www.biodicon.com Biological Diversity and Conservation

ISSN 1308-8084 Online ISSN 1308-5301 Print

Research article
DOI: 10.46309/biodicon.2024.1548060
18/1 (2025) 31-40

Analysis of landscape structure changes in Marmara Lake and its surrounding area using remote sensing data

Kübra GÜNBEY[1], Harun BÖCÜK [*1]
ORCID: 0000-0003-1589-9699; 0000-0002-4480-5295

[1] Eskişehir Technical University, Faculty of Science, Departmant of Biology, 26470, Eskişehir, Türkiye

Abstract

This study investigates temporal changes in the landscape structure of Lake Marmara (Gölmarmara, Manisa, Türkiye), a designated bird sanctuary and registered wetland, over 10 years period using remote sensing techniques. The analysis employed the Normalized Difference Vegetation Index (NDVI) on satellite imagery from 2015 and 2024, processed through the ArcGIS/ArcMap software, to assess landscape metrics within the study area. The Normalized Difference Water Index (NDWI) was also utilized to evaluate the interactions between the water body, wetlands, and their surroundings. The findings were further supported by surface temperature analysis (STA) and comparative data. NDVI analysis revealed a 39.38% reduction in the Lake Marmara water body, an 11.09% decrease in forested areas, and an 8.28% decline in tree/shrub areas over 10 years. The dominant tree species in the forest vegetation was *Pinus brutia*, while other prevalent species included *Quercus coccifera, Cistus creticus, Pistacia terebinthus, Pistacia lentiscus, Arbutus andrachne, Arbutus unedo, Olea europaea, Erica arborea, Phillyrea latifolia*, and *Sarcopoterium spinosum*. Conversely, residential areas expanded by 21.21%, and agricultural areas increased by 4.11%. NDWI analysis indicated a 14.46% reduction in moderately dry areas and a 41.92% increase in dry areas. Furthermore, surface temperature data showed an increase over the 10 years. This study is expected to contribute significantly to the field by providing insights into sustainable land use and planning strategies. It offers a comprehensive perspective on wetland management and conservation of biological diversity by elucidating the temporal and spatial relationships between wetlands and their environment, considering both ecological and anthropogenic factors.

Keywords: ecology, remote sensing, landscape character analysis, NDVI, NDWI.

---------- * ----------

Marmara gölü ve yakın çevresinin peyzaj karakterinde meydana gelen değişimin uzaktan algılama verileri kullanılarak araştırılması

Özet

Bu çalışmada, kuş cenneti ve tescilli bir sulak alan olan Marmara Gölü (Gölmarmara, Manisa, Türkiye) ve yakın çevresinin peyzaj karakterindeki değişimler, zamansal olarak 10 yıllık süreçte uzaktan algılama yöntemleri aracılığıyla incelenmiştir. Bu kapsamda 2015 ve 2024 yıllarına ait uydu görüntüleri üzerinde ArcGIS/Arcmap programı aracılığıyla bitki örtüsü tabanlı analizler (NDVI) yapılarak çalışma alanının peyzaj metrikleri incelenmiştir. Çalışma alanı ayrıca su kütlesi ve sulak alanların çevresiyle olan ilişkisi üzerinden normalize fark su indeksi analizi ile (NDWI) değerlendirilmiştir. Sonuçlar yüzey sıcaklık analizi (YSA) verileriyle desteklenerek karşılaştırılmıştır. NDVI analiz sonuçlarına göre, 10 yıllık süreçte Marmara Gölü su kütlesinin 39.38%, ormanlık alanlarının 11.09% ve ağaç/çalı alanlarının ise 8.28% oranında azaldığı tespit edilmiştir. *Pinus brutia* orman vejetasyonunun baskın bitkisidir. *Ouercus coccifera*, *Cistus creticus*, *Pistacia terebinthus*, *Pistacia lentiscus*, *Arbutus andrachne*, *Arbutus unedo*, *Olea europaea*, *Erica arborea*, *Phillyrea latifolia*, *Sarcopoterium spinosum* ise alanda sık rastlanan diğer türlerdir. Buna karşın yerleşim alanlarının 21.21%, tarımsal alanların ise 4.11% oranında arttığı belirlenmiştir. NDWI analiz sonuçlarına göre ise, orta derecede kurak alanların 14.46% azalmasına karşılık, kurak alanların 41,92% oranında arttığı görülmüştür. Ayrıca 10

[*] *Corresponding author* : Tel.: +902222137889; Fax.: +902223204910; E-mail: hbocuk@eskisehir.edu.tr

Received: 10.09.2024 Published: 15.04.2025 BioDiCon. 1167-100924

yıllık süreçte yüzey sıcaklığının da arttığı belirlenmiştir. Sulak alanların çevresiyle olan ilişkisini ekolojik ve antropojenik etmenler dahilinde zamansal ve mekansal boyutta ortaya koyması nedeniyle, bu çalışmanın sulak alan yönetiminde bütüncül bir bakış açısı ile birlikte alan kullanım/planlama ve biyolojik çeşitliliğin korunması stratejilerinde sürdürülebilir eylemlerin oluşturulması açısından alana katkı sağlayacağı düşünülmektedir.

Anahtar kelimeler: ekoloji, uzaktan algılama, peyzaj karakter analizi, NDVI, NDWI.

1. Introduction

The factors that define landscape character are identifiable and comprehensible, whether positive or negative, about the landscape structure. These factors emerge from ecological and anthropogenic influences within landscape metrics and vary according to the balance between land cover and land use [1]. Detecting land cover changes, such as spatial degradation, fragmentation, and reformation caused by ecological and anthropogenic factors, and understanding their impacts in terms of cause-effect relationships, are crucial for developing and planning new land-use strategies [2].

Changes in land cover can be detected through temporal and spatial change analyses using remote sensing methods, which is one of the key approaches for identifying deteriorations in landscape metrics [3]. Spatial analyses of green areas can be performed both temporally and spatially using two-dimensional data derived from multi-spectral satellite images, allowing the examination of the heterogeneous structure of vegetation (Normalized Difference Vegetation Index - NDVI) [4]. Numerous studies in the literature focus on detecting changes in landscape metrics through time-series analyses and multi-structural change detection approaches based on remote sensing systems [5]. Such studies also facilitate the detection and modeling of land degradation, regeneration areas, and changes in photosynthetically active vegetation [6]. Furthermore, remote sensing applications play a critical role in the development of land use planning and management policies due to their capacity to support various applications, such as spatial planning, land management, and the processing of data layers [7].

Wetlands and their interaction with the surrounding environment are critical components of the landscape due to their role in sustaining ecosystems [8]. Water plays a central role in shaping entire ecosystems, influencing life sustainability, vegetation, biodiversity, land cover classifications, and land use. Therefore, it is essential to examine the condition of wetlands and their environmental interactions [9]. Remote sensing methods, such as the Normalized Difference Water Index (NDWI), allow for the assessment of temporal and spatial changes in wetlands, providing valuable data that can serve as a reference for wetland management [10].

Marmara Lake (Gölmarmara, Manisa, Türkiye) is an alluvial barrier lake covering approximately 6,000 hectares. It is fed by groundwater sources, the Gördes Stream, and various feeding channels. The lake hosts 144 species of water birds and is listed as a Wetland of International Importance. Additionally, it is recognized as a nationally significant wetland and a registered bird sanctuary. However, due to significant water loss in recent years, the lake is at risk of extinction, having reportedly dried up completely in August 2021 [11]. Given its national and international significance, Marmara Lake and its surrounding area were chosen as the study site. The objective was to assess the temporal and spatial changes in the landscape metrics of Marmara Lake and its immediate surroundings over 10 years period using remote sensing methods.

2. Materials and methods

2.1. Research area

The study area encompasses Marmara Lake and its immediate surroundings in the Manisa province of Türkiye (Figure 1). The total area covers approximately 67,873 hectares.

2.2. Materials

Landsat 8 satellite images were utilized for this study, sourced from the official website of the United States Geological Survey (USGS). The images selected were from June 2015 and June 2024, spanning 10 years. To ensure high image quality, efforts were made to select images with minimal cloud cover and temporal proximity. Specifically, data from June 18, 2015, with a cloud cover of 3.76%, and June 16, 2024, with a cloud cover of 0.01%, were chosen for analysis. The analyses were conducted using the relevant satellite bands from these images.

Figure 1. Satellite image of the study area

2.3. Methods

The procedures conducted within the study are outlined in the workflow plan (Figure 2). Initially, satellite data was acquired (https://earthexplorer.usgs.gov/). In the second phase, analyses were performed using the ArcGIS/ArcMap software. These analyses included NDVI, NDWI, and surface temperature analysis (STA). The analysis results were classified based on reflectance values, followed by spatial calculations of the classified data. Finally, the obtained results were compared.

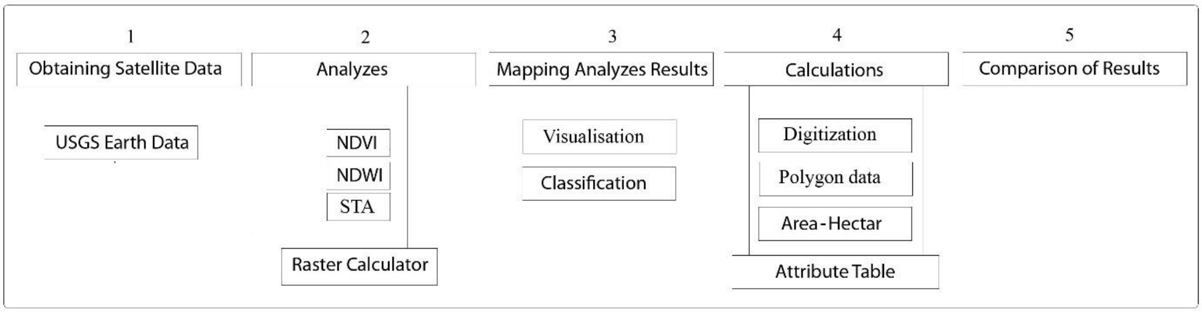

Figure 2. Workflow plan

2.3.1. NDVI (Normalized Difference Vegetation Index) Analysis

NDVI analysis was conducted on satellite data from 2015 to 2024 to assess vegetation density in the study area. The analysis was performed using the ArcGIS software, applying the formula provided below. The red and near-infrared bands from Landsat 8 satellite data were used for the study area. The resulting images were classified based on their reflectance values. This classification divided the area into five categories: forest areas, tree/shrub areas, agricultural lands, residential areas, and water bodies, which were then visualized accordingly.

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

2.3.2. NDWI (Normalized Difference Water Index) Analysis

NDWI analysis was conducted on all images to identify the spatial distribution of water within the study area. For this analysis, Band 3 and Band 5 data from Landsat 8 satellite images were utilized. The analysis was performed using the ArcGIS software, following the formula provided below. The resulting data were classified based on their reflectance values. This classification categorized the area into four groups: dry areas, moderately dry areas, humid areas, and water bodies, which were subsequently visualized.

$$NDWI = \frac{(Band\ 3 - Band\ 5)}{(Band\ 3 + Band\ 5)}$$

2.3.3. Surface temperature (ST) analysis

Surface temperature analysis was conducted on all satellite data to determine the surface temperature of the study area. The relevant bands from the satellite data were used for thermal analysis. The analysis was carried out using the ArcGIS software, following the formula provided below. The results were classified based on reflectance values and visualized by dividing the data into four categories.

$$Tb = \frac{K2}{\ln(\frac{K1}{L\lambda}+1)} - 273.15$$

$$Pv = (\frac{NDVI - NDVImin}{NDVImax - NDVImin})^2$$

$$\varepsilon TM6 = 0.986 + 0.004\,P\,v$$

$$Ts = \frac{Tb}{1+(\lambda \times \frac{Tb}{\frac{h \times c}{b}}) \times ln\varepsilon\lambda}$$

(*Tb: Thermal band, Pv: Proportion of vegetation,* **ε: Emissivity, Ts: Surface temperature)**

3. Results

3.1. NDVI (Normalized Difference Vegetation Index) Analysis

The results of the NDVI analysis are shown in Figure 3 and the corresponding area calculations are shown in Table 1. In June 2015, the forest area was 6,448.89 ha, while by June 2024 it had decreased to 5,733.56 ha, representing a decrease of 11.09% over the 10 years. Areas with tree and shrub vegetation were recorded at 16,912.54 hectares in June 2015, decreasing to 15,511.56 hectares by June 2024, reflecting an 8.28% reduction over the same period. Agricultural areas increased from 19,961.04 hectares in June 2015 to 20,780.62 hectares in June 2024, showing a 4.11% increase. Residential areas expanded from 16,709.03 hectares in June 2015 to 20,252.67 hectares in June 2024, resulting in a 21.21% increase over the 10 years. Meanwhile, water bodies, which covered 5,706.3 hectares in June 2015, had decreased to 3,459.22 hectares by June 2024, marking a 39.38% decline over the 10 years.

In the research area, *Pinus brutia* is the predominant tree species within the forest vegetation. Other common species in the region include *Quercus coccifera*, *Cistus creticus*, *Pistacia terebinthus*, *Pistacia lentiscus*, *Arbutus andrachne*, *Arbutus unedo*, *Olea europaea*, *Erica arborea*, *Phillyrea latifolia*, and *Sarcopoterium spinosum*. Aquatic plants such as *Phragmites australis*, *Potamogeton natans*, *Potamogeton perfoliatus, Potamogeton nodosus*, *Potamogeton pectinatus*, *Myriophyllum spicatum*, and *Ranunculus* spp. are also present. The herbaceous vegetation predominantly includes species characteristic of maquis and garrigue ecosystems [3].

Landscape character analysis is a method for promoting sustainable land use by detecting, monitoring, and quantifying changes in biodiversity and landscape metrics [12]. NDVI analysis, a crucial technique in remote sensing for monitoring vegetation changes, provides insights into variations in landscape metrics, including the number, size, shape, and distribution of vegetation patches in ecosystems [13, 14]. This study examines changes in landscape metrics, such as forest areas, tree and shrub areas, agricultural lands, residential areas, and water bodies, alongside spatial, areal, and dimensional changes in landscape patches. According to area calculations for June over the past 10 years, there has been a reduction in forest and tree/shrub areas, as well as a decrease in water bodies. These reductions are primarily attributed to anthropogenic factors, and climate change, including rising temperatures, irregular precipitation patterns, and decreased precipitation levels [15]. Conversely, residential and agricultural areas have increased, largely due to the expansion of living spaces to accommodate population growth and anthropogenic influences, including the expansion of agricultural land [16]. While the increase in agricultural areas is not directly linked to heightened agricultural activities within the context of anthropogenic factors, it is hypothesized that agricultural activities may have decreased in the previous 10 years due to reduced water bodies. However, between 2015 and 2024, agricultural activities are thought to have risen due to population growth and the expansion of new agricultural areas. The 2024 data also suggests that fallow and uncultivated lands, which have seen reduced agricultural activity, may have been reclassified as agricultural areas, reflecting an overall increase in agricultural land over 10 years.

To obtain the analysis results, land cover classification was performed based on reflectance values. Examination of the analysis images reveals confusion in area classification based on these reflectance values, manifesting as displacement and spatial changes in landscape metrics. For instance, Figure 3 illustrates that the water body appears to be concentrated in areas outside of Marmara Lake. This indicates that the reflection values used for area classification may correspond to the same reflectance values as those representing the water body. Consequently, this visual evidence suggests an anticipated increase in the water mass. However, the area calculations indicate that the water body in Marmara

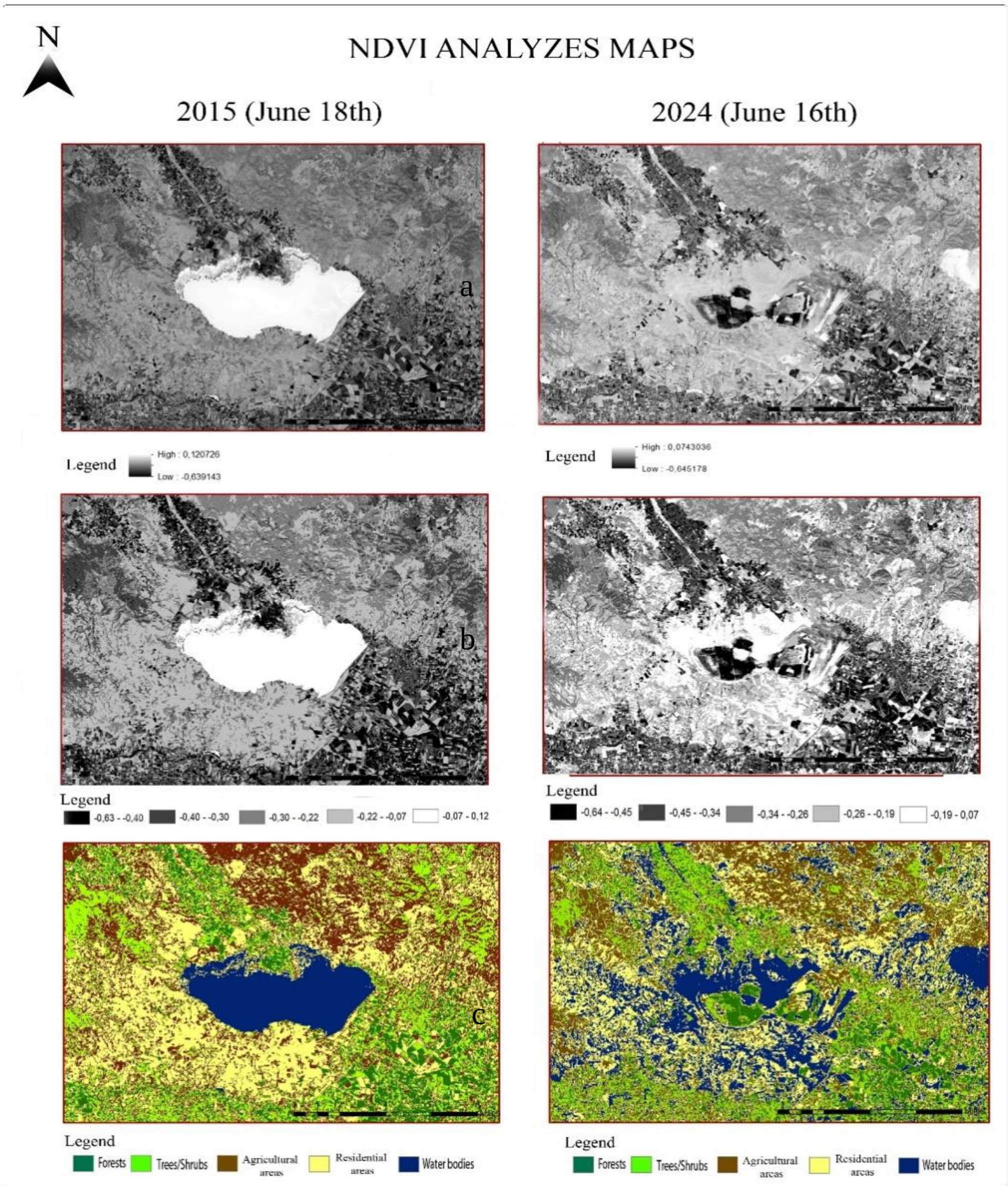

Figure 3. Results of normalized difference vegetation index (NDVI) analyses
(a. Maximum/minimum levels of reflection values, b. Classification of reflection values,
c. Classification of vegetation and water bodies)

Table 1. Numerical values of vegetation and water bodies in the research area

Categories	2015 (June, 18th)	2024 (June, 16th)	Change (%)
Forest Areas	6.448,89	5.733,56	-11.09
Tree/Shrubs	16.912,54	15.511,56	-8.28
Agricultural areas	19.961,04	20.780,62	4.11
Residential areas	16.709,03	20.252,67	21.21
Water bodies	5.706,13	3.459,22	-39,38

Lake has actually decreased in size, implying that the reflection values may lead to discrepancies in the representation of landscape metrics [20].

3.2. NDWI (Normalized Difference Water Index) Analysis

The analysis results are presented in Figure 4, with area calculations detailed in Table 2. As of June 2015, dry areas covered 10,214.16 hectares, increasing to 14,495.64 hectares by June 2024, reflecting a 41.92% increase. Moderately dry areas, which covered 20,785.78 hectares in June 2015, decreased to 17,779.55 hectares by June 2024, showing a reduction of 14.46%. Humid areas increased from 29,031.56 hectares in June 2015 to 30,003.22 hectares in June 2024, representing a 3.35% increase. Conversely, the water body, which covered 5,706.13 hectares in June 2015, decreased to 3,459.22 hectares by June 2024, indicating a 39.38% reduction in the area occupied by water bodies.

NDWI (Normalized Difference Water Index) analysis enables the examination of the natural water balance in landscape character and the temporal and spatial changes in wetlands, which are represented as water bodies in land cover classifications. Understanding the relationship between wetlands and their environment, as well as their role in the landscape structure, is crucial [8]. This study's NDWI analysis reveals a significant reduction in the water body of Lake Marmara and its surroundings over the past 10 years. Such a substantial loss of water is expected to have a negative impact on the ecosystem.

In this study, the focus was on calculating the areal extent of water bodies rather than their volumetric quantity. It is anticipated that a reduction in the areal size of water bodies will correspond with a decrease in their volumetric amount. The observed areal loss in water bodies is attributed to rising temperatures due to climate change, alterations in precipitation patterns, and reductions in precipitation levels. However, it is noted that the shoreline has shifted, with the water mass and surrounding land expanding towards the water. Changes in water surfaces manifest in two ways: complete disappearance or drying of water bodies in shallow lakes due to global warming and its effects, and coastal retreat at varying rates in deeper lakes. It is believed that coastal retreat has occurred in Marmara Lake, which reportedly dried up completely in August 2021 [11]. NDVI analysis further suggests that the reduction in water bodies may also be linked to anthropogenic activities, such as the expansion of agricultural and residential areas.

In the study area, while there is a modest increase in humid areas (3.35%), the increase in dry areas is considerably larger (41.92%). This observation is consistent with the substantial water loss recorded. Additionally, examination of the analysis images reveals that landscape patches representing various metrics have changed in spatial distribution, form, and density over the 10 years. These changes are likely attributable to the rising temperatures observed in June 2024 [18].

3.3. Surface temperature (ST) analysis

Analysis visuals are given in Figure 5 and numerical results are given in Table 3. Accordingly, in June 2015, the temperature in an area of 7,883.16 hectares was between 22.56 - 26.72 °C, in an area of 17,396.35 hectares was between 26.72 - 31.25 °C, in an area of 25,639.34 hectares was 31.25 - 34 °C and in an area of 16,954.87 hectares was between 34.29 - 41.50 °C. According to the weighted average result made by taking into account the temperature spectrum and areas, the average temperature of June 2024 was determined as 36.88 °C while it was 32.14 °C in June 2015. In this case, it is seen that the average temperature of the area increased by 14.76% in 10 years.

The analysis visuals are presented in Figure 5, and the numerical results are provided in Table 4. In June 2015, temperatures were recorded as follows: 7,883.16 hectares had temperatures ranging from 22.56 °C to 26.72 °C; 17,396.35 hectares ranged from 26.72 °C to 31.25 °C; 25,639.34 hectares ranged from 31.25 °C to 34 °C; and 16,954.87 hectares ranged from 34.29 °C to 41.50 °C. The weighted average temperature for June 2015 was 32.14°C, while for June 2024 it was 36.88 °C, calculated based on the temperature ranges and corresponding areas. This represents a 14.76% increase in the average temperature over the 10-year period.

The observed increase in average temperature is thought to have contributed to the reduction in water bodies and the expansion of dry areas in the region. It is suggested that temperature alone may not be the sole factor responsible for the decrease in water mass; anthropogenic factors also play a significant role [18]. Spatial changes, as reflected in satellite images, can lead to confusion in landscape metrics [19]. However, these changes do not affect land use classification since areas with the same reflectance value are represented collectively [20]. Consequently, landscape patches may exhibit variations in shape and size [21], which is attributed to differences in reflectance values across distinct areas [17]. The diversity in landscape structure is linked to ecological corridors [22]. Structurally, a corridor is a landscape element that differs qualitatively from adjacent areas [23]. To address deteriorations in landscape character, the creation of ecological corridors is recommended [24]. This study suggests adopting sustainable ecosystem-based approaches to address existing issues related to the degradation of Marmara Lake's landscape structure and to manage area losses in the future. Such approaches may include green infrastructure or blue-green infrastructure initiatives, rainwater management, climate adaptation, mitigation of heat island effects, sustainable energy production, and provision of clean water [25].

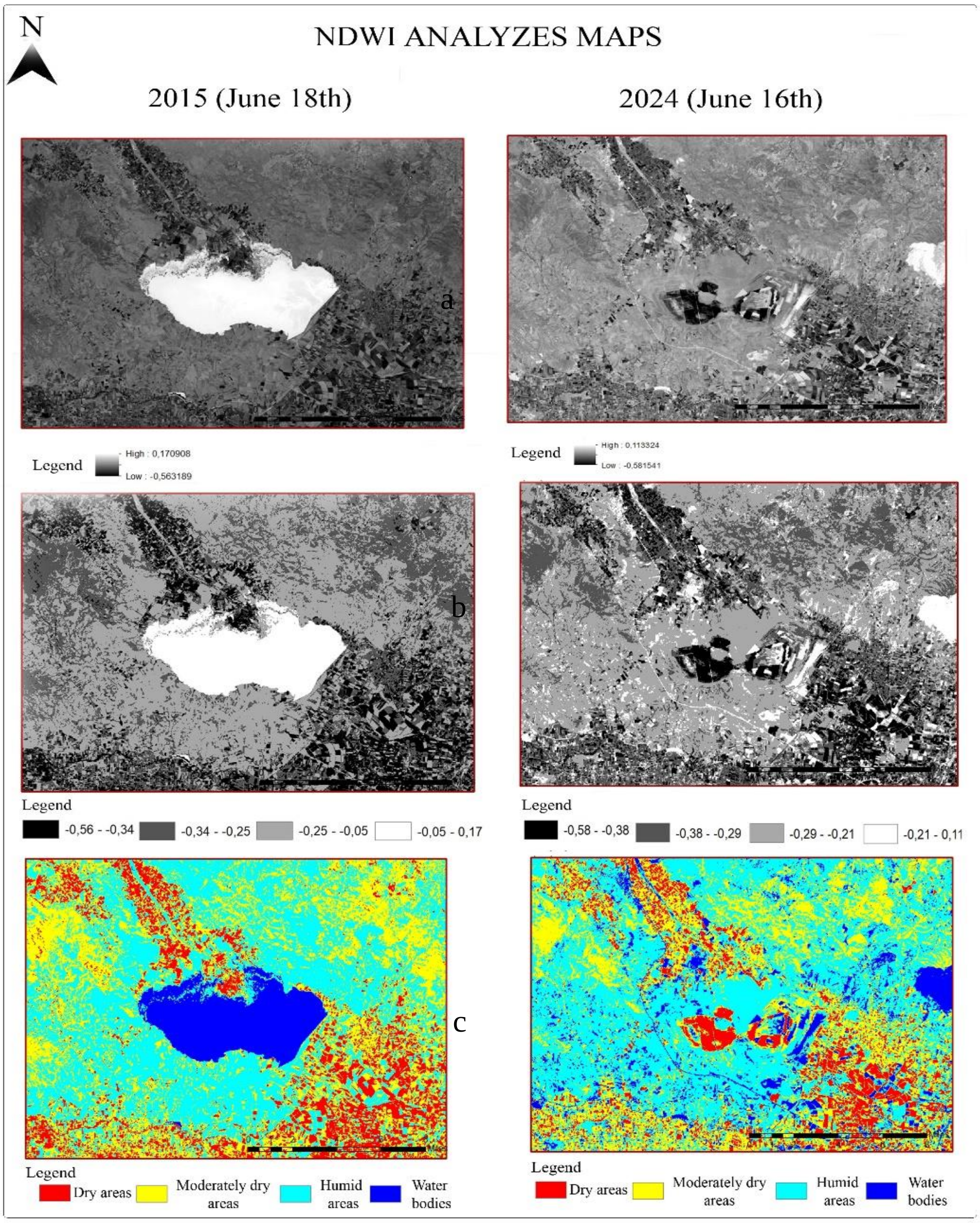

Figure 4. Results of normalized difference water index (NDWI) analysis
(a. Maximum/minimum levels of reflection values, b.Classification of reflection values, c.Classification of areas according to water content)

Table 2. Numerical values of areas according to water content

Categories	2015 (June 18th)	2024 (June 16th)	Change (%)
Dry areas	10.214,16	14.495,64	41,92
Moderately dry areas	20.785,78	17.779,55	-14,46
Humid areas	29.031,56	30.003,22	3,35
Water bodies	5.706,13	3.459,22	-39,38

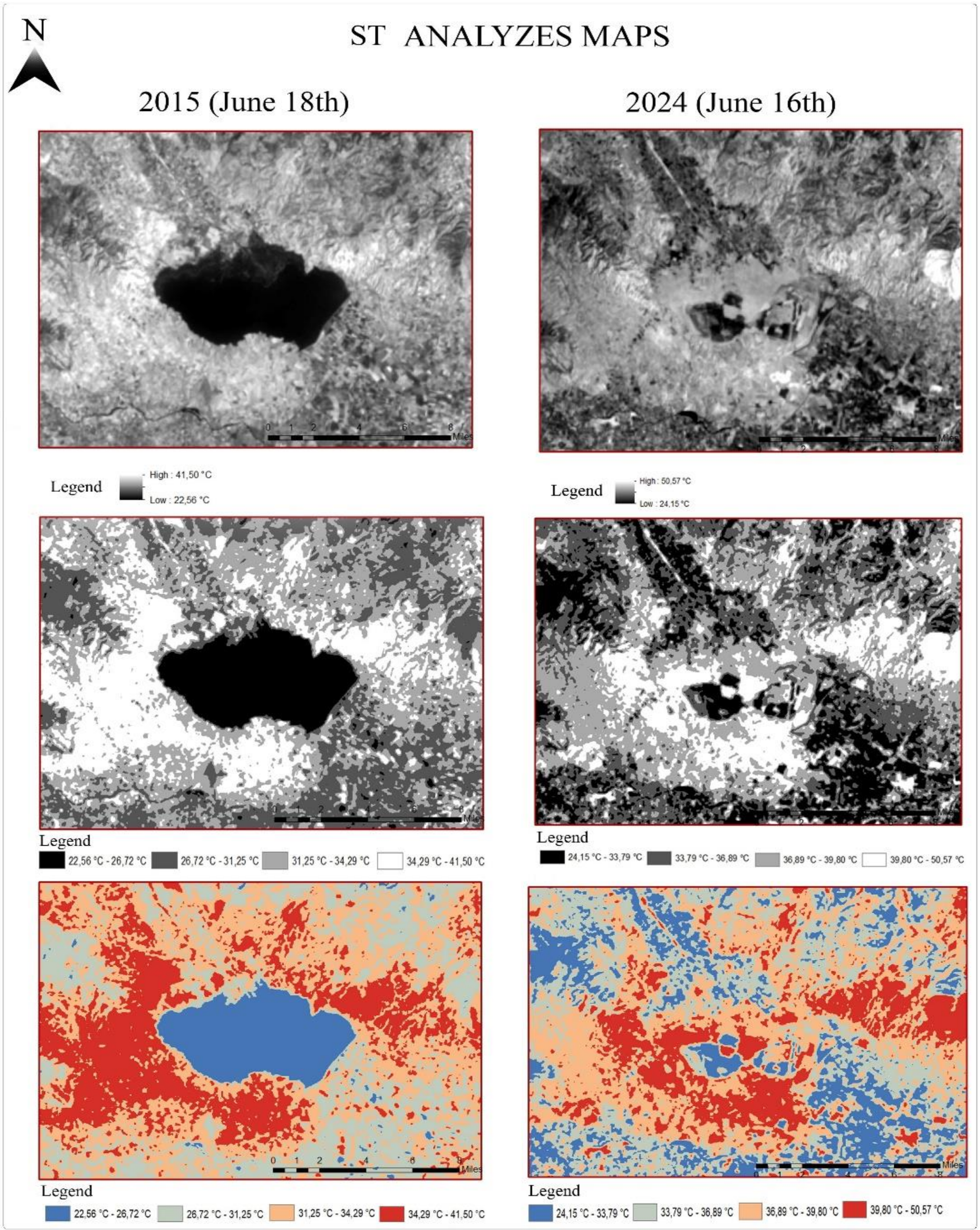

Figure 5. Results of surface temperature (ST) analysis
(a.Maximum/minimum levels of reflection values, b.Classification of reflection values, c.Classification of areas according to surface temperature)

Table 3. Numerical values of surface temperature analysis of the research area

2015 (June 18th)		2024 (June 16th)	
Temperature Spectrum (^{0}C)	**Area (ha)**	**Temperature Spectrum (^{0}C)**	**Area (ha)**
22,56 --- 26,72	7.883,16	24,15 --- 33,79	12.640,95
26,72--- 31,25	17.396,35	33,79--- 36,89	20.471,28
31,25---34,29	25.639,34	36,89--- 39,80	22.980,99
34,29--- 41,50	16.954,87	39,80--- 50,57	11.780,49

Over the 10-year period, changes in land cover have been influenced by anthropogenic factors, resulting in deterioration of landscape metrics, fragmentation, and changes in the extent and density as well as temperature values of the area. Analyses of the water body status, as indicated by NDWI, reveal a decrease in the area covered by water bodies in Marmara Lake, suggesting a potential for water scarcity in the near future. Consequently, it is crucial to re-evaluate and adjust wetland management policies and land use regulations to address these emerging challenges.

4. Conclusions and discussion

This study aimed to elucidate the changes in landscape character and metrics of Marmara Lake and its surrounding areas, along with their underlying causes. The investigation involved analyzing land cover changes in Marmara Lake and its vicinity through vegetation and wetland analyses (NDVI and NDWI), with the findings supplemented by climatic factors (surface temperature analysis). Notably, over the 10 years from 2015 to 2024, there has been a significant reduction in forest and tree/shrub areas, alongside an increase in agricultural and residential areas. Additionally, the substantial rise in dry areas, in response to a severe decrease in water bodies, represents a concerning trend for Marmara Lake and its surroundings. We believe that the insights gained from this study will contribute to the field, assist decision-makers, and inform the development of effective conservation policies for both biological diversity and nature.

References

[1] Karaali, İ., Tanyaloğlu, E.E., Atak, B.K., Nurlu, E. (2020). Alan kullanım/arazi örtüsü değişiminin mekansal ve zamansal analizi, İzmir, Türkiye örneği. *International Journal of Eastern Anatolia Science Engineering and Design*, 2 (2), 308–324.

[2] Crespo, A, Velázquez, J, Herráez, F., Gülçin, D., Özcan, A.U., Hernando, A., Castanho, R.A. (2023). Territorial planning of rustic land constructions and their adaptation to climate change in the province of Malaga Spain. *Land Use Policy*, 129, 106644, https://doi.org/10.1016/j.landusepol.2023.106644.

[3] ülersoy, A.E. (2013). Marmara gölü yakın çevresindeki arazi kullanım faaliyetlerinin zamansal değişimi (1975-2011) ve göl ekosistemine etkileri. *Türk Coğrafya Dergisi*, 61, 31-44.

[4] Kasimati, A., Psiroukis, V., Darra, N., Kalogrias, A., Kalivas, D., Taylor, J.A., Fountas, S. (2023). Investigation of the similarities between NDVI maps from different proximal and remote sensing platforms in explaining vineyard variability. *Precision Agriculture*, 24, 1220–1240.

[5] Şimşek, F.F, Durduran, S.S. (2023). Land cover classification using land parcel identification system (lpıs) data and open source eo learn library. *Geocarto International*, 38(1), 1–18.

[6] Eckert, S. (2015). Trend analysis of MODIS NDVI time series for detecting land degradation and regeneration in Mongolia. *Journal of Arid Environments*, 113, 16–28.

[7] Sruthi, S., Mohammed Aslam, M.A. (2015). Agricultural drought analysis using the NDVI and land surface temparature data: a case study of Raichur district. *Aquatic Procedia*, 4, 1258–1264.

[8] Tonyaloğlu, E.E., Atak, B.K., Yılmaz, T. (2020). Korunan alanlarda bütüncül yönetim: Büyük Menderes deltası ve bağlantılı sulak alan sistemi örneği. *Turkish Journal of Forest Science*, 4 (2), 282–301.

[9] Kahraman, E., Kaya, L.G. (2022). Yapay Sulak Alan Uygulamalarında Alan Seçim Kriterlerine Farklı Bir Yaklaşım: Antalya Çandır Çayı ve Yakın Çevresi Örneği. *Düzce Üniversitesi Orman Fakültesi Ormancılık Derg*isi, 18 (1), 88–103.

[10] Aksoy, T, Sarı, S., Çabuk, A. (2019). Sulak alanların yönetimi kapsamında su indeksinin uzaktan algılama ile tespiti, Göller Yöresi. *GSI Journal Serie B: Advancements in Bussiness and Economics*, 1(2), 35–48.

[11] Körbalta, H. (2019). Marmara gölü neden kuruyor? *Kent Akademisi*, 12 (39), 441 – 459.

[12] Zhuang, Q.D., Hussein, M.K., Ariffin, N.F.M., Yunos, M.Y.M. (2022). Landscape character: a knowledge mapping analysis using CiteSpace, *International Journal of Environmental Science and Technology*, 19, 10477–10492.

[13] Lemenkova, P., Debeir O.R. (2022). Libraries for remote sensing data classification by k-means clustering and NDVI computation in Congo River basin, DRC. *Applied Science*, 12 (24), 12554, https://doi.org/10.1016/j.geosus.2023.09.002.

[14] Huang, S., Tang, L., Hupy, J.P., Shao, G. (2020). A commentary review on the use of normalized difference vegetatıon index (NDVI) in the era of popular remote sensing. *Journal of Foestry Research*, 32, 1–6.

[15] Özdemir, S., Özkan, K., Mert, A. (2020). An ecological perspective on climate change scenarios. *Biological Diversity and Conservation*, 13 (3), 361–371.

[16] Tokgöz, G., Güngör, O. (2023). Amanos Dağları'nın sağladığı ekosistem hizmetlerinin DSPIR çerçevesi ile incelenmesi. *Türkiye Peyzaj Araştırmaları Dergisi*, 6 (2), 120–136.

[17] Gülçin, D. (2018). Arazi kullanımlarının sınıflandırılmasında piksel ve obje tabanlı sınıflandırmanın karşılaştırılması. *Adnan Menderes Üniversitesi Ziraat Fakültesi Dergisi*, 15 (2), 43–49.

[18] Atak, B.K, Tonyaloğlu, E.E. (2020). Alan kullanım/arazi örtüsü ve bitki örtüsündeki değişimin arazi yüzey sıcaklığına etkisinin değerlendirilmesi: Aydın ili örneği. *Türkiye Ormancılık Dergisi*, 21 (4), 489–497.

[19] Şensoy, S., Shahin, L., Yılmaz, E., Türkoğlu, N., Çiçek, İ., Darende, V., Yazıcı, B. (2017). Antalya yüzey ısı adası özelliklerinin uydu verileri ile analizi. *Meterolojik Uzaktan Algılama Sempozyumu*, 16-19 Ekim 2017, Antalya.

[20] Rincon, V., Velázquez, J., Gülçin, D., López-Sánchez, A., Jiménez, C., Özcan, A.U., López-Almansa, J.C., Santamaria, T., Sánchez-Mata, D., Çiçek, K. (2023). Mapping priority areas for connectivity of yellow winged darter (*Sympetrum flaveolum* Linnaeus 1758) under climate change. *Land*, 12, 298, https://doi.org/10.3390/land12020298.

[21] Krsnik, G., Reynolds, K.M., Murphy, P., Paplanus, S., Garcia-Gonzalo, J., Olabarria, J.R.G. (2023). Forest use suitability: toward decision–making–oriented–sustainable management of forest ecosystem services. *Geography and Sustainability*, 4(4), 414–427.

[22] Gregory, A., Spence, E., Beier, P., Garding, E. (2021). Toward best management practices for ecological corridors. *Land*, 10 (2), 140, https://doi.org/10.3390/land10020140.

[23] Santos, J.S., Leite, C.C.C., Viana, J.C.C., Santos, A.R., Fernandes, M.M., Abreu, V.S., Nascimento, T.P., Santos, L.S., Fernandes, M.R.M., Silva, G.F., Mendonça, A.R. (2018). Delimitation of ecological corridors in the Brazilian Atlantic forest. *Ecological Indicators*, 88, 414–424.

[24] Popescu O., Tache, A., Petrişor, A. (2022). Methodology for identifying ecological corridors: spatial planning perspective. *Land*, 11 (7), 1013, https://doi.org/10.3390/land11071013.

[25] Parlak, E., Atik, M. (2020). Dünyadan ve ülkemizden mavi–yeşil altyapı uygulamaları, *Peyzaj*, 2 (2), 86–100.