Assessment of human-induced effects in the Sultan marshes (Ramsar Protection), Kayseri (Turkey)

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Abstract This study examines the drying in the Sultan Marshes and the spatio-temporal change of different land cover classes. Corine land cover change outputs were examined for four periods (1990–2000; 2000–2006; 2006–2012; and 2012–2018). During these analyses, the period when the water area changes in the lakes occur the most was determined. Moreover, other land cover changes occurring in the region were defined. The LCC results were compared and discussed in terms of some human factors (i.e., human development index and terrestrial human footprint). According to the results of this study, it was observed that there was a severe decline in the lake surface water located in the Sultan Marshes National Park Area. The water’s surface in the lakes decreased by 50% in the 2000s compared to previous years and decreased until 2006. This withdrawal was prominent especially in Lake Yay and Lake Çöl. Considering the human factors (Human Development Index) and variables (terrestrial Human Footprint) in terms of the spatio-temporal land cover change, it is seen that the human development in the region increased from 0.54 to 0.81 from 1990 to 2018, and the human footprint increased the most in 1993. Water area changes occurred at a high rate between 1990–2000 and 2000–2006. It results from the growing demand for basic needs (such as water consumption and food diversity) with increasing human development and expanded agricultural practices in the region and overuse of the ground and aboveground waters that are the source of the lakes. Especially between 1990 and 2000, the high number of human interventions in the region caused the human footprint to be higher in 1993 than in 2009. Unless the Sultan Marshes have the proper planning and policies, it faces the danger of complete drying up with the effects of climate change in the future.

Keywords GIS · Land cover change · Wetlands · Global terrestrial human footprint · Human Development Index

Introduction

Wetlands are one of the most biologically productive ecosystems of the earth and are the subject of many studies (Biler & Altındağ, 2020). They are a vital habitat for many living species, especially migratory birds. These areas are vital for oxygen in the atmosphere and organic materials to dissolve. As essential carbon
sinks, wetlands are also suitable feeding, breeding, and sheltering environments for many species and varieties. In addition, they have significant functions such as fishing, irrigation, drinking water supply, flood control, feeding groundwater, and scientific, educational, esthetic, archeological, hereditary, and historical benefits that are not intended for consumption (Bürgi et al., 1997). Moreover, while wetlands provide many financial profits to the region where they are located, they also protect the natural balance and biological diversity (Biler & Altındağ, 2020).

However, these areas are threatened by many human activities that cause habitat and species loss. Anthropogenic activities such as pollution, deterioration of water balance (underground water withdrawal, deterioration of natural drainage direction, changing the direction of surface water flow, holding surface water with dams and barriers, etc.), agricultural activities, drying, filling, waste storage and industrial and residential use are the most significant threats to wetlands (Barbier, 1993; Barbier et al., 1997; Bergstrom & Stoll, 1993; Biler, 2019; Biler & Altındağ, 2020; Sönmez & Somuncu, 2016; Turner et al., 2000).

Research reveals that wetland ecosystems, which make up approximately 6% of the earth, are the most threatened areas among natural resources (Barbier et al., 1997). The destruction and loss of wetlands are appalling in almost every part of the world, especially in the Mediterranean countries. In France, there is a decrease of 10,000 ha every year. 60% of wetlands in Spain have been lost so far. 80% of salty marshes in Portugal are under threat of disappearance. In Greece, 60% of the wetlands have been dried to obtain agricultural land. Wetlands have decreased by 28% in Tunisia in the last 100 years (Kence, 2005; Korkanç, 2005). Turkey has lost more than 50% (1.3 million ha) of wetlands throughout its history (Korkanç, 2005; Özesmi & Özesmi, 1997). Sultan Marshes are one of the most valuable areas among them, and it is struggling to survive despite the problems it has been experiencing for years.

Turkey is greatly affected by climate change, and so is the Mediterranean basin. Furthermore, arid and semi-arid regions of the country are most likely to be impacted by future changes in increasing temperature and decreasing precipitation (IPCC, 2014). For all the aforementioned reasons, the lakes and wetlands in these regions face a significant threat of drying (Abujayyab et al., 2021; Aydin et al., 2020; Ormeci & Ekercin, 2007). Additionally, human factors also affect the lakes and wetlands (Yılmaz, 2010). Therefore, it is crucial to examine the temporal changes of (1) the “level of human development” and (2) “the human footprint” together with spatio-temporal land cover changes to reveal human influence in the lakes and wetlands. In this study, these examinations were carried out for Sultan Marshes wetland, which is a valuable Ramsar area (Ramsar Site No. 661 in 1994) (RSIS, 2008) in the arid, semi-arid region and one of the areas where the pressure of anthropogenic processes on wetlands can be observed most clearly.

Landcover plays a significant role in the climate and biogeochemistry of the earth system. Therefore, understanding patterns in land cover and alterations of land cover classes over time is essential to recognize, monitor, and manage several processes at the global level. Accurate and spatially detailed maps on land cover are relevant to a broad range of issues, including deforestation, desertification, urbanization, land degradation, loss of biodiversity and ecosystem functions, water resource management, agriculture and food security, urban and regional development, and climate change, and they are critical for making informed policy development, planning, and resource management decisions (Buchhorn et al., 2020).

In this context, this study aims to reveal the land cover changes (1990–2018) around Sultan Marshes with CORINE land cover change (LCC) periods. The analyses will determine the period when the water area changed the most. Moreover, other land cover changes in the area will be introduced. Finally, the LCC results will be compared and discussed with several human factors (i.e., Human Development Index and terrestrial Human Footprint).

Study area

Sultan Marshes National Park (Fig. 1) is located 70 km south of Kayseri Province in the Central Anatolia Region, within Develi, Yeşilhisar, and Yahyalı districts of Kayseri. Sultan Marshes National Park has an average altitude of 1071 m and is between 38° 12′ 14″ – 38° 25′ 49″ N and 35° 02′ 20″ – 35° 22′ 20″ E. The national park area is 24,523 ha, and the total area including the buffer zone is 39,057 ha (Aksoy, 2012).

Sultan Marshes is located in the center of the Develi Closed Basin and has a catchment area of
319,000 km². Erciyes Mountain is an extinct volcano with a height of 3916 m in the northeast of the wetland (Şenkul et al., 2022). The area consists of fresh, salty, and slightly salty lakes and marsh ecosystems. The leading lakes are Lake Yay (Yay Gölü) (3650 km², maximum depth 1.5 m, with two islands) and Lake Çöl (Çöl Gölü) (2600 km²), which dries up significantly in summer. In its natural condition, Sultan Marshes are fed by Yahyah, Develi, Ağcaşar, and Yeşilhisar streams; Soysalı, Çayırözü, and Yerköy springs and groundwater (Somuncu, 1988; Özsesmi et al., 1993; Sönmez & Somuncu, 2016; KTB, 2021).

Sultan Marshes are located in Develi Plain which is a closed basin (Şenkul et al., 2022). Sultan

Fig. 1 Sultan Marshes and National Park  (Source: Doğal Koruma ve Milli Parklar, 2021 from https://www.arcgis.com/apps/View/index.html?appid=5f3978146c4643438ab46620e275269)
Marshes allow the ecosystem to live and prevent floods and overflows in the plain. Most of the protected area is owned and managed by the state, and the local communities have agricultural activities and reed cutting (Özesmi et al., 1993; KTB, 2021).

Sultan Marshes National Park is a rare wetland habitat of international importance due to the coexistence of fresh and saltwater ecosystems. It is also critically significant due to its rich flora and fauna diversity (Aksoy, 2012; Sönmez & Somuncu, 2016).

In Sultan Marshes, 11.6% (50 species) of the 430 natural plant species which inhabit the steppe ecosystem are endemic. Especially, salty lakes are surrounded by sea cowpea (Salicornia) steppes. The swamps in the south consist mainly of Phragmites, Typha, Juncus, and Carex genus (Aksoy, 2012).

Among the fauna richness, Sultan Marshes have a special significance for bird species because they are located at the intersection of two valuable bird migration routes passing through Turkey and Africa, Europe, and Asia. Therefore, it has a vibrant species diversity as it provides different incubation, feeding, breeding, accommodation, and shelter (KTB, 2021). It is supposed that 600,000 water birds made their nests there when ecosystem features in Sultan Marshes were almost ideal. Three hundred and one bird species have been identified in Sultan Marshes according to the bird counting studies (Özesmi et al., 1993; Turan et al., 1995; KTB, 2021). Little cormorant, tawny heron, paddy egret, spoonbill, gray duck, summer duck, Hungarian duck, mottled duck, goose tail, crane, axilla, swamp swallow, maple plover, great plover, spur lapwing, laughing tern, little tern, and whiskered tern are among the valuable species. Ruddy shelduck prefers the area in summer, while many flamingos, cranes, and apricots use the area in fall. Many waterfowls (130,000 species) are observed in winter and during migration (KTB, 2021). Although the region has not been thoroughly studied, over 90 species of plankton, 60 species of insects, 19 species of mollusks, ten species of reptiles, three species of amphibians, 21 species of mammals, and 174 plant species have been identified (Özesmi et al., 1993). Some parts of the marshes in the north (partly irrigated) have been converted into the grain, sugar beet, and sunflower fields. In addition, sheep are grazed in the surrounding steppes, and cattle are grazed in marshy areas (KTB, 2021).

Sultan Marshes are one of the areas with the highest protection status in Turkey. In 1971, 45,000 ha in the region was reserved as a Wildlife Protection Area. An area of 17,200 ha was given the status of Nature Protection Area in 1988 and the natural protected (SIT) area in 1993. In 1994, 17,200 km² area was selected as one of Turkey’s first five Ramsar sites. In 2006, the protection status of the Sultan Marshes was changed and declared as a National Park. The last two statuses are based on the Nature Conservation Area borders, which do not include Lake Çöl and most nearby steppes (Sönmez & Somuncu, 2016; KTB, 2021). In the 1950s, a part of the Kepir Marshes in the north was distributed to the villagers by the state. These 1900 hectares of the marshes, which are within the borders of the Nature Conservation Area, have mainly been converted into agricultural land and pasture recently. Today, a maximum of 500 hectares of Marshes preserves their natural characteristics (KTB, 2021).

Material and method

This study determined how the land cover in and around the Sultan Marshes changed for four periods (1990–2000, 2000–2006, 2006–2012, 2012–2018) between 1990 and 2018. In addition, the spatio-temporal change of land covers was compared with the temporal change of the human development index of the region and the temporal change of the human footprint. The data used in the study are given in Table 1.

In this study, the land use/cover (LULC) data were obtained from the Coordination of Information on the Environment (CORINE) Land Cover (CLC) inventory, which was initiated in 1985 (the reference year 1990). Updates have been produced in 2000, 2006, 2012, and 2018. It consists of an inventory of land cover in 44 classes (CORINE, 2021). For this study, land cover change (LCC) data are obtained from CORINE database (CORINE, 2021) as vector layers for 1990–2000, 2000–2006, 2006–2012, and 2012–2018. LULC classes are also considered based on these CORINE layers, as given in Table 2.

In the present study, CORINE land cover change layers of the Sultan Marshes were examined in 4 periods, and it was determined which land cover class was transformed into another land cover class. The
change in and around Sultan Marshes was assessed by evaluating different parameters. This study discusses the role of temporal change in human development values and temporal change of human footprint on wetlands to interpret LCC results without assessing the climatic parameters.

Subnational Human Development Index (HDI) for the period 1990–2018 measures the average subnational values for three dimensions of human development: education, health, and standard of living. In its official version defined at the national level, these dimensions are measured with the following indicators: Education measured with the variables’ Mean years of schooling of adults aged 25+ and “Expected years of schooling of children aged 6”; health measured with “Life expectancy at birth” and standard of living measured with “Gross National Income per capita.” This dataset is translated from the United Nations Development Programme’s (UNDP) official Human Development Index (HDI) to the subnational level using subnational values retrieved from the Area Database of the Global Data Lab (GDL) (Institute for Management Research at Radboud University (R.U.) (Smits & Permanyer, 2018)), national statistical offices, and the E.U. statistical office (Eurostat) (Smits & Permanyer, 2018).

Initially calculated for United Nations (UN) member states in 1975, HDI is arguably the most widely used index for 182 countries using a consistent framework. HDI is comprised of four component indices to measure three development dimensions: (1) quality of life, (2) education levels, and (3) standard of living. The component indices to measure these dimensions are life expectancy for (1), expected and mean years of schooling for (2), and GNI-per-capita for (3) (Susnik & van der Zaag, 2017). For Central Anatolia, HDI values were attained for the cities as Aksaray, Kayseri, Kirikkale, Kirschir, Nevsehir, Nigde, Sivas, and Yozgat, and they combined as one region by GDL.

The global Human Footprint (HF) data were created based on (1) extent of built environments, (2) cropland, (3) pastureland, (4) human population density, (5) night-time lights, (6) railways, (7) roads, and (8) navigable waterways by Venter et al. (2016a, b, c). These impacts were weighted according to estimates of their relative levels of human pressure and then summed together to create the standardized HF for all non-Antarctic land areas at 1-km resolution (Venter et al., 2016a, b, c). In this study, HF values for 1993 and 2009 were obtained for Sultan Marshes because 1993 and 2009 were included in the database.

### Results and discussions

Figure 2 shows how CORINE land cover change layers changed (LCC) between 1990–2000 and 2000–2006. The field size of this change is included in Table 3. Figure 3 and Table 4 also provide LCC results for 2006–2012 and 2012–2018.

According to Fig. 3 and Table 3, these two periods cover the years when water bodies changed considerably. The water bodies in the coastal areas of Lake Yay and south of Lake Çöl in Sultan Marshes turned into inland marshes between 1990 and 2000. From 2000 to 2006, the interior of Lake Yay apparently became a “beaches, dunes, sands” class. There was also a transformation into irrigated agricultural lands around the national park in this period. There
is a transformation from orchards and pasture areas to irrigated agricultural areas. Also, it was determined that an area of 82 ha in the east of the wetland transitioned to the urban area.

Based on the results of the present study, it is observed that there was a severe decline in the surface water in the lakes in Sultan Marshes National Park. The surface water decreased by 50% in the 2000s compared to previous years and decreased until 2006. This withdrawal was more prominent especially in Lake Yay and Lake Çöl. According to Dadaser-Celik et al. (2007), substantial declines in seasonally fluctuating water levels were recorded in Sultan Marshes from 1993 to 2003. In the presented study, the major changes of the surface water area in Sultan Marshes were identified between 1990 and 2006 just as Dadaser-Celik et al. (2007) state. The present study indicates that the changes were related with the growing irrigation trends (340 ha transformed into the permanently irrigated land: 1990–2006) in the area. This result is compatible with Dadaser-Celik et al. (2007), who indicate that the hydrologic changes in Sultan Marshes ecosystem are related to intensification of irrigated agriculture in the catchment. Surface water in the area was used by three major reservoirs for flood irrigation (Dadaser-Celik et al., 2007), and the water bodies began to be transformed into the inland marshes between 1990–2000, subsequently

| CORINE land cover classes | Land cover sub-classes |
|---------------------------|------------------------|
| Artificial surfaces       | Discontinuous urban fabric |
|                          | Continuous urban fabric |
|                          | Industrial or commercial units |
|                          | Construction sites |
|                          | Leisure and sport facilities |
|                          | Networks of rail and road and associated land |
|                          | Airports |
|                          | Mineral extraction sites |
|                          | Dumpsites |
| Agricultural areas        | Non-irrigated arable land |
|                          | Permanently irrigated land |
|                          | Vineyards |
|                          | Fruit trees and berry plantations |
|                          | Olive groves |
|                          | Pastures |
|                          | Complex cultivation patterns |
|                          | Land principally occupied by agriculture, with significant areas of natural vegetation |
| Forest and semi-natural areas | Broad-leaved forest |
|                            | Coniferous forest |
| Wetlands                   | Mixed forest |
|                            | Natural grasslands |
|                            | Sclerophyllous vegetation |
|                            | Transitional woodland-shrub |
|                            | Beaches, dunes, sands |
|                            | Bare rocks |
|                            | Sparsely vegetated areas |
|                            | Burnt areas |
| Water bodies               | Inland marshes |
|                            | Water bodies |
|                            | Sea and ocean |
Fig. 2 The changes of the land cover classes for two periods: a 1990–2000 and b 2000–2006
Fig. 2 (continued)
into the beaches-dunes-sand between 2000 and 2006 according to the present study. Furthermore, the surface water change is linked by Sönmez and Somuncu (2016) to changes in the precipitation regime due to climate change and agricultural activities. The preference for irrigated agriculture over rainfed agriculture and agricultural production requiring high water are the main reasons for this decline especially during 2000s (Sönmez & Somuncu, 2016).

In addition, the distribution of reed-marsh areas in the region is wholly related to the water level. It is known that the areas where the water is declined, especially the bases of Lake Yay and Lake Çöl, have turned into reed-marsh areas. Therefore, there has been an expansion, especially in reed-marsh areas, as of the 2000s due to the decrease of surface water area. Sönmez and Somuncu (2016) determined the increase in reed and marsh areas as 8775 ha for 2003 and 10,380 ha for 2014. This is primarily associated with the complete drying of Lake Yay between 2000 and 2006 and the increase of reeds and marshes in the southeast.

There are also other studies in the literature about Sultan Marshes. Dadaser-Celik et al. (2008) demonstrated the change in Sultan Marshes between 1980 and 2003 with satellite images. Their analysis shows that lake surface areas decreased by 93% from 1980 to 2003. Lake Yay was almost completely dry in 2003. The marshes receded more than 50%, and the surrounding steppe expanded into the lakes and marshes. Additionally, agricultural activities expanded in the western and eastern parts (Kepir Marshes) of the study area. Although the years 2000 and 2003 had lower than average annual precipitation and lower annual precipitation than in 1980 and 1987, the changes in Sultan Marshes are so significant that they cannot be solely attributed to weather fluctuations. According to the authors, surface water diversions and increased use of spring waters and groundwater are responsible for the changes. Kesikoglu et al. (2019) focused on the changes from 2005 to 2012 in Sultan Marshes. They observed that marshes and steppe areas decreased while water and agricultural areas expanded from 2005 to 2012. These changes could result from water transfers to the marshes from the neighboring watershed.

The present results are also compatible with the Global Surface Water Occurrence Change Intensity database. The database was developed by the European Commission Joint Research Centre as “Global Surface Water Datasets” (Global Surface Water Explorer, 2020) to provide maps of surface water location and temporal distribution from 1984 to 2020 and offer statistics on the extent and change of those water surfaces. For example, Fig. 4 features the

### Table 3 The land cover changes in two periods, 1990–2000 and 2000–2006

| LCC (1990–2000) | Area (ha) | LCC (2000–2006) | Area (ha) |
|----------------|----------|----------------|----------|
| Berry plantations and fruit trees to permanently irrigated land | 173 | Non-irrigated arable land to permanently irrigated land | 35 |
| Fruit trees and berry plantations to pastures | 89 | Permanently irrigated land to non-irrigated arable land | 37 |
| Pastures to discontinuous urban fabric | 82 | Pastures to permanently irrigated land | 65 |
| Pastures to permanently irrigated land | 45 | Natural grasslands to permanently irrigated land | 13 |
| Natural grasslands to discontinuous urban fabric | 6 | Sparsely vegetated areas to permanently irrigated land | 9 |
| Natural grasslands to industrial or commercial units | 28 | Water bodies to beaches, dunes, sands | 2598 |
| Beaches, dunes, and sands to industrial or commercial units | 19 | Water bodies to inland marshes | 906 |
| Dunes, beaches, sands to land principally occupied by agriculture, with significant areas of natural vegetation | 57 | | |
| Sparsely vegetated areas to mineral extraction sites | 21 | | |
| Inland marshes to natural grasslands | 752 | | |
| Water bodies to beaches, dunes, and sands | 192 | | |
| Water bodies to inland marshes | 2356 | | |
Fig. 3 The changes of the land cover classes for two periods: a 2006–2012 and b 2012–2018
spatio-temporal change of Lake Yay and Lake Çöl in Sultan Marshes.

In Fig. 4, shades of green and “green” in “Water Occurrence Change Intensity” indicator signify increases of the water occurrence, and shades of red and “red” point to decreases (black is no change). The concentration of the color symbolizes the intensity of change (as a percentage). For example, bright red areas show a more significant water loss than dark red areas in “Global Surface Water Explorer,” the study by Pekel et al. (2016). According to Fig. 4, the lakes in Sultan Marshes were mainly dry between 1984 and 2020. The changes which are inferred from the Global Water Occurrence Change Intensity database are consistent with CORINE LCC findings in the present study. It may be seen in Fig. 4 that the water areas of the lakes, which are the most significant sources of Sultan Marshes, have disappeared over the years.

Two of the critical reasons for this change are the population growth in the region and the increasing levels of human development and accordingly their basic needs over time. When the changes in Human

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**Table 4** The land cover changes in two periods, 2006–2012 and 2012–2018

| LCC (2006–2012)                          | Area (ha) | LCC (2012–2018)                          | Area (ha) |
|------------------------------------------|-----------|------------------------------------------|-----------|
| Pastures to non-irrigated arable land    | 19        | Construction sites to industrial or commercial units | 12        |
| Pastures to permanently irrigated land   | 284       | Permanently irrigated land to vineyards   | 77        |
| Beaches, dunes, and sands to waterbodies | 82        | Pastures to permanently irrigated land    | 3003      |
| Sparsely vegetated areas to Mineral extraction sites | 8        | Sparsely vegetated areas to Industrial or commercial units | 24        |
| Sparsely vegetated areas to waterbodies  | 46        | Sparsely vegetated areas to mineral extraction sites | 5         |
|                                          |           | Inland marshes to permanently irrigated land | 99        |

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**Fig. 4** Water occurrence change intensity between 1984 and 2020 in Lake Yay (in the middle) of Sultan Marshes and Lake Çöl (in the north) (Source: Global Surface Water Explorer—https://global-surface-water.appspot.com/map)
Development Index (HDI) in the region over time are examined, it is seen that there was an increase between 1990 and 2018 (Fig. 5).

HDI values in this region expanded from 0.54 to 0.81 between 1990 and 2018. The results show that the standard of living in the region has increased. The rising standard of living means that people demand more and more basic needs such as water, electricity, and food products. However, according to United Nations Development Programme (UNDP) reports, no country or no city has achieved high human development without causing significant environmental harm (Development & Cooperation, 2021). According to Susnik and van der Zaag (2017), HDI is tightly linked to the economic and personal resource uses. For example, the authors evaluated access to safe drinking water (as a percentage of the total population), and strong correlations were identified between water use and HDI. It also supports that the increased HDI is associated with the amount of water withdrawn for domestic water and agricultural irrigation in the region. Since this population growth and the rise of the level of human development in Sultan Marshes naturally require greater use of the plain and marshes, the expansion of agricultural areas, the inclusion of irrigated agricultural products (e.g., sugar beet) in agricultural areas, and the use of chemical fertilizers and pesticides have started to damage the ecosystem (KTB, 2021).

The increase in the level of human development between 1990 and 2018 and the increase of human-induced practices in this region (such as agricultural activities, mining, and construction) also caused the change of the terrestrial human footprint in the region (Fig. 6).

As a result of present study, it is seen that HFP1993 is high in Lake Yay and Lake Çöl (surface water resources for Sultan Marshes) (Fig. 6) because the main changes occurred between 1990 and 2000. Particular attention should be paid to Land Cover Change (LCC) areas because HFP values are higher in the transformed areas. Considering HFP1993 data obtained as stated in methodology, it may be inferred from LCC findings of 1990–2000 that there is a transition between “Fruit trees and berry plantations” and “Permanent irrigated land” in areas with high footprint values. Besides, the conversion between “Water bodies” and “Inland marshes” is also documented in areas with high values. In HFP2009 data obtained as stated in methodology of present study, the human footprint in previous years was low in the area where Lake Yay was located. Since human-induced effects have already contributed to the drying up of the lake in previous years, and there is a “beaches, dune and sand” area left instead of the lake; therefore, the human footprint has naturally decreased.

The increase of agricultural practices and irrigation activities in and around Sultan Marshes and the population growth naturally caused the lakes to become
Fig. 6 The Human Footprint (HFP) for a HFP1993 and b HFP2009 with the land cover change (LCC) results (1990–2000 in (a) and 2006–2012 in (b))
Fig. 6 (continued)
sensitive. Despite an important protected area, human activities such as overgrazing, water use, and agricultural activities around the marshes are severe threats to this wetland (Dadaser-Celik et al., 2007). It is noteworthy that these factors play a remarkable role in reducing the water surface in Sultan Marshes. It has led to an increase in the amount of areas entirely devoid of vegetation. Based on the result of the present study, it is possible to claim that there is an association of the increase in plant-free surfaces with (1) the destruction of natural vegetation around the reed area, (2) groundwater consumption, and (3) land cover change.

Furthermore, significantly reducing steppe and pasture areas and spatial expansion in irrigated agricultural areas exacerbate wind erosion in and around the study area. They cause the dunes to expand rapidly, and sandstorms adversely affect agricultural areas and settlements (Sönmez & Somuncu, 2016). Increased agricultural activities and continuous drying of water areas will put Sultan Marshes at the risk of losing its unique biodiversity. Therefore, the most remarkable factors in the loss of wetland functions of Sultan Marshes are human activities. Combined with climate change, these activities make the wetland even more vulnerable.

Conclusion

According to the “Ramsar Convention on Wetlands of International Importance especially as Waterfowl Habitat,” Sultan Marshes is one of twelve internationally significant wetlands in Turkey. Additionally, the Turkish government has designated it as a “National Park” and a “Nature Conservation Area.” However, human-induced impacts have made Sultan Marshes even more vulnerable today. Excessive water withdrawal, especially for flood irrigation and agricultural activities, caused the two lakes in the reeds to dry up substantially from the 1980s (Lake Çöl and Lake Yay) to 2006–2012. It has resulted in the formation of swampy areas in the reeds and then the appearance of sandy areas. Although Sultan Marshes is under protection, wrong and uncontrolled agricultural practices threaten both the marshes and their biodiversity. These results have made Sultan Marshes more sensitive to rainfall with the increasing effects of climate change, as seen in many lakes and wetlands, in Central Anatolia. In a drier future, Sultan Marshes will turn into one of the drying wetlands and lakes if the necessary precautions are not taken.

Special practices and regulations are required around wetlands and lakes where agricultural activities are intense. The restriction of irrigated agriculture in the region, the adoption of modern irrigation techniques by farmers, and the adoption of effective water management policies suitable for the region will play an essential role in mitigating the problems. As Dadaser Çelik (2021) stated, the most vital thing for Sultan Marshes is to perform water management at the basin scale considering the impacts of future climate changes and to regulate basin areas with all the criteria effecting the basin (such as agriculture, population, human-needs-HDI, climate, and land use management) with a more holistic approach by all the stakeholders such as local users and local administrations. For example, restoration of threatened and damaged wetland ecosystems is based on ecosystem service plans of the water use and agricultural production plans. Integrating these plans into strategies to mitigate climate change would ensure sustainable wetland ecosystem services. Thus, the sustainability of life forms in Sultan Marshes and other wetlands may be ensured by preserving the ecosystem structure.

Furthermore, spatial and temporal monitoring of all wetlands, especially Sultan Marshes, requires modern monitoring systems. The monitoring studies (especially based on the water level, vegetation change, land loss, and possible losses in ecosystem services) should be organized by the regional municipalities and regularly checked by the Ministry of Environment.

Ecological tourism can be encouraged with a conscious ecological tourism policy by limiting agricultural activities in the valuable wetlands such as Sultan Marshes. Thus, the natural balance of the wetlands will not be disturbed. So, the wetlands can contribute to both the local economy and the national economy rather than only the income that agriculture may bring. This way, conservation awareness can be created by reducing anthropogenic pressures on wetlands.

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Data availability Data will be available on reasonable requests.

Declarations

Conflict of interest The authors declare no competing interests.

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