly to ES decline or cause shifts in the provision and flow of specific ES (Gómez-Baggethun et al., 2019; Boix et al., 2020). The assessment of ecosystems' status at a European level indicated that more than half of ecosystems are in a non-favourable state, which remains stable or is getting worse (Abdul Malak et al., 2015). Modification, loss and fragmentation of habitats, in combination with pollution and climate change, are the most important pressures that ecosystems face (Ghosn et al., 2010). There is an important knowledge gap in the combined pressures and causes that result from ecosystem degradation as well as a lack of spatial data to map biodiversity and ES provisioning.

Mapping the historical change in wetlands has the value of indirectly quantifying the human impact on the natural environment, which can then be used for management and education toward sustainable development (Burkhard et al., 2012). At finer spatial scales, using data from inventories or databases, coupled with land cover data may provide better insights for ES level provision in environmentally sensitive areas (Schmidt and Seppelt, 2018; Linney et al., 2020).

Larnaca salt lake ecosystem in Cyprus is an area where important changes have had adverse effects over the past 50 years, yet unquantified impacts on ES provision. The latter mirrors the limited research in Cyprus regarding ES despite recent attempts (Manolaki and Vogiatzakis, 2017; Vogiatzakis et al., 2020). Therefore, this study aimed to assess in a spatially explicit manner the changes in ES, which took place from 1963 to 2015 in the Larnaca salt lake ecosystem. The objectives were to:

i. test the applicability of a biophysical approach for ES assessment in wetlands;
ii. use proxy data and experts' opinion for ES mapping and;
iii. identify spatiotemporal changes in ES, linked to LULC changes over fifty years.

MATERIALS AND METHODS

Study Area

The study area is located to the west of the city of Larnaca, Cyprus (34° 54′ 0′′ N, 33° 37′ 0′′ E) comprising a unique ecosystem of a complex network of lakes (Alyki, Orphani, Soros, Spyros and Airport Lake). Alyki is the largest lake of the ecosystem with an area of 449 ha and 11.5 km in diameter (Hadjichristophorou, 2008). The ecosystem is one of the most important wetlands in Cyprus and the East Mediterranean, of international ecological significance, declared as a Ramsar site by a decision of Council of Ministers (1997), Special Protected Area under Barcelona Convention, Important Bird Area while almost the entire area (1560 ha) belongs to Natura 2000 network of protected areas (CY6000002 Alykes Larnacas) (**Figure 1**).

Cyprus is located along one of the main migratory routes between Europe and Africa, and the Middle East. Birdlife International has identified Cyprus as an Endemic Bird Area (EBA) in Europe. Important bird species recorded in the area include *Oxyura leucocephala, Phoenicopterus roseus, Numenius arquata, Charadrius alexandrinus, Egretta garzetta, Grus grus, Glareola pratincola, Tadorna tadorna, Grus virgo, Vanellus spinosus, Melanocorypha calandra, Himantopus himantopus, Francolinus francolinus* (Hellicar et al., 2014). Also, the area hosts key habitat types included in the Annex I of the EU Habitats Directive (European Council, 1992) such as Coastal Lagoons (1150), Annual vegetation of drift lines (1210), Pseudo-steppe with grasses and annuals of the Thero-Brachypodietea (6220) and Red Data Book plant species *Hippomaranthum scabrum* (Fenzl) Boiss., *Ferula scabra* (Fenzl), *Crypsis factorovski*, *Filago mareotica, Limonium mucronulatum, Ophrys kotschyi* and the endangered *Suaeda aegyptiaca* (with its largest recorded population in Cyprus 2 -3 thousand plants) (Tsintides, 2007).

Despite its ecological importance, during the last 50 years, the entire ecosystem has undergone important land cover changes, due to urbanisation and the construction of the Larnaca international airport. The most significant threats for this wetland are: (1) the presence of the Larnaca International Airport, (2) human activities such as desalination, wastewater treatment, road network maintenance/expansion, (3) urbanisation, (4) tourist activities within the salt lakes, (5) agriculture.

In this study, we investigated the ES provided by the Larnaca Salt Lake complex with a total area of 2880 ha, including the Natura 2000 site (**Figure 1**). The study area was delimited based on the coverage, availability and quality of past orthophotos, and included, in addition to the protected area, its surrounding rural areas. This is also the reason why 1963 was selected as a reference year for comparison.

LULC Spatiotemporal Changes

Land use/cover changes (LULC) in the study area were examined between 1963 and 2015 using orthophotos and satellite images respectively, to relate spatial variations in wetlands extent with the provision of the selected ecosystem services (ES).

For mapping recent land cover (2015), we used the available CORINE 2012, classification at the 3rd level. To verify the validity of the available land cover maps and update information, a combination of remote satellite images analysis using Google Earth Pro l with field observations (10 visits). Field visits took place from March 2015 to February 2016. Layers were digitised in Google Earth (kml type), using the UTM WGS84 36S. The obtained kml polygons were processed in ArcGIS (v10.2) and in the attribute table, land use in CORINE (level 3) was recorded.

For mapping historic LULC, we used orthophotos (5,000 m × 5,000 m, 1 dpi resolution from 1963), obtained from the Cyprus Land Registry (Land and Surveys Department; CGRS 1993 LTM reference system). The historic land cover was determined using photo-interpretation and archived cadastral records.

We used five commonly employed landscape metrics for diversity, composition and configuration namely Richness, Shannon's diversity index (SHDI), Shannon's evenness index (SHEI), Dominance, Mean Shape index (MSI) to study the complexity of the study area in terms of land use types for the two years of reference. Indices were calculated using the V-Late 2.0 beta extension for GIS (Lang and Tiede, 2003). Diversity metrics are often used in landscape ecology to quantify landscape composition and are often met with similar criticisms to those expressed in biodiversity studies (Chiarucci et al., 2011). However, when richness and evenness are evaluated independently, as carried out herein, they provide a more informative and complete way to measure diversity aspects (McGarigal, 2015).

Ecosystem Services (ES) Mapping

We selected four ecosystem services, one per ecosystem category following the Millennium Ecosystem Assessment (2005) framework (provisioning, regulating, supporting and cultural) namely food provision, climate regulation, avifauna support and landscape aesthetics (**Table 1**). For each ES, an indicator was employed as a proxy for mapping, and the percentage of change (**Δ%**) between the two reference years was calculated per indicator based on the equations presented in **Table 1**.

Food Provision

Crop yield was used as an indicator for the estimation of food provisioning (Eq. 1 and **Table 1**). Firstly, the agricultural land of the study area was grouped based on the following major crop categories: (1) cereals (wheat and burley), (2) olive trees, (3) vegetables and melons (e.g., cucumbers, watermelons, tomato), (4) citrus (e.g., orange, lemon trees), (5) arable land (cereals) and natural vegetation (in our case, approx. 75% arable land and 25% natural vegetation), (6) Olive trees with cereals as an additional

FIGURE 1 | Study area.

crop in the main field (75% of the area of the field occupied by cereals) (Statistical Service, 2019).

The next step was to link the agricultural crop types to the CORINE Land Cover Class (CLC), as obtained by the land cover (shown in **Supplementary Table 1**; **Supplementary Material**).

Additionally, for the determination of the food provisioning service in the area, and according to the above classes, we obtained data from the Statistical Service (2019), related to the yields (tons/ha) of these crop types, during the period 1963–2015. These data are available at a national level for each of these years (but not area specific). In more detail, in our case for the yield of cereals, wheat and barley yields were averaged. For vegetables and melons yield, the respective yields for the crops such as carrots, tomato, cucumber, melons, watermelons, etc., were averaged. The citrus yield was the average of that for oranges, lemons and grapefruits. For class 243 (Land principally occupied by agriculture with significant areas of natural vegetation), the yield was considered to be 75% of class 211 (Non-irrigated arable land). In the case of olives and cereals cultivation in the same field, the sum of the olive yield to 75% of the yield of cereals was used for the estimation of the total yield. In this case, for the yields of cereals, we assumed that 75% of the land in an

TABLE 1 | Indicators and methods for the estimation of the Ecosystem Services.

Ecosystem service category (MA, 2005)	Ecosystem service	Indicator	Method (reference)	Equation used
Provisioning	Food provision	Crop yield	Yields (tons/ha) of crop types	Eq. (1) $B_{\text{tot,year}} = \sum_{i}^{n} B_i A_i$ $B_{tot,year}$: the total yield produced in Tons/year in study area in each reference year (1963, 2015); Bi is the yield attributed in the polygon i; Ai: the area of the polygon (ha).
Regulating	Climate regulation	Carbon storage potential	TESSA	Eq. (2) $C_{\text{tot,year}} = AGB_C + BGB_C + Soil_C + DOM\_C$ AGB_C: Above ground live biomass carbon stock; BGB_C: Below ground live biomass carbon stock, $Soil_C$: soil carbon; DOM_C: Dead organic matter carbon
Supporting	Avifauna support	Avifauna support potential	Expert opinion	Eq. (3) $E_{tot,\ year} = \left(\sum_{i}^{n} \varepsilon_i A_i\right) \div A_{tot}$ εi: average experts score for the class of the polygon i, Ai: the area of the polygon; A_{tot} is the total study area (ha)
Cultural	Landscape aesthetics	Landscape naturalness	Hemerobiotic scale	Eq. (4) $N_{tot,\ year} = \left(\sum_{i}^{n} N_i A_i\right) \div A_{tot}$ Ni: index for naturalness of the polygon i with Ai area, Atot.: the total area of the study area.
The percentage of change between the two reference years				Eq. (5) $\Delta X_{tot,\%} = \frac{X_{tot,\ 2015} - X_{tot,\ 1963}}{X_{tot,\ 1963}} \times 100$ X: $B_{tot,year}$; $C_{tot,year}$; $E_{tot,year}$; $N_{tot,year}$

TABLE 2 | The qualitative index to convert each of the 4 indicators values to a 0–5 scale.

Yield (Mg/ha) (B)	C storage potential (Mg C/ha) (A)	Avifauna support (experts score) (E)	Hemerobiotic index (H)	Qualitative index
B = 0	$0 \leq A \leq 30.0$	$0 \leq E \leq 0.5$	$6 < H \leq 7$	0 zero
$0 < B \leq 1$	$30.0 < A \leq 50.0$	$0.5 < E \leq 1.5$	$5 < H \leq 6$	1 very low
$1 < B \leq 5$	$50.0 < A \leq 70.0$	$1.5 < E \leq 2.5$	$4 < H \leq 5$	2 low
$5 < B \leq 10$	$70.0 < A \leq 90.0$	$2.5 < E \leq 3.5$	$3 < H \leq 4$	3 moderate
$10 < B \leq 20$	$90.0 < A \leq 110.0$	$3.5 < E \leq 4.5$	$2 < H \leq 3$	4 high
$20 < B \leq 30$	$110.0 < A \leq 130.0$	$4.5 < E \leq 5.0$	$1 < H \leq 2$	5-very high

olive tree plantation (200 trees per ha) is available for the crop, as a 2 m radius circle remains unplanted per olive tree (equal in total to 25% of the field area) to avoid tree (and roots) damaged by machinery.

These data (yields) were divided into two periods. Period A: 1991–2018 (n = 28), representative for the year 2015 and period B: 1960–1990 (n = 13), representative for the year 1963. This distinction was necessary for two reasons: (a) the dataset from the Statistical Service contained missing values for the decades 1960–1970 and 1970–1980 and (b) the use of multiannual data gives a better estimate, since yield loss is common in agricultural products, for some years. Therefore, after summary statistics computation, average values of the yields for these two periods were compared, using one-way Anova (**Supplementary Table 1**). The analysis revealed significantly higher olive groves yield for the period B (F = 10.6; Df = 1,39; $P < 0.05$) and significantly higher vegetables yields for the period A (F = 11.25; Df = 1,39; $P < 0.05$). No difference was observed for the other crop types, for the two periods studied (**Supplementary Table 1**).

In ArcGIS, in the attribute table, yield (for each of the two periods) was linked to each of the mapped polygons, under the common field "land cover class" and in the 3rd CORINE level. Yield (tons/ha) was presented in a 0–5 level (zero to very high) quality index as given in **Supplementary Table 1** and **Table 2**. Food production (Tons/year) for 1963 and 2015 was estimated after Eq. 1 (**Table 1**). Equation 5 (**Table 1**) presents the change in food provisioning in this area between 2015 and 1963.

Carbon Storage Potential

Above and below ground live biomass (AGB_C, BGB_C), dead organic matter (DOM_C) and soil ($Soil_C$) carbon stock were estimated following TESSA toolkit (Peh et al., 2013) for every habitat type. Each CLC was matched to one of the following TESSA habitat type categories namely tree-dominated, crop-dominated, grass-dominated habitat or wetlands (**Supplementary Table 2**). Artificial areas, mainly sealed surfaces, were excluded from the calculations since their contribution to C storage is insignificant (**Supplementary Table 2**).

TABLE 3 | Diversity and form analysis at a landscape level.

	1963	2015
Diversity analysis		
Richness	16	16
Shannon's diversity	1.815	2.030
Shannon's evenness	0.654	0.732
Dominance	0.958	0.742
Form analysis		
Total patches	67	89
Mean shape index	2.294	2.262
Mean perimeter-area ratio	0.025	0.034
Mean fractal dimension	1.334	1.344

The coefficients to estimate AGB_C for the terrestrial habitat types were obtained from Annex II of the TESSA toolbox (Peh et al., 2013) and for wetlands from IPCC (2006) and they are provided in **Supplementary Table 3**. Estimates for the BGB_C were performed using a below-ground to above-ground biomass ratio conversion factors (**Supplementary Table 3**) from IPCC (2006, 2013, 2014). BGB for permanent woody crops were obtained from Annex II of the TESSA toolbox (Peh et al., 2013). To calculate biomass carbon stock, biomass (below and above live biomass) was multiplied by a conversion factor (CFC) of 0.5 for tree-dominated, forest plantations, perennial crop-dominated habitats, or by 0.47 for grass-dominated habitats and by 0.45 for salt marshes.

The C content in the soil ($Soil_C$) was estimated according to the values for each of the soil categories (e.g., Cambisols) available in IPCC (2006). Soil related data about the study area were obtained from the BIOframe platform.[1] A representative value for the soil types, which are Cambisols and Solonetz, in the study area and considering the semi-arid climatic conditions, is 38 Mg C/ha (**Supplementary Table 3**; **Supplementary material**) (Papini et al., 2011).

The DOM_C in coniferous forests is 28.2 and for eucalyptus forests 20.3 Mg/ha (IPCC, 2006; **Supplementary Table 2**). For mixed forests, an average value between coniferous and broadleaved forests was considered. For all the other vegetation types, the respective value was zero (IPCC, 2006; **Supplementary Table 2**). Accordingly, for each of the land cover mapped in the study area, a value of total C storage potential was calculated based on Eq. 2 (**Table 1**) and presented in **Supplementary Table 2**.

Using ArcGIS total C was linked to the mapped polygons, under the common field of "land cover class" and in the 3rd CORINE level. C storage potential was then converted into a 5-scale qualitative index (zero to very high), as given in **Table 2**. The % change ΔCtot, % for the two reference years was also estimated following Eq. 5 (**Table 1**).

Bird Fauna Support

Expert opinion was used for the evaluation of the avifauna support potential of this area (Eycott et al., 2011; Stevenson-Holt et al., 2014). A group of 14 experts from Cyprus was asked to evaluate CORINE land cover classes on a scale from 0 to 5 (where 0 was the lowest value and 5 the highest) for their suitability to support bird species richness, irrespectively of the presence of rare or threatened species (Pitzii, 2017). Experts were identified based on their research and/or practical experience in land management for birds in Cyprus. Kendall (W) coefficient was used to determine the degree of agreement among the experts' answers (0 to +1; where 0 means total disagreement and +1 the opposite) (Legendre, 2005). SPSS was used for this analysis. The average (n = 14) value of the experts' response was attributed in each mapped land cover/use category in the study area. Two of the mapped classes in area 521 "Coastal lagoons" and 421 "Salt marshes" were not available in the CLC for Cyprus, therefore 512 "Water bodies" and 412 "Peat bogs" were used, respectively. In ArcGIS, maps were built for 1963 and 2015, according to the CORINE classes (**Supplementary Table 2** and **Table 4**). Bird fauna support potential was estimated according to Eq. 3 (see **Table 1**). The difference in bird fauna support potential between 1963 and 2015 was calculated using Eq. 5 (**Table 1**).

Landscape Aesthetics

Landscape naturalness was used as a proxy for landscape aesthetics, assessed by using the hemerobiotic scale (Winter et al., 2010; Rüdisser et al., 2012; **Table 2** and **Supplementary Table 4**). For each of the maps (1963 and 2015) the naturalness index (H) was estimated and the difference between 1963 and 2015 was calculated according to Eq. 5 (**Table 1**).

RESULTS

LULC Changes

Figure 2 presents the area for each CLC, at the 3rd level, for the two reference years (1963, 2015). In 1963 the dominant land use/cover types were semi-natural (421, Salt marshes with halophytic vegetation; 521, Coastal wetlands) and agricultural (211, Non-irrigated arable land) while artificial surfaces were minimal (see also **Supplementary Table 4**). The semi-natural areas in 2015 were then reduced (both aquatic and terrestrial) as well as the agricultural land (i.e., 211) while the area of the artificial surface has been increased. The changes in land cover in the study area are presented in **Supplementary Table 4**. In 2015, the construction of the airport changed the spatial configuration of the land cover/use types in the study area since it divided the area into two main regions, north and south of the airport.

The form and diversity of the area have remained remarkably stable over the past 50 years (**Table 3**). However, there has been an overall increase in the total land parcels in the area, while the number of patches and the Mean NN of the dominant land cover types i.e., 211, 421, and 521 have increased (**Table 4**).

Ecosystem Services

Food Provisioning

The total yield potential for 1963 was estimated to be 5803 Mg/year while the respective value for 2015 was 1447 Mg/year. The observed reduction in food provisioning for this

[1] http://www.cyprusbiodiversity.eu/bioframe/

TABLE 4 | Landscape metrics of the Dominant land cover types.

Year	CLC code	CLC description	% of total area	No of patches	Mean patch size	Mean nearest neighbor
	211	Non-irrigated arable land	40.76	23	51.13	57.76
1963	421	Salt marshes	17.84	9	51.79	0
	521	Coastal lagoons	20.77	6	99.87	217.87
	211	Non-irrigated arable land	29.42	24	42.13	93.32
2015	421	Salt marshes	11.42	15	22.88	4.83
	521	Coastal lagoons	22.07	6	106.25	183.04

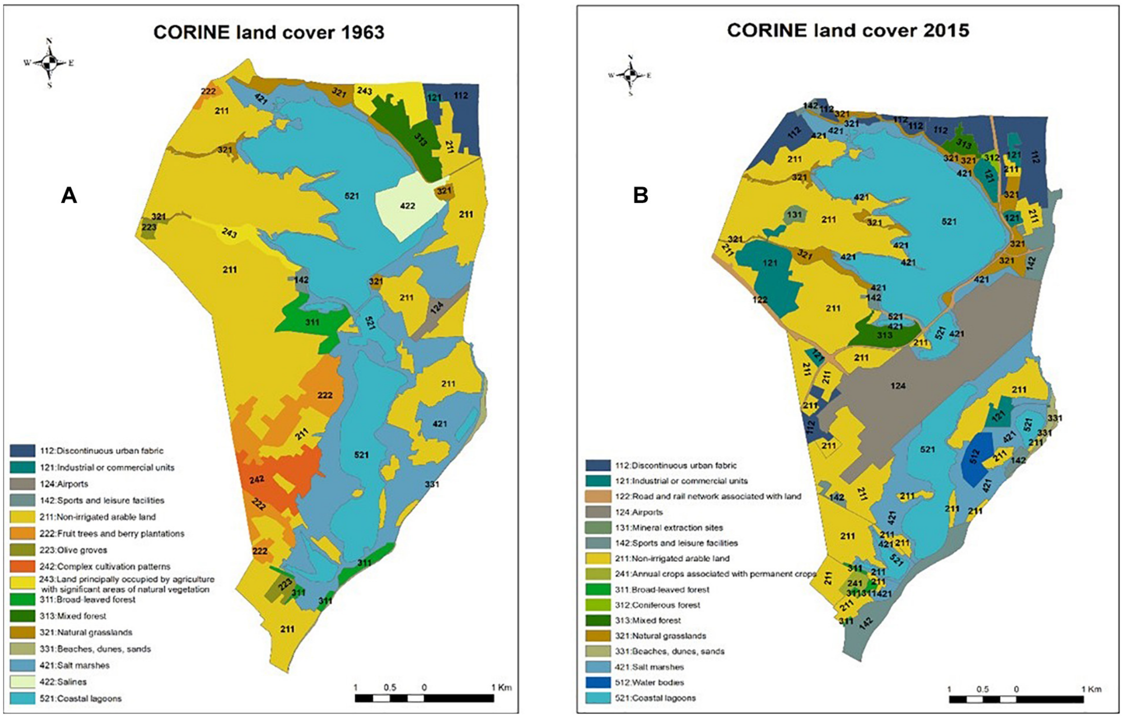

FIGURE 2 | Land cover in 1963 **(A)** and 2015 **(B)** in Larnaca Salt Lake.

area between this period is 75% (**Supplementary Table 5**). Orchards, which are characterised to have high food supply potential (yield) have been substituted by artificial surfaces (CLC 112, 121-1, 124) or arable land (CLC 211), with no or highly reduced food supply potential (**Figures 2**, **3**).

Carbon Storage Potential

Total carbon storage potential for 1963 was 246,397 Mg C while the respective figure for 2015 was 155,534 Mg C. Generally, a decreasing trend in C storage potential between 1963 and 2015 (**Figure 4**) was observed and this reduction was estimated to be 37% (**Supplementary Table 5**). The observed drop in C storage resulted mainly from artificial constructions like the airport (124), which caused a severe fragmentation of the semi-natural land cover of the study area (see also **Figure 2**). Besides, human-made commercial and urban land uses caused an additional reduction in carbon storage potential since they replaced significant semi-natural areas (see also **Figure 2**). For example, salt marshes and mixed forest, found in the southeast part of the study area, were significantly reduced or lost by 2015 and were replaced mainly by sports and leisure facilities (**Figure 4**). In the western part of the study area, non-irrigated land, which was extensive in 1963 (**Figure 2**) was significantly fragmented by 2015, following the construction of industrial units and mineral extraction sites (**Figure 4**).

Avifauna Support

According to the analysis, the capacity of the study area to support avifauna was reduced in 2015, compared to 1963 by 13% (**Supplementary Table 5**). The establishment of the airport, the urban sprawl, and the establishment of animal husbandry facilities were the main factors for this reduction (**Figure 5**). Apart from the construction of the airport, which caused a severe reduction in the capacity of the area to support avifauna based on the index (E) other artificial areas also caused a reduction of avifauna support ES. As in the case of carbon sequestration,

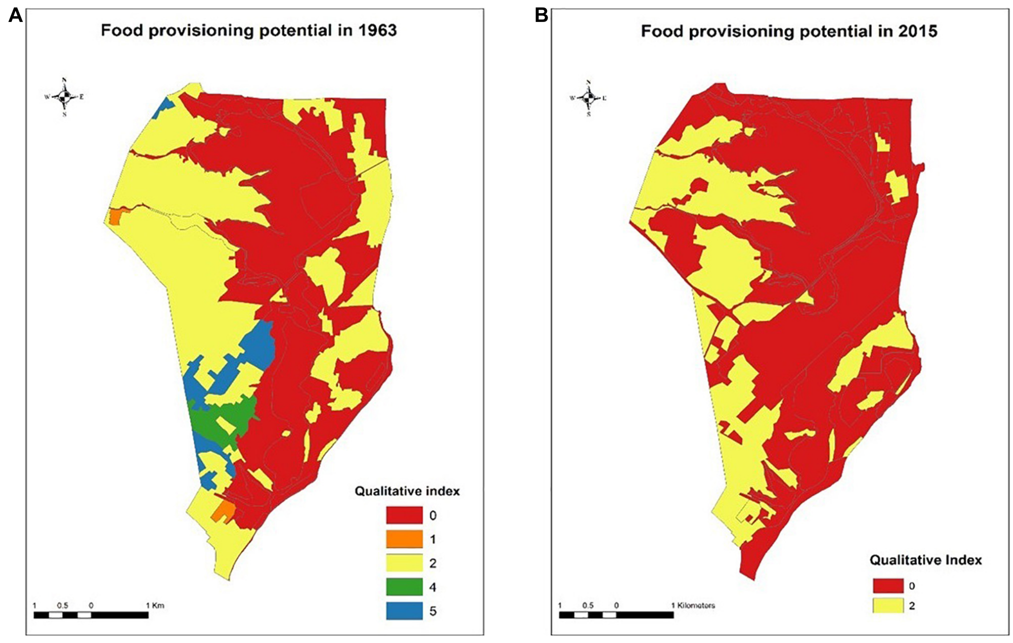

FIGURE 3 | Food provisioning and relative change between year 1963 **(A)** and 2015 **(B)**.

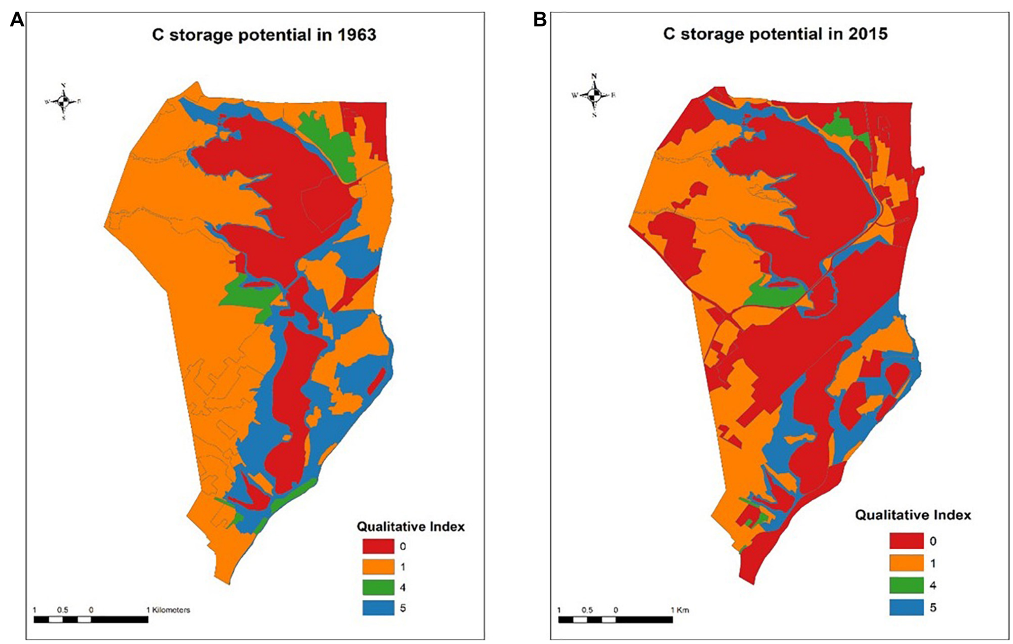

FIGURE 4 | Spatial distribution of the total Carbon storage in the study area and the changes during the period 1963 **(A)** to 2015 **(B)**.

changes in land use/cover especially along the coast from semi-natural to artificial land cover (leisure and sports facilities) reduced E (**Figure 5**).

Landscape Aesthetics

According to naturalness mapping (**Figure 6**), landscape aesthetics have changed during the studied period with the index (N) reduced by 17%. Spatially this is translated as change taking place in the whole area for 2015 except for the wetlands that seem to have kept their 1963 (landscape) value, to a large extent.

Synthesis of All ES Assessment

A synthesis of the results from all four ES measured in this study is presented in **Figure 7** as a percentage of change in the four

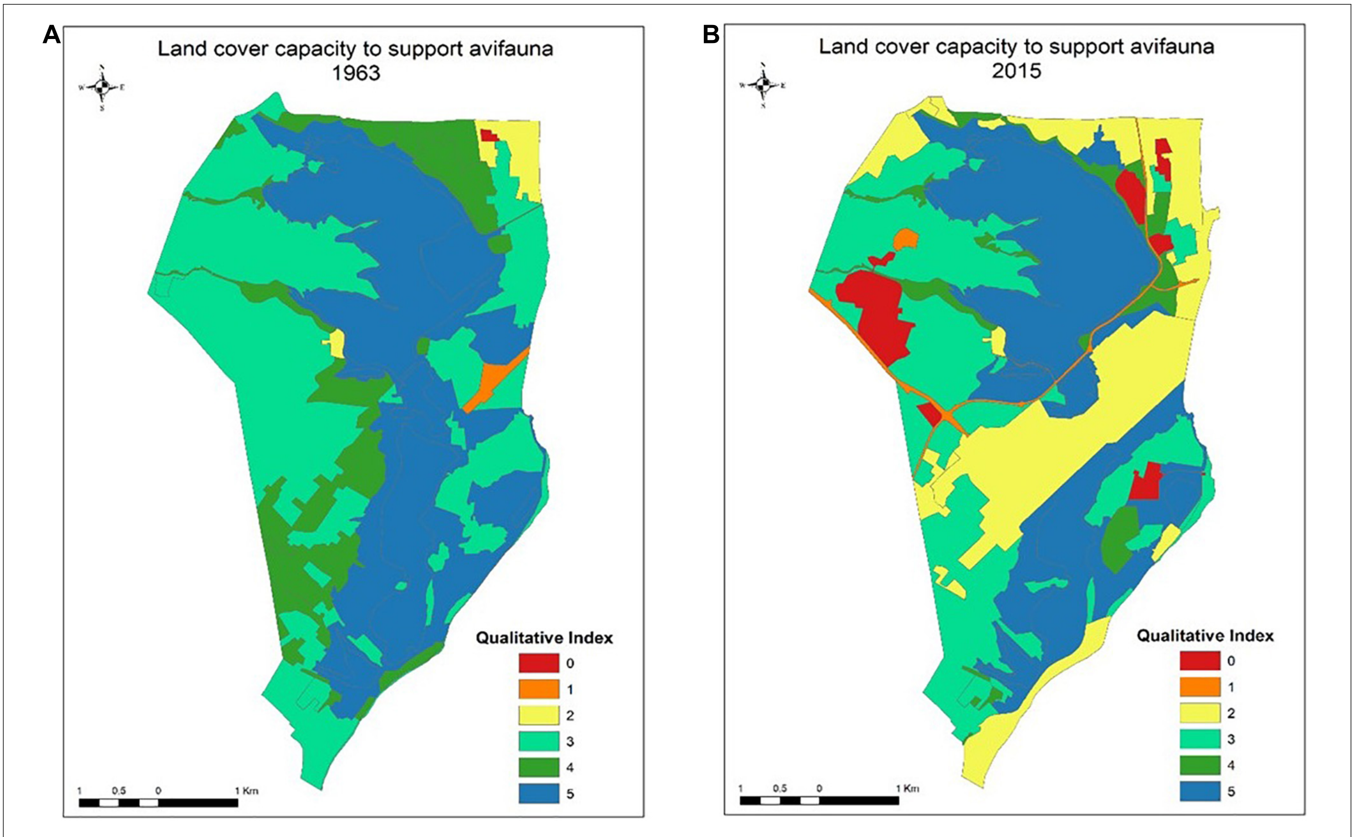

FIGURE 5 | Avifauna support in the area and the changes between 1963 **(A)** and 2015 **(B)**.

indices used for these services between the reference years (1963, 2015). Overall, a significant reduction in all ES between 1963 and 2015 was observed, with the highest reduction identified in food provisioning (75%) followed by a 37% reduction in C storage, an 11% reduction in habitat naturalness, and 13% in avifauna support. This figure reflects the LULC changes recorded, as 37% of agricultural, 36% of natural, 24% of wetlands και 5% of water areas in this area (present in 1963) were converted to artificial areas for human uses.

DISCUSSION

This study proposes an approach to assess and map a representative number of ES provided by a Ramsar temporary salt lake ecosystem in Cyprus. With this approach, we mapped current and past LULC, according to CORINE land cover classification (level 3) and we assessed changes in terms of ES provision over 50 years for an ecosystem of international importance. Results demonstrated that long term changes in the area associated with land use caused significant impacts on the ecosystem, landscape structure and the provided services. Even though scientific attention to the ecology and function of temporary wetlands has been historically limited (Williams, 2006; Boix et al., 2020), it is well documented that they are threatened by human-made habitat degradation and loss mainly due to land-use changes and urbanisation (Calhoun et al., 2017). However, to the best of our knowledge, studies that investigate the effects of land-use changes and habitat loss on ecosystem function and services are still limited. This is the first study that quantifies the temporal and spatial changes in the ecosystem services provided by a temporary salt lake in Cyprus and one of the few in the East Mediterranean.

LULC

Human activities like agriculture and urban sprawl are associated with significant threats to the study area, as for the majority of the temporary water bodies worldwide (Williams, 2006), and these are in agreement with other studies in the Mediterranean, reporting important LULC changes in the 21st century (Vogiatzakis et al., 2008; Parcerisas et al., 2012). Undoubtedly, the construction of the airport is the most profound land-use change in the area, resulting in soil surface sealing, a significant loss of semi-natural habitats, mainly salt marshes and halophytic vegetation, and severe fragmentation of the entire ecosystem. Moreover, the area due to its position is under continuous pressure from coastal development, which is partly responsible for changes in agriculture uses and abandonment. Mediterranean coastal ecosystems are vulnerable to anthropogenic pressures due to population expansion and intensification of the touristic and

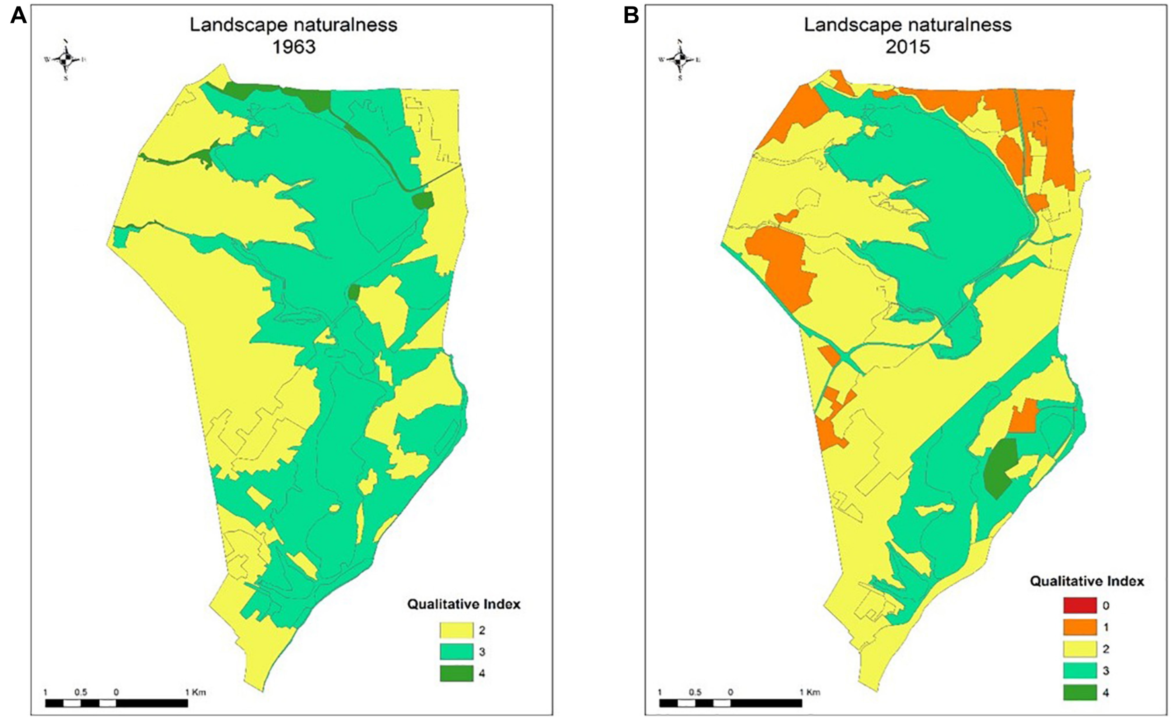

FIGURE 6 | Landscape naturalness and its changes between 1963 **(A)** and 2015 **(B)**.

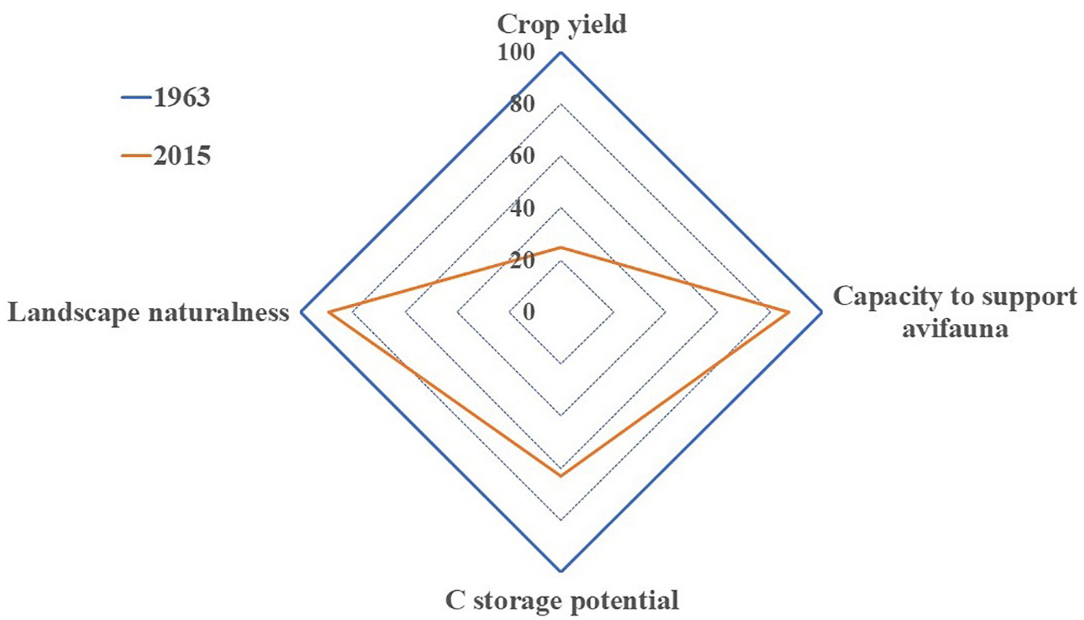

FIGURE 7 | Percentage of change in ecosystem services provision capacity indices in the study area.

industrial sectors (Malavasi et al., 2013; Martínez-Fernández et al., 2015).

In addition to the temporal dimension of LULC change assessing its spatial dimension is also common in wetlands mapping (Bortels et al., 2011) and this was also employed by this study. Results demonstrated that the landscape composition and diversity of the study area have remained remarkably stable over the past 50 years. Therefore, the area has retained its character overall, mainly because in both years (1963–2015) the water bodies, i.e., the lake itself, occupy a large part of the area without significant reduction. This is in contrast with other studies in the Mediterranean reporting a polarised territorial matrix in coastal wetlands (Zorrilla-Miras et al., 2014), leading to a contrasting habitat condition between the protected and non-protected part of the area. What has changed significantly, however, is the number of land parcels and the proximity between patches of the dominant land-use types in the past (i.e., 211 and 421).

There is ample evidence in the literature demonstrating the clear link between landscape composition and configuration on avifauna richness in different ecosystems (Morante-Filho et al., 2018). To date, there have been limited attempts to link landscape structure with ES provision (Zorrilla-Miras et al., 2014; Varin et al., 2019) and even fewer attempts trying to identify the relative influence of composition and configuration in the provision of these ES (Lamy et al., 2016). Although this study did not link explicitly landscape structure to ES, it is expected that this is certainly the case at least for avifauna richness and landscape aesthetics given that temporary wetlands is an ecotone between land and water, providing foraging and resting sites for migrating species (Calhoun et al., 2017).

Ecosystem Services

The four services were selected due to their importance in Cyprus. Since the island is a biodiversity hotspot (Médail and Diadema, 2009), habitat quality is an important service for sustaining biodiversity in the long term. Agriculture remains one of the most important economic activities, and this is the reason why we chose to map food provision. Carbon storage is also an important service especially for climate regulation, given the scenarios for future climatic change on the island (Lelieveld et al., 2016). Finally, we selected to map landscape aesthetics since the site is one of the main tourist attractions on an island which is a major tourist destination in the Mediterranean (Vogiatzakis et al., 2020).

The results suggest that land-use change has negative effects on ecosystem services in the study period (1963 and 2015). The reduction in total yield between 1963 and 2015 was 75%, and since the yield for each crop type is similar between 1963 and 2015, the observed decrease seemed to be caused by the reduction of agricultural land (43%) and the conversion to other land uses. This reduction is mainly attributed to the removal of tree crops (orchards) from the area and a shift to annual crops (wheat and burley) or complete change to non-agricultural use. These changes also resulted in increased mechanisation of agricultural production which in addition to biodiversity and food provisioning impacts, leads to increased GHG emissions due to fuel consumption for cultivation, pesticide application, and harvesting (Litskas et al., 2019).

The significant reduction of carbon storage in the area (by 37%) can be attributed to three factors: (1) the great reduction of the halophytic vegetation in the south part of the area, (2) the loss of forested areas and (3) the replacement of tree crops (orchards) by arable land in the central part of the area. Carbon storage in halophytic vegetation was estimated to be 129 Mg/ha, similar to other studies (Sousa et al., 2012). These communities have increased C storage potential, mainly through their extensive root system. Additionally, the transition to urban and artificial surfaces minimizes the C storage potential of an area, due to extensive vegetation clearance and soil compaction (Chen et al., 2013).

In the period 1963–2015, the halophytic vegetation around the lake fell from 600 to 329 ha while the aquatic environment (salt lake area) is more or less the same. Experts have indicated that these two habitats are the most important for avifauna support. Land cover changes and natural vegetation removal affects species richness, especially when specialisations (e.g., a bird and a plant species) are observed. In this case, vegetation removal results in species replacement (e.g., specialists are replaced by generalists) (Boren et al., 1999). The index used for avifauna support evaluation shows a decrease during the studied period (1963–2015) especially when habitat loss was taking place. However, a large part of the study area continues to maintain a high capacity to support avifauna, which is also documented by the continued high visitation by birds annually (Game and Fauna Service data)[2], but admittedly the effect of this deterioration is still unknown. Annual bird surveys run by the Game and Fauna Service in Cyprus may provide supporting evidence, although land cover change is not the only factor that impacts bird species particularly in the light of climate change (Lemoine et al., 2007).

The assessment of landscape aesthetics, as a cultural service, was based on the concept of naturalness using a hemerobiotic scale, employed for the evaluation of the degree of human interventions in a natural landscape (Frank et al., 2013; Taelman et al., 2016). The index used showed a decrease between 1963 and 2015, mainly in the area of the airport and its surrounding infrastructure. Additionally, north of the salt lake, many of the agricultural areas have been changed to urban. The maintenance of natural vegetation strips in the perimeter of the water bodies was important for the preservation of naturalness in the salt lake ecosystem. Given that the lake receives a high number of visitors all year round a deterioration of the overall area's naturalness might also impact the quality of the service provided (i.e., visitors' experience).

Overall, the greatest ES changes between 1963 and 2015, in the study area are related to C storage and biomass production from crops and they are attributed to LULC changes. The ES landscape naturalness and bird fauna support were affected to a lesser extent during this period, mainly because the water bodies' characteristics (e.g., area, surrounding strips vegetation) were maintained. However, the impact of this change on other groups of organisms needs further investigation. Recent studies indicate that climate change affects C storage in the soils (Lozano-García et al., 2017; Soleimani et al., 2017). Climate change affects Cyprus and this particular area, as there is a reduction in the annual rainfall and increase in mean annual temperature during the period 1963–2015 (Lelieveld et al., 2016). This may in turn affect C storage in the area as well as plant biomass and yield, especially in non-irrigated crops. However, in this research, such parameters (e.g., C storage potential per soil/habitat type) were considered constant during the study period (1963–2015).

[2]www.cypruswildlife.org.cy

The changes recorded have the potential to affect societies differently, although landscape aesthetics have not been influenced significantly over the years. Given that migratory birds are one of the area's main attraction, habitat loss, fragmentation and deterioration has resulted already in reduced species diversity. This may affect the tourism and related services sectors which have superseded the agricultural sector in the area. In addition, soil surface sealing has brought irreversible loss and significant depletion of both agricultural yield and carbon storage in the area.

Limitations

Mapping LULC changes over a long period is usually constrained by data availability (thematic and spatial resolution) and this was also the case in this case study. The use of the 3rd level of CORINE for LULC identification gave a sound basis for inter-annual comparison. Besides, the use of land cover data is a standard step in biophysical mapping for ES (Burkhard et al., 2012; Kroll et al., 2012). The C storage analysis was based on IPCC guidelines (IPCC, 2006) and we are aware of the several shortcomings that have been reported concerning the broad vegetation types and the conversion factors used (see for example Manolaki and Vogiatzakis, 2017). However, given that the same methodology was used in both reference years, the changes were reported consistently and therefore trends hold. However, field studies would have been preferable to provide an accurate estimate of carbon storage (Smith et al., 2013). Regarding the bird fauna supported by the land cover in this area, we relied on experts' opinions which are commonly used in this type of exercise (Burkhard et al., 2012). The Kendall (W) index was used to evaluate the degree of agreement among the expert opinions and indicated that most of the experts agreed in their judgment although there was not an absolute agreement. This fact is desired in studies where expert opinion is used for assessment purposes (Vogiatzakis et al., 2016).

Restoration/Management Implications

In addition to a quantitative assessment of ES, this study provides a methodology to detect spatial variations of ES and identify the influence of anthropogenic activities. The abrupt change brought by the airport's construction, was followed by urban sprawl at the fringes of the study area with changes in agricultural uses, but also abandonment at certain places. These pressures continue to be reported for the study area in the national report to the European Commission as part of Cyprus's obligation for the implementation of the Habitats Directive (European Council, 1992). The effects of LULC on landscape configuration and its link to ES provision in the wetlands mosaic have been explored in some studies (Laterra et al., 2012; Varin et al., 2019) pointing to two major processes i.e., simplification vs polarisation of land uses. With the integration of ES in landscape planning and policy (Albert et al., 2014) determining the spatial pattern of different land uses provides a link to understand the spatial pattern of ES. Setting in place a monitoring scheme over time to evaluate the state of the salt lake area and beyond i.e., at the watershed level will assist with ES provision evaluation and guide restoration efforts to target problematic areas. This study is an attempt to highlight this gap and the need for LULC monitoring particularly in and around wetlands given their importance for a range of services. It comes at a time when the first national MAES assessment is underway with funding from an EU LIFE+ project (physis.cy), and provides useful methodological insights for its implementation.

CONCLUSION

Our results indicate that it is possible to assess ES potential in an area for a given period and spatial scale using LULC data. In this study, the method was selected after reviewing the available alternatives in contrast to the limitations presented in the previous paragraph. The study confirms that Larnaca salt lake ecosystem has lost an important part of ES potential, during the last 50 years. An important decrease is observed in biomass production from the cultivated crops as well as in C storage, which is attributed to the LULC changes. Halophytic vegetation removal is the main factor for the reduction in C storage in this area. The conversion of tree crops to annual crops is the main cause for the reduction in food provisioning. Avifauna support and landscape aesthetics are less affected during the 50 years. However, airport expansion, tourism and urban development are factors that will continue to harm this Ramsar site. The subsequent ecological degradation will cause a significant deviation from the Ramsar convention's objectives, the preservation of the wetlands' ecological character of sustainable management and use.

One of the challenges for improving the effectiveness of the Ramsar Site Network is effective management and reporting (Kingsford et al., 2021). This research supports the view that LULC changes in such important ecosystems could have significant effects on ES and can be used for both management and monitoring purposes. Larnaca salt lake was designated as a Ramsar site (Ramsar site no. 1081) in 2001 long after the construction of the airport. Its inclusion in the convention made very little practical difference in the area's management until 2004, when the site was included in the European network of protected areas Natura 2000 which entailed legal obligations at the national level. The ratification of a convention like Ramsar which does not bear a binding legal obligation to the ratifying countries often leads to no formal management on the ground and what is commonly referred to paper designations (Bonham et al., 2008). The consequences as demonstrated by this study could only lead to depletion of the ES provided by such sites at the national and global level, given their importance for birds' migration. The results could be considered in the management plans for the salt lake of Larnaca, as well as similar Ramsar sites in other Mediterranean areas. Moreover, further study of the ES and broad dissemination to the stakeholders and the public could lead to increased support from the society toward the maintenance of the ecosystems.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

II and IV contributed to the conception and design of the study. II carried out the mapping and fieldwork. PM and VL carried out the analysis. VL wrote the first draft of the manuscript. PM and IV wrote sections of the manuscript. All authors contributed to the manuscript revision, read, and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fevo.2021.662107/full#supplementary-material

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