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DYNAMICS OF AQUATIC INVASIVE ALIEN SPECIES (IAS) HABITATS IN THE KIZILIRMAK DELTA, BLACK SEA, TURKIYE

Neira Purwanty ISMAIL[1*], Coşkun ERÜZ[2], Fatma TELLİ KARAKOÇ[2], Mehmet AYDIN[3], Koray ÖZŞEKER[4]

[1]Karadeniz Technical University, Sürmene Marine Science Faculty, Department of Fisheries Technology Engineering, Trabzon, Turkiye (neira.ismail@gmail.com)
[2]Karadeniz Technical University, Sürmene Marine Science Faculty, Department of Marine Science and Technology Engineering, Trabzon, Turkiye (ceruz@ktu.edu.tr; fatma.tellikarakoc@ktu.edu.tr)
[3]Ordu University, Fatsa Marine Science Faculty, Department of Fisheries Technology Engineering, Ordu, Turkiye (maydin@odu.edu.tr)
[4]Karadeniz Technical University, Institute of Marine Science and Technology, Trabzon, Turkiye (koray_ozseker@ktu.edu.tr)

Abstract. The Kızılırmak Delta is the only and the largest (up to 21.700 ha) habitat located in the Black Sea specifically on the northern side of Turkiye. The delta is known as a sanctuary for both native and migratory bird species in the region. Therefore, the Kızılırmak Delta has been registered and has the status of a Ramsar Protected Area at the international level since 1998. Furthermore, the Kızılırmak Delta was also designated as Ist, IInd, and IIIrd Priority of Natural Protected Areas and Wildlife Development Areas at the national level. These statuses are mainly due to the rich biodiversity of flora and fauna found in the delta. The delta provides a wide range of habitats from sea, river, lake, reed, marsh, and flooded forest to dunes. It is ecologically important, serving as a sanctuary and providing a feeding, breeding, and nursing ground for aquatic and terrestrial species in the region. Also, the local community utilized the surface and underground waters for various purposes such as drinking water, irrigation water, agricultural, fishing, and livestock grazing fields. The abundance of natural resources has attracted an increase in anthropogenic activities around the delta which, if not properly regulated, can affect the natural ecosystem. Such as the introduction of alien species for social and economic purposes into the Kızılırmak Delta community has the potential to add to the loss of native species. Since Invasive Alien Species (IAS) is known as one of the biggest threats that can destroy natural ecosystems. Not to mention climate change's effect on the world's wetlands which can exacerbate ecosystem degradation. Accordingly, monitoring and management of aquatic species habitats needs to be done properly to mitigate the impact of environmental degradation in the future. The present study attempts to conduct research on habitat changes to monitor the existence and dissemination of aquatic Invasive Alien Species (IAS) in the Kızılırmak Delta by utilizing remotely sensed data and Geographic Information System (GIS) methods. The result shows that the Kızılırmak Delta, which consists of several shallow lakes, is subject to change due to seasonal changes and extreme weather. This has the potential to expand the distribution of aquatic species in the delta. Isolation and control of aquatic Invasive Alien Species (IAS) in the Kızılırmak Delta must be carried out by considering the whole water body system. Moreover, this study supports scientific evidence of monitoring the dynamic of aquatic habitats in the Kızılırmak Delta.
Keywords: Delta, wetlands, aquatic habitat, invasive alien species, Black Sea, Kızılırmak

1 INTRODUCTION

Freshwater resources, most of which are preserved in shallow lakes and wetlands, are of great importance to both aquatic and terrestrial ecosystems. With only 2.5% of the earth's total freshwater resources, shallow lakes and wetlands are highly productive compared to deeper waters due to the dominance of aquatic plant communities. The abundance of aquatic plants increases the ecological and

conservation values of this area as a consequence of improved water quality, and diversity of organisms. Therefore, wetlands are often considered reserves of the earth's natural treasure because of their rich biodiversity (Campbell, 2020; Dodds & Whiles, 2010; Schlesinger & Bernhardt, 2020).

Shallow lakes and wetlands provide a wide range of ecosystem services ranging from protecting groundwater reserves to reducing the negative impacts of flood waters and similar natural disasters. Furthermore, shallow lakes and wetlands contribute a positive effect on local climate elements specifically precipitation and temperature. These water bodies act as climate softeners by increasing the humidity in the region where it is located, specifically in. However, shortly after the shallow lakes and wetlands are dried, the climate of a region becomes harsher, and the decrease in groundwater is inevitable and may even be vulnerable to earthquakes (Kuşçu Şimşek & Ödül, 2018).

Apart from the water supply, shallow lakes and wetlands are also vital natural resources for economic activities. These water bodies provide significant contributions to the economy of the region and the state through fisheries, agriculture and animal husbandry, reed production, tourism, and transportation opportunities. For instance, the most productive agricultural lands in Turkiye occupies the floodplains of rivers such as Büyük Menderes, Kızılırmak, Yeşilırmak, Seyhan, Ceyhan, Sakarya, Euphrates and Tigris. In a nutshell, wetlands are the earth's most important ecosystem due to their ecological and economic functions (Díaz-Pinzón et al., 2022).

Despite their enormous ecological and economic values, half of the world's wetlands have been lost due to anthropogenic activities. Like any other wetlands area in the world, Turkiye also lost its natural wetland areas. It is reported that, at least 291.339 ha almost one-fifth of the total natural wetlands area in Turkiye have lost in nearly one hundred years (Ataol & Onmuş, 2021). Flood control and drainage (for land acquisition, fighting against malaria, etc.) are the two main causes of direct and complete loss of wetlands. The use of the stream water resources that feed the wetlands for different purposes also indirectly causes the wetlands to dry out. Apart from these reasons, global warming, climate changes and the decrease in precipitation also play an active role in the drying up of the wetlands. In addition, construction of dams and drainage for agricultural, urban developments, housing, fishing etc. purposes lead to land use change and the loss of natural wetland areas.

Furthermore, increased anthropogenic activities in deltaic wetlands can lead to a decrease in biodiversity and the threat of extinction of some species in the ecosystem. The intensification of fisheries has led to the introduction of new species into the wetlands. The introduction of alien species for social and economic purposes into a wetland community has the potential to exacerbate the loss of native species. Invasive Alien Species (IAS) is known as one of the biggest threats to biodiversity that can destroy natural ecosystems. In wetlands, particularly aquatic species live in habitats that are interconnected through waterbodies. The example of the most important invasive species of sea snail was transported to the Black Sea by ballast water in the port of Novorossiysk in the 1940s and soon spread to the north-west and north-east Black Sea and later was first reported and spread along the Turkish coasts in 1969. Due to the absences of natural predators, alien species can multiply rapidly and cause the collapse of native species in the region. Another example of an invasive alien species is *Mnemiopsis leidyi* (comb jelly or sea walnut) which enter the Black Sea by ballast water in 1982 preying on zooplankton and fish larvae and has important role in collapsing the food chain and fishing catch in the Black Sea (Eren TUREYEN, n.d.; Kasapoglu et al., 2011; Oguz, 2017).

The Kızılırmak Delta is one of the remaining natural wetland areas in Turkiye which has not lost its deltaic features. It is also known as the only and largest delta (56.000 km^2) delta and wetlands (11.600 km^2) on the Black Sea of Turkiye. In order to protect and sustainably use wetlands especially as a habitat for waterfowl, in 1998 the Kızılırmak Delta has been registered and has the status of a Ramsar Protected Area. Also, as an effort to preserve the natural life in the Kızılırmak Delta, several protection statuses with different limitations have been determined. The area has the I^{st}, II^{nd} and III^{rd} status of Natural Protected Areas, Wildlife Development Area. In addition, the protection-use criteria of the area at certain standards were regulated in the Kızılırmak Delta Environmental Plan (Ministry of Environment and Urbanization (MEU) Republic of Turkiye, 2018).

Given the importance of the Kızılırmak Delta which has an ecological and socio-economic role for living organisms, it is very important to observe and assess changes in the wetlands. Changes in wetland areas as a consequence of both natural and human factors can affect the organisms; mainly changes in aquatic habitats can expand and narrow the distribution of aquatic organisms in the area. The introduction of aquatic alien species on one side of a shallow lake has the potential to affect the communities connected by the wetlands.

The present study aims to conduct research on aquatic habitat changes to monitor the the existence and dissemination of aquatic Invasive Alien Species (IAS) in the Kızılırmak Delta. In addition, this research provides information for better management of the Kızılırmak Delta for the current and future state. This study utilizes remotely sensed dataset history of water detection over the thirty-seven years (1984-2021) period and Geographic Information System (GIS) technique. In addition, this study provides scientific evidence of long-term monitoring of the dynamic of aquatic habitats in the Kızılırmak Delta.

2 METHODOLOGY

2.1 Study area

The Kızılırmak Delta is geographically formed by the alluvial and flow of the Kızıl River, which originally from the Kızıl Mount (3025 m) situated in the east of the İmranlı District of Sivas Province, flows westward approximately 1.355 km across the provincial borders of Sivas, Kayseri, Nevşehir, Kırşehir, Kırıkkale, Çankırı and Samsun at the Bafra Cape to the Black Sea. It is also known as the second largest delta (56.000 ha) and riverbasin in Turkiye. A large part of the Kızılırmak Delta (~11.000 ha) formed a wetland area consists of a wide range of habitat types such as sea, rivers, lake, reeds, marsh, meadow, pasture, flooded forests, dunes, and agricultural fields. The protection status of the delta is 19770.3 ha as the 1st priority, 63.02 ha as the 2nd priority and 3764.2 ha as the 3rd priority of the Natural Protected Area (Ministry of Environment and Urbanization (MEU) Republic of Turkiye, 2018; Yavuz, 2011).

It was observed that there are seven main lake habitats in the Kızılırmak Delta from largest to smallest in size: Balık Lake (1389), Gernek lake (589 ha), Uzun Lake (293 ha), Liman Lake (272 ha), Karaboğaz Lake (170 ha), Gıcı Lake (125 ha); and Tatlı Lake (52 ha). In addition, Altınlı Lakeü Sülüklü Lake and Mülk Lake are smaller lakes habitats (Ministry of Environment and Urbanization (MEU) Republic of Turkiye, 2018). The study area was the extent shallow lakes wetland of the Kızılırmak Delta as given in the following map (Figure 1).

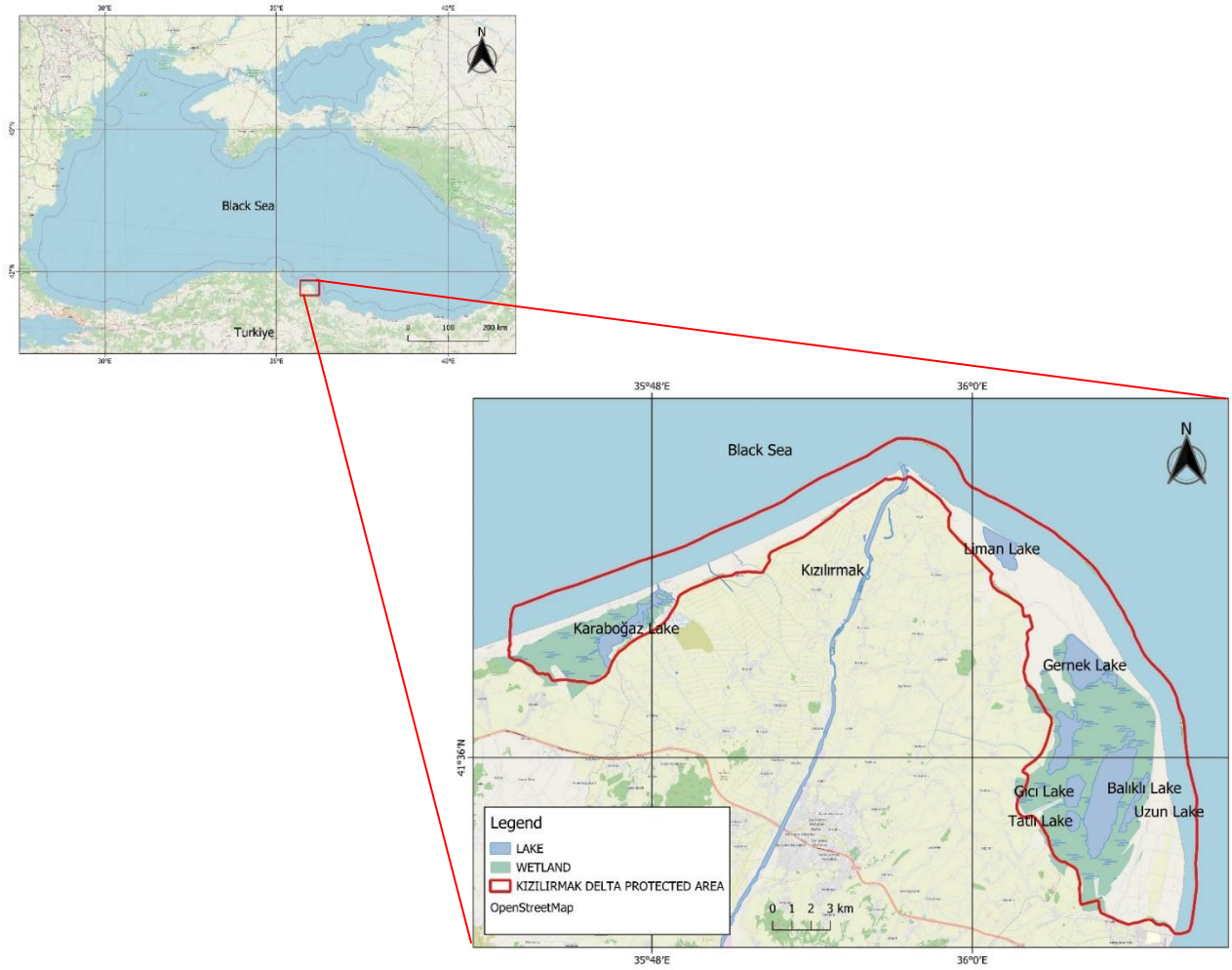

Figure 1. Study area extent of shallow lakes and wetlands of the Kızılırmak Delta, Black Sea, Turkiye

The surface and underground waters, which are the most important resource values of the Kızılırmak Delta utilized by the local community for various purposes such as meeting water needs in drinking-use, agricultural irrigation, animal herding and fishery in the region. The majority of people in the Kızılırmak Delta relied on agriculture, specifically field and garden farming. Rice cultivation is an important agriculture sector carried out in the part closest to the water source. The Kızılırmak Delta is also known as one of the richest plains in Turkey in terms of agricultural potential: wheat, corn, rice, sunflower, sugar beet, tobacco and winter vegetables are grown in the delta. In addition, the wetland areas are also used as a field for buffalo grazing and fishing (*Kızılırmak Deltası, Kuş Cenneti ve Mandacılık*, n.d.; Ministry of Environment and Urbanization (MEU) Republic of Turkiye, 2018).

It is observed that in the context of fishery, fishing activities around the delta are intense. As a result of fishery intensification also for socio-economic purposes, several Invasive Alien Species (IAS) have been introduced to the area either under control or uncontrol.

2.2 Methods

In the present study, remote sensing data and Geographic Information System (GIS) techniques were utilized in order to observe the dynamics of aquatic habitat in the Kızılırmak Delta. The dynamics of aquatic habitat were monitored through the occurrence of water bodies using multi-temporal satellite images. The use of muti-temporal satellite images allows analyzing the historical change in the study area.

In this study, the multi-temporal distribution of water of the study area over the past thirty-seven years from 1984 to 2021. The dataset was developed by the European Commission's Joint Research Centere in the framework of Copernicus Programme. The dataset was produced from Landsat imagery (from United State Geological Survey - USGS and National Aeronautics and Space Agency - NASA) and applicable for water resource and biodiversity conservation purposes (Pekel et al., 2016). Datasets are open access available online on the following web map address: https://global-surface-water.appspot.com/map

Data visualizations were performed using QGIS 3.30 (*Download QGIS*, n.d.). The Global Surface Water data used in this study are given in Figure 2.

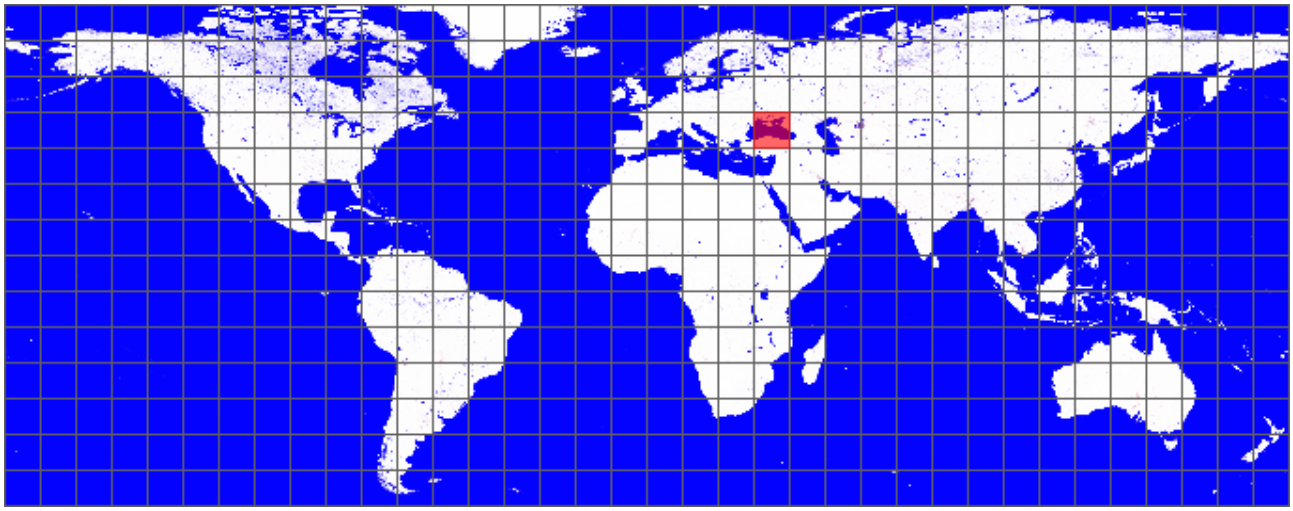

Figure 2. The Global Surface Water data of the study area is marked (square) with top left-corner at 30E, 50N (*Global Surface Water Explorer*, n.d.)

In the context of aquatic Invasive Alien Species (IAS), three shallow lakes which are located within the 1st priority of the Natural Protected Area of the Kızılırmak Delta were sampled. A total of seven marine/brackish water Invasive Alien Species (IAS) were sampled from the lakes. This field study is within the scope of BSB - 1121 IASON Project Invasive Alien Species Observatory and Network Development for the Assessment of Climate Change Impacts in the Black Sea Deltaic Protected Areas" (Eruz et al., 2022). Instead of specific aquatic species, this was conducted by discussing the habitat of aquatic species habitat in general in the Kızılırmak Delta.

3 RESULTS AND DISCUSSIONS

Wetland water occurrence: aquatic habitat change

In the present study, monitoring the aquatic habitat in the Kızılırmak Delta has been carried out by observing the water occurrence particularly in the shallow lakes and wetlands the delta using a multi-temporal dataset. This multi-temporal dataset allows historical observation of the occurrences of water in a specific water body in a certain period. As for this study, the seasonal and annual occurrence of water in the Kızılırmak Delta over a period of thirty-seven years (1984-2021) has been observed.

It is observed that seven main shallow lakes: Balık Lake, Gernek Lake, Uzun Lake, Liman Lake, Karaboğaz Lake, Gıcı Lake, and Tatlı Lake of the Kızılırmak Delta are constantly inundated by water as indicated by 100% (always) water occurrence (dark blue color). While the occurrence of water in smaller lakes and wetlands varies (sometimes occurs) below 100% over a period of thirty-seven years (1984-2021). As reported that changes in the water level of Balık Lake have been observed to vary since it was first recorded in 1959 (Ministry of Environment and Urbanization (MEU) Republic of Turkiye, 2018). The water occurrence in the Kızılırmak Delta is given in Figure 3.

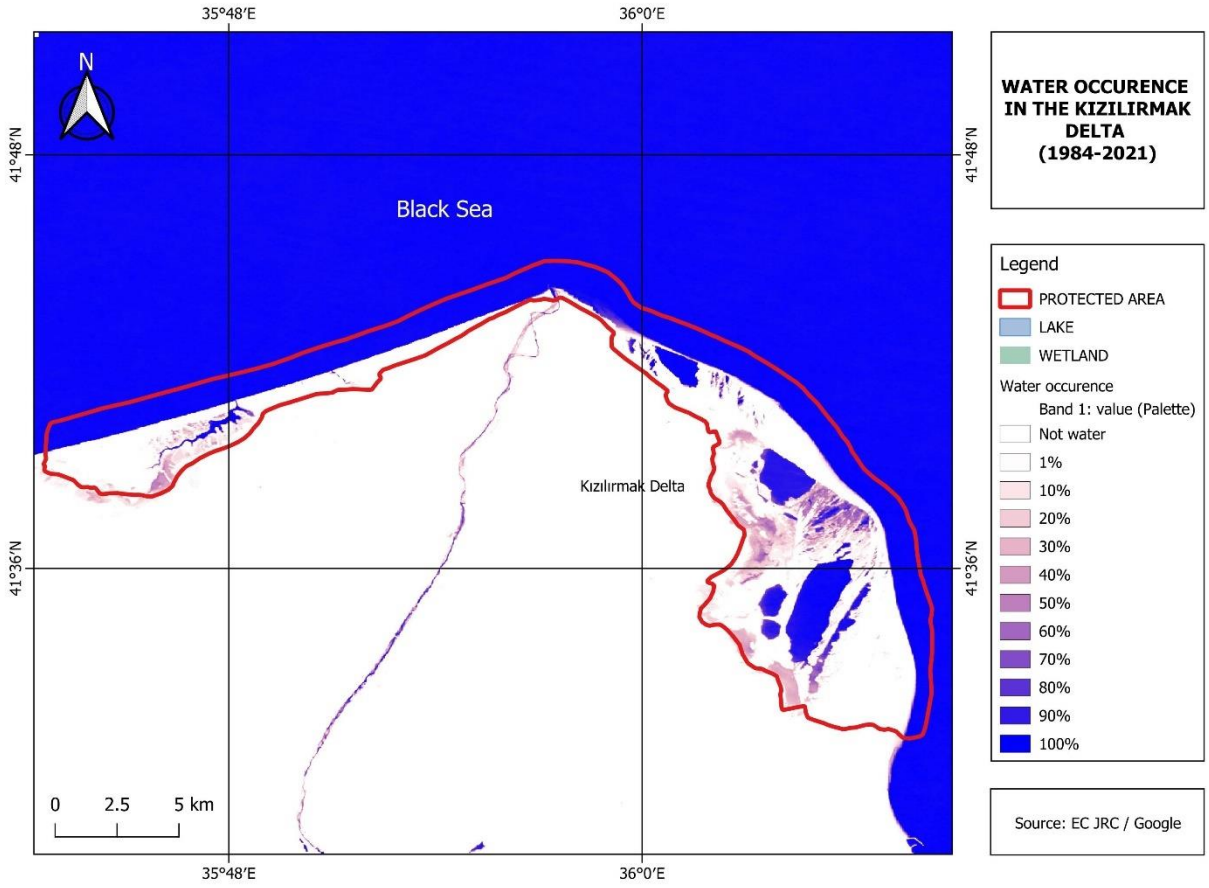

Figure 3. Water occurrence in the Kızılırmak Delta (1984-2021)

The changes in water occurrence of the Kızılırmak Delta are due to seasonal variations. The inundation in wetland areas varies for certain months (below 12 months) within a year (for year 2021 data). Meanwhile, water occurrences in the seven main shallow lakes occur throughout the seasons as indicated by 12 months of water occurrences (dark blue color). Water seasonal occurrence (year 2021) in the Kızılırmak Delta is shown in Figure 4.

The water re-occurrence documented the inter-annual variability of water availability frequency of water returns from one year to another (expressed as a percentage). It is observed that water re-occurrences in the shallow lakes and wetlands of the Kızılırmak Delta within period of thirty-seven years (1984-2021). Figure 5 shows the water re-occurrence in the study area (1984-2021).

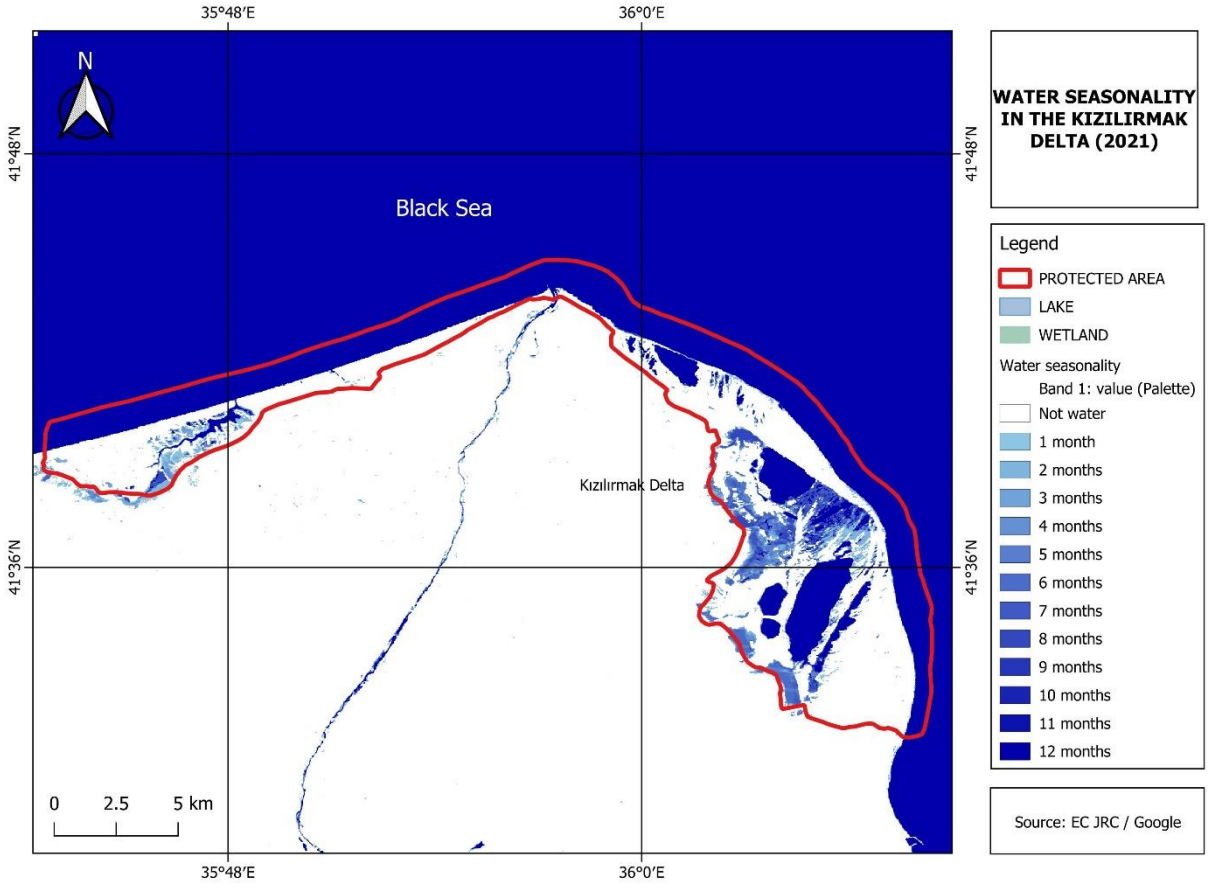

Figure 4. Seasonal water occurrence in the Kızılırmak Delta (year 2021)

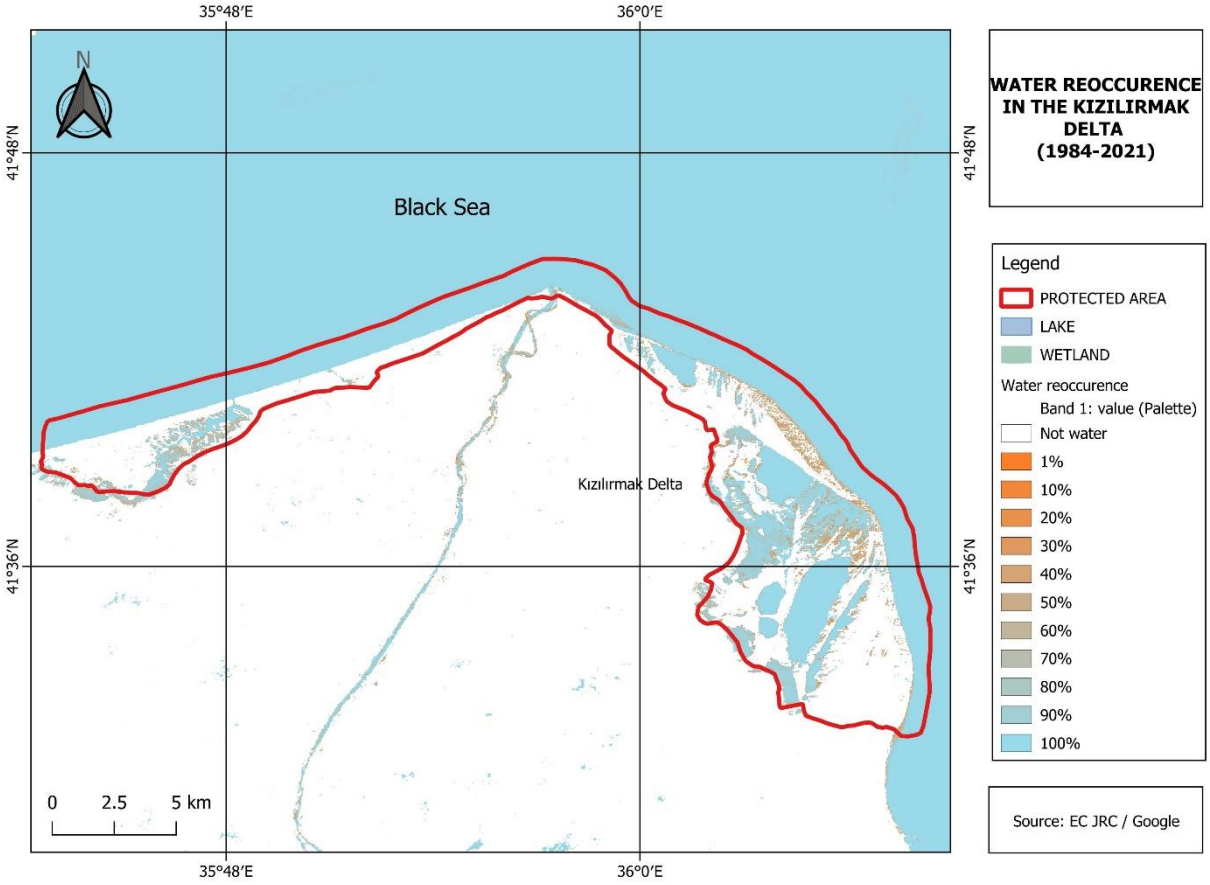

Figure 5. Annual water reoccurrence in the Kızılırmak Delta (1984-2021)

Aquatic Invasive Alien Species (IAS) habitat change

Over the period of 1984 - 2021, water occurrences in the Kızılırmak Delta have changed. Although the water occurrence of the seven main shallow lakes was relatively stable, (no change; dark color), the water occurrence in surrounding lakes and wetlands areas varied over thirty-seven years. It was observed that the increase in water occurrence (indicated by green color) is more dominant than the decrease in water occurrence (indicated by red color) in the Kızılırmak Delta.

These results are in accordance with the results of pervious study, which reported that erosion occurred in the Kızılırmak Delta River mouth, which most likely due to the dam construction in the upper reaches of the river (Harun Reşit Bağcı & Muhammet Bahadır, 2020; Ozturk et al., 2015; Zeybek et al., 2011). In addition, it is reported that 21.2% (equal to 291.339 ha) of natural wetland areas in Turkiye have been lost in a period of almost a hundred years (1920's – 2014). However, this number is relatively low compared to wetland loss in the North America and European countries (Ataol & Onmuş, 2021). It is fair to say that the Kızılırmak Delta aquatic habitat is susceptible to change. Anthropogenic activities both upstream and downstream of the Kızılırmak Delta have an impact on the water occurrence and sediment deposition of the delta river mouth.

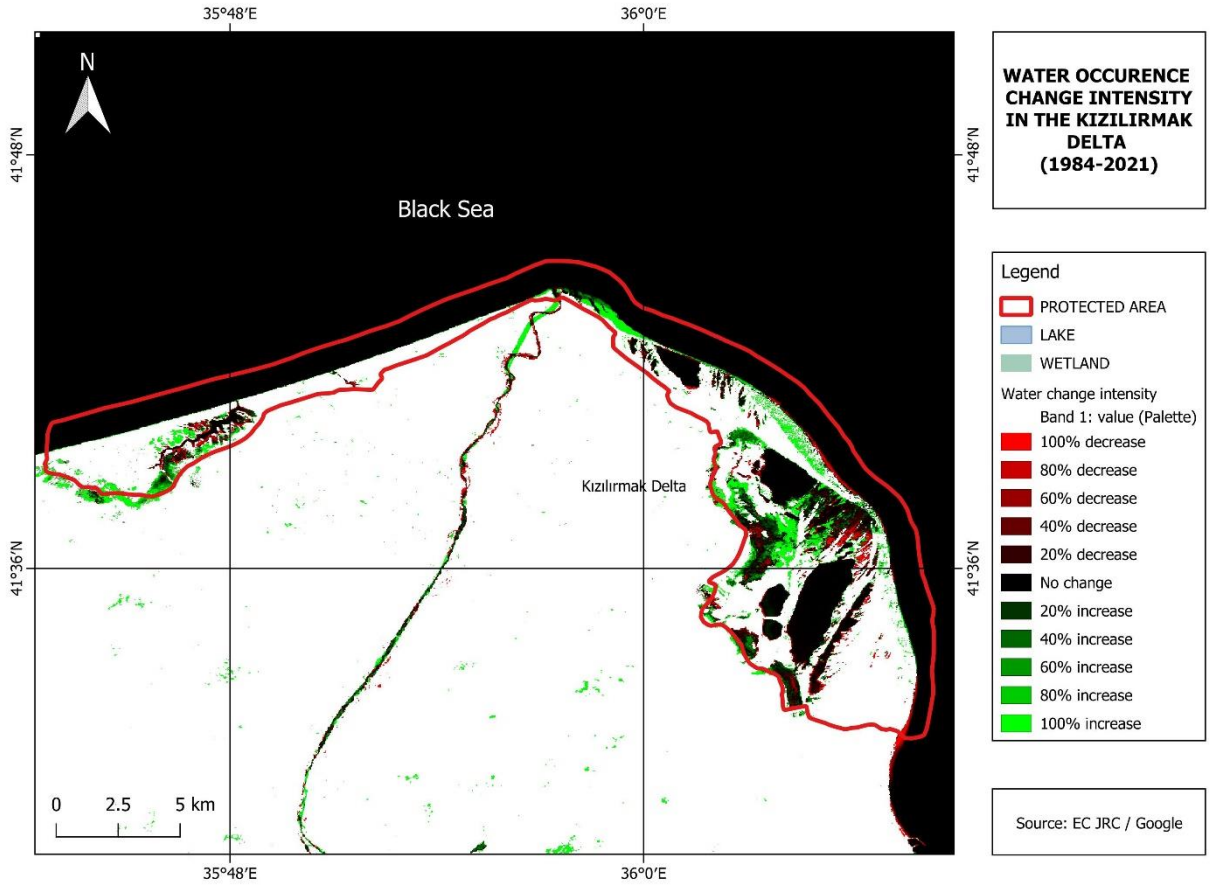

Figure 7. Water occurrences change intensity in the Kızılırmak Delta

The maximum extent of detected water in the Kızılırmak Delta during the period of thirty-seven years (1984-2021) period is shown in Figure 6. Wetlands are areas of seasonal as well as permanent inundation throughout the year. Based on this observation, the shallow lake areas and wetlands are interconnected in maximum extent water. Changes in the condition of water occurrence allow the expansion and narrowing of the distribution of aquatic species in the Kızılırmak Delta, with no exception for aquatic alien species. Changes in aquatic habitats potentially affect the aquatic species community in the Kızılırmak Delta. In the context of aquatic Invasive Alien Species (IAS), isolation or control of aquatic habitats cannot be carried out at one point or lake. The system should be managed as a whole or a single lake system. The expansion and retraction of wetland areas replenish water and provide rich organic matters to the wetland community. However, has the potential to expand the aquatic Invasive Alien Species (IAS) habitat in the ecosystem.

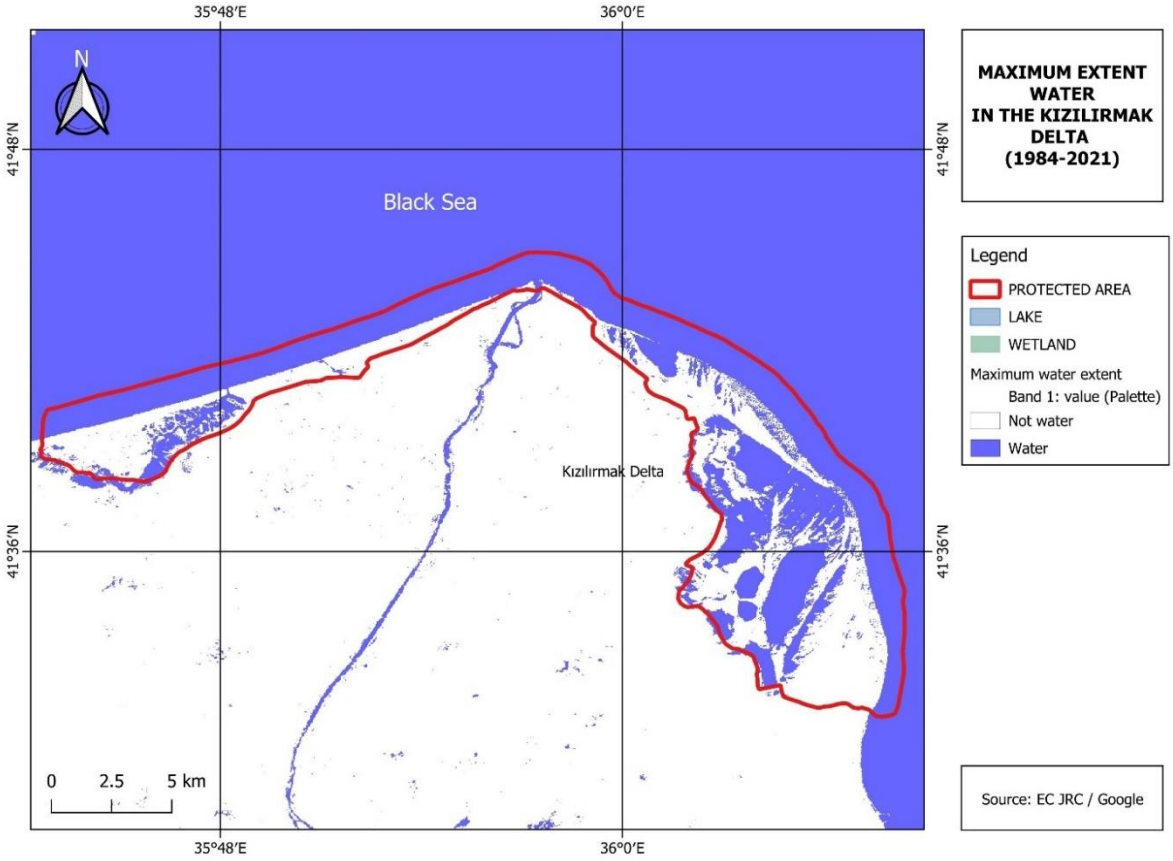

Figure 6. Maximum water extent in the Kızılırmak Delta (1984-2021)

Moreover, climate change accelerated the spread of many alien species and offered new opportunities and zones of invasion to these species. Climate change also reduces the resistance of habitats to biological invasion: pressure due to climate change and the extinction of native species create a new opportunity for invasive species to displace native species. Severe climate events such as hurricanes, floods and droughts caused by climate change led to the relocation of Invasive Alien Species (IAS) to a new habitat and reduced habitat resistance (Gentili et al., 2021).

4 CONCLUSIONS

The Kızılırmak Delta is known as the only and the largest Ramsar Protected Area on the Black Sea coast of Turkiye. It provides a sanctuary for feeding, breeding, and nursing the aquatic and terrestrial species. Moreover, the ecosystem provides a wide range of economic benefits from agriculture and livestock to fishery grounds. Despite their ecological and economic importance, anthropogenic activities in deltaic areas cause the loss of wetland areas. Accordingly, efforts for the protection and conservation of wetlands which are important habitats for terrestrial and aquatic species need to be properly carried out. Based on the observation results, the occurrence of water in the Kızılırmak Delta both seasonally (2021) and annually varies over thirty-seven years from 1984 to 2021. The seven shallow lakes remain inundated throughout the year while wetlands areas experienced a reduction in water occurrence. The change in water occurrence has the potential to affect the aquatic species that inhabit it. Water bodies that are connected to each other under certain conditions allow aquatic species including Invasive Alien Species (IAS) to disseminate across the system. Therefore, isolation and control of aquatic IAS need to be done by considering the system as a single unit of system. Moreover, climate change exacerbates ecological degradation in this area, leading to ecological and socio-economic loss.

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