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RESEARCH ARTICLE

A REMOTE SENSING APPROACH OF LAND AND WATER CONTENT CHANGE BETWEEN 2014 AND 2024 TO THE PORSUK DAM AND ITS NEAR SURROUNDINGS

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Abstract

Observing, monitoring, and characterizing land changes in natural ecosystems, affected by many natural and anthropogenic environmental factors, is critical for making effective and sustainable management decisions and for their protection. Today, remote sensing methods, with their many different approaches and techniques, allow for continuous and controlled monitoring of spatial change, especially over large areas, providing cost- and time-effective solutions. This study aimed to determine the changes in the land and water potential of the Porsuk Dam Lake and its surroundings between Eskişehir and Kütahya provinces using remote sensing methods over 10 years. In this context, Landsat satellite data for the years 2014 and 2024 and the days with the least cloudiness were obtained, and normalized difference vegetation index (NDVI) and normalized difference water index (NDWI) calculations were made on these data using the ArcGIS/ArcMap program. Later on, the results, obtained, were compared and the changes in the land and water potential were determined. According to the results of NDVI analysis, the presence of forests (4.78%) and areas with herbaceous vegetation (5.56%) increased in 10 years, while the soil (-2.70%), tree/shrub areas (-1.26%) and water bodies (-5.87%) decreased. According to the results of NDWI analysis, it was determined that dry (2.02%) and moderately dry (10.81%) areas increased, while water bodies (-8.87%) and humid areas (-11.71%) decreased. The results were also supported by surface temperature analysis. Since the results obtained from the study include data on temporal and spatial changes, it is thought that they will contribute to future planning, management, and decision-making processes and studies to be carried out in this field later.

Keywords

Land change,
Ecology,
NDVI,
NDWI,
Time series

Time Scale of Article

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1. INTRODUCTION

The Earth's surface is changing at an unprecedented rate. Anthropogenic impacts have affected more than half of the Earth's land surface [1], while climate change and other disturbances have also affected all land surfaces. Accordingly, changes in land use and land cover are observed on a global scale due to factors such as decrease in biodiversity, soil degradation, decrease in land productivity, soil and water pollution, climate change, urbanization, destruction and reconstruction of agricultural

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areas [2-4]. These changes result in the deterioration, fragmentation, extinction and class change of the landscape character within the ecosystem [5]. To detect these changes, effective surface research techniques have been used depending on the land use and area change, such as geospatial and remote sensing techniques [3, 6-9].

Satellite remote sensing is crucial for investigating global land change, as it allows for synoptic and repetitive measurements at many resolutions (spectral, spatial, and temporal) [10-12]. Remote sensing data has also numerous other applications, such as land cover classification, soil moisture measurement, forest type classification, liquid water content measurement, etc. [8]. The availability of present and historical satellite data, the ability of remote sensing systems to monitor land cover and detect spatial changes along with increasing technology, and the availability of spatial planning, land management, processing of data layers, and ground-based modeling systems make it easier to follow spatial changes [8, 13, 14].

Remotely sensed images do not always directly reflect changes in the land surface. At this point, factors such as image recording, atmospheric conditions, natural soil wetness fluctuations, vegetation phenology, topography illumination, sensor and sun affect the spectral change [4]. To eliminate these changes or keep them at a minimum level, analyses are performed with various band combinations. One of these analyses is the normalized difference vegetation index (NDVI) analysis, developed to simplify multi-spectral imagery, which is presently the most widely used index for used to asses and model vegetation, phenology, and distribution [6, 15-17]. It is also possible to see and classify land cover classification, water bodies, open space, shrub areas, and agricultural and forest areas within the reflectance values of NDVI with vegetation features that cannot be directly detected with remote sensing images. (8, 16). The main purpose of the analysis is to obtain information about vegetation and detect plant health and growth with remotely sensed data [18, 19] and information about temporal and spatial changes depending on various factors such as fire, soil degradation, etc. [20]. There are many studies throughout the World in the literature on vegetation evaluations using NDVI analysis [21- 24].

Another analysis most used in the evaluation of land changes is the normalized difference water index (NDWI) analysis. The temporary absence of vegetation and small amounts of ground cover cause soils to be directly exposed to the effects of precipitation events, and the disappearance of vegetation disrupts the natural water balance of the areas [25]. Thanks to NDWI (normalized difference water index) analysis, which is used to determine the water content in the ecosystem, its spatial changes and boundaries over time, the lands within the research area can be evaluated in various class categories (arid, semi-arid, humid, etc.) [26]. There are many studies in the literature on water content evaluations using NDWI analysis [27-29]. In this respect, the results of the NDVI analysis are supported by the results of the NDWI analysis. Thus, it is possible to examine the spatial change situation in the field classification category by comparing two mutual analysis data.

Porsuk Stream is an important stream that flows through the provinces of Kütahya and Eskişehir and feeds one of the most important rivers in Turkey Sakarya River. Porsuk Dam, located on this river, is a very important dam for the region, especially for the accumulation of drinking and utility water. It also plays an important role in preventing possible floods in the region [30]. In this study, it was aimed to determine how the land structure and water content of Porsuk Dam Lake and its near surroundings changed between 2014 and 2024 (within a 10 years) using remote sensing methods (NDVI and NDWI).

2. MATERIALS AND METHODS

2.1. Study area

The study area covers the Porsuk Dam Lake and its nearby surroundings, one part of which is within the borders of Eskişehir and the other part of Kütahya province (Figure 1). The surveyed area is approximately 93,000 hectares in size.

Figure 1. Satellite image of the research area (https://earthexplorer.usgs.gov/)

2.2. Materials

Within the scope of this study, real Landsat 8 satellite images obtained from the official website of the United States Geological Survey (USGS) were used (https://earthexplorer.usgs.gov/). The relevant satellite bands for the region obtained from these satellites were used in the analyses. The images are from the year 2014, and the year 2024 has been chosen as a representation of 10 years. In addition, to avoid any problems with image analysis, an attempt was made to determine days that were close to each other as the dates when both the images were available and the cloudiness rate was lowest. In this context, the dates of 23 May 2014, when the cloudiness rate was 10.53, and 18 May 2024, when the cloudiness rate was 0.08, were determined and the study was carried out using the data of these days.

2.3. Methods

The work plan followed during the study is shown in Figure 2. Accordingly, satellite data were acquired in the first phase. Satellite data were analyzed using the ArcGIS/ArcMap program after pre-processing. In this context, the NDVI and NDWI analyses were performed together with the Surface Temperature Analysis (STA). Then, the analysis results were classified according to their reflection values and classified images were obtained. The area was then calculated by converting these raster data. Finally, the obtained results were compared.

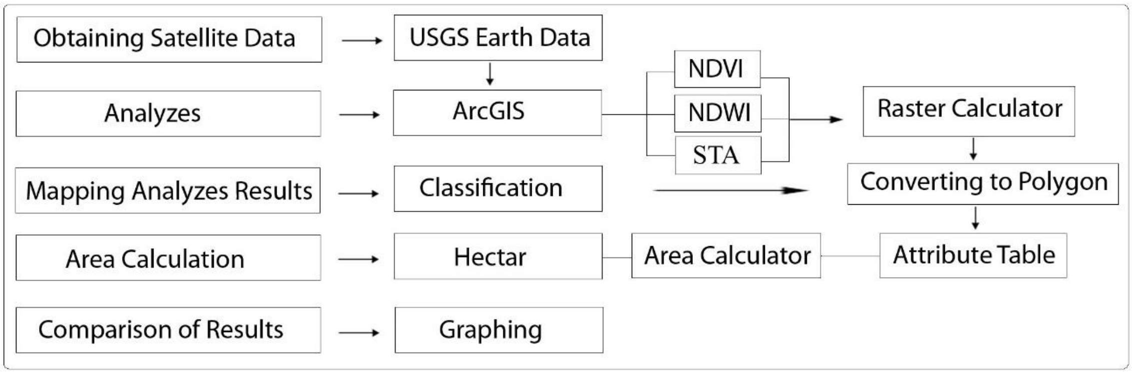

Figure 2. Study work plan

2.3.1 NDVI (Normalized Difference Vegetation Index) Analysis

NDVI analysis was performed on images from 2014 (May 23rd) and 2024 (May 18th) in order to determine and classify the vegetation density in the study area. For this purpose, red and near-infrared bands of the images of the region obtained from the Landsat 8 satellite on the specified dates were used. NDVI analysis was performed based on the formula given below. The calculation data obtained as a result of the analysis were classified into 5 categories as water body, soil area, herbaceous area, tree/shrub and forest areas, based on reflection values, and the obtained results were visualized.

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

2.3.2 NDWI (Normalized Difference Water Index) Analysis

NDWI analysis was performed on images from 2014 (May 23rd) and 2024 (May, 18th) to determine and classify the water situation in the study area. For this purpose, related bands (Band 3 and Band 5) bands of the images of the region obtained from the Landsat 8 satellite on the specified dates were used. NDWI analysis was performed based on the formula given below. The calculated data obtained from the analysis were classified into 4 categories as dry areas, moderately dry areas, humid areas, and water bodies based on reflection values, and the obtained results were visualized.

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

2.3.3. ST (Surface Temperature) Analysis

ST analysis was performed on images from 2014 (May, 23rd) and 2024 (May, 18th) to determine and classify the surface temperature in the study area. For this purpose, the related band (Band 10) of the images of the region obtained from the Landsat 8 satellite on the specified dates were used. SA analysis was performed based on the formula given below (Tb: Thermal band, Pv: Proportion of vegetation, ε: Emissivity, Ts: Surface temperature). The calculated data obtained from the analysis were classified into 4 categories, dry areas, moderately dry areas, humid areas, and water bodies based on reflection values, and visualized.

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

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

$$\varepsilon TM6 = 0.986 + 0.004\, Pv$$

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

3. RESULTS AND DISCUSSION

3.1. NDVI (Normalized Difference Vegetation Index)

Visual results of NDVI analysis are given in Figure 3 and numerical results are given in Table 1. Accordingly, it is seen that the soil areas in the research area covered 30,966.00 ha in 2014 and 30,130.45 ha in 2024. This means that soil areas have decreased by 2.70% in the last 10-years. It is seen that herbaceous vegetation covered an area of 17,202.20 ha in 2014, and this area reached 18,158.13 ha in 2024. It was determined that the areas with herbaceous vegetation increased by 5.56% in the 10 years. It was seen that areas with tree/shrub vegetation covered 34,285.61 ha in 2014 and 33,854.94 ha in 2024. It means that the areas with tree/shrub vegetation decreased by 1.26% in 10 years. It is seen that forest areas covered an area of 9,008.42 hectares in 2014, and this area reached 9,439.09 hectares in 20024. It was seen that the areas with forest vegetation increased by 4.78% in the 10 years. Finally, when the water body is evaluated, it is seen that it covered an area of 2,050.49 hectares in 2014, and by 2024, this figure decreased to 1,930.11 hectares. This means that over the 10 years, the water bodies have decreased by 5.87%.

Vegetation change is a complex process that mirrors the dynamics of terrestrial ecosystems [24, 25]. The normalized difference vegetation index (NDVI) is an important statistic in satellite remote sensing for monitoring vegetation change. Therefore, it has been widely used to track dynamic vegetation changes [24]. For this reason, many studies have been carried out in Turkey and the world focusing on NDVI to determine the changes in vegetation [15, 19, 22-24, 26, 27, 31].

In a healthy terrestrial ecosystem, vegetation tends to develop towards climax vegetation, while in an unhealthy one, there may be regression and losses in terms of vegetation [32]. When our study is evaluated in this context, the fact that the areas with forest vegetation have increased over 10 years suggests that progressive climax processes are effective in the area and that the vegetation in the research area, which is relatively free from anthropogenic effects, is relatively healthy. In the study, it is seen that while forest areas increase, tree/shrub areas decrease. It is thought that the vegetation in areas with tree or shrub vegetation 10 years ago could not i) reach the reflectance values of the forest, ii) developed in this process and covered more area more densely, and iii) reflectance values of these areas moved to the forest borders.

The water mass in the research area was evaluated in terms of the surface area it covers, since it is difficult to determine the amount of water it has. In this study, it can be seen that the area covered by the lake of the Porsuk Dam has decreased by 5.87% in 10 years. While land areas are expected to increase in areas where water is withdrawn, it is seen that these areas also decrease. It is thought that the soil areas, exposed to the decrease in water, are covered by herbaceous plants, and thus the areas with herbaceous vegetation increase. In other words, vegetation has responded effectively to change in its environment and exhibits a dynamic movement [5, 24, 26].

3.2. NDWI (Normalized Difference Water Index)

Visual results of NDWI analysis are given in Figure 4 and numerical results are given in Table 2. Accordingly, it is seen that dry areas covered an area of 51,939.28 ha in 2014 and 52,989.54 ha in 2004. It means that dry areas increased by 2.02% in the 10 years. It was determined that moderately dry areas covered an area of 16,423.67 hectares in 2014, and this number reached to 18,198.48 ha in 2024. It was seen that the number of moderately dry areas increased by 10.81% in the 10 years. It was determined that humid areas covered 23,099.28 ha in 2014 and 20,394.59 ha in 2024. It is seen that in the 10 years, humid areas decreased by 11.71%. Finally, when the water body is evaluated, it is seen that it covered an area of 2,050.49 hectares in 2014, and by 2024, this figure decreased to 1,930.11 hectares. This means that the water body decreased by 5.87% over the 10 years.

Today, one of the most important problems in the world is global warming. Global warming brings with it many problems such as area and vegetation change, changes in climate elements, and sustainability. Climate warming accelerates the global hydrological cycle and alters precipitation patterns due to greater evaporation and water vapor from rising temperatures [33, 34]. It is a very difficult process to prevent even with new and harsh measures [4]. According to the results of the NDWI analyses performed in this study, it is seen that the area covered by the water mass decreased by 5.87%. The water mass contributes to the water level of its surroundings, especially by distributing to its near surroundings both as capillaries and as moisture in the atmosphere through evaporation [32]. When water mass decreases, dry or moderately dry areas are expected to increase, as in our study area. In our study, this situation shows that while the dry and moderately dry areas increase, the humid areas decrease.

However, one of the important factors caused by global warming is the issue of climate change. Climate shifts can occur in many different ways at the local level [35, 36]. In this study, although the relatively healthy vegetation developing despite the decrease in the water mass and the water potential in the surrounding area seems like a contradiction, it is actually thought that this situation is due to climate change. Spring rains normally occur in May in the research area [34]. However, in 2024, it was observed that these precipitations occurred at the end of May and early June, rather than in the middle of May as expected (data not shown). Therefore, it is seen that the water mass and moist areas are less in 2024 compared to 2014 due to the delay in the spring rains expected in 2024. For this reason, in this study, which aims to determine what changes have occurred in the area over 10 years, very close days of the year were selected. However, taking into account climate change, conducting an analysis covering June 2024 will take this study further and make the results more clearly understandable.

3.3. ST (Surface Temperature)

Visual results of NDWI analysis are given in Figure 5 and numerical results are given in Table 3. Accordingly, on May 23, 2014, the temperature in the 446.31 ha part of the research area was between -3 and 14.18 ^{0}C, in the 12,649.30 ha area the temperature was between 14.18 and 25.29 ^{0}C, in the 17,888.16 ha area the temperature was between 25.29 and 25.29 ^{0}C. It was determined that the temperature was between 31.58 and 36.82 ^{0}C in the 31456.79 ha area and between 36.82 and 50.45 ^{0}C in the 31,072.16 ha area. On May 18, 2024, the temperature was between 14.01 and 25.12 ^{0}C in the 8,753.12 ha part of the research area, between 25.12 and 29.13 ^{0}C in the 13700.86 ha part, and 29.13 ^{0}C in the 21,557.71 ha part. It was determined that the temperature was between 32.32 and 35.39 ^{0}C in the 28,851.77 ha part and between 35.39 and 44.13 ^{0}C in the 20,649.26 ha part. According to the weighted average calculation based on the midpoints of the temperature spectra and the area where they are seen, while the average temperature of the area was 34.14 ^{0}C in 2014, this figure was determined to be 32.11 ^{0}C in 2024.

The presence of parts with different temperature values in the area can be explained by different ecological elements in the very wide area. These involve many factors including the difference in the amount of heat retention of water, soil or vegetation, elevation, and bedrock elements [32]. Of course, only one day surface temperature analysis for the years 2014 and 2024 may prevent us from reaching a clear conclusion about the temperature of the region. However, it is clear that it gives an idea about the temperature values of the area. In our study, in general, it can be seen that 2014 was 2 ^{0}C

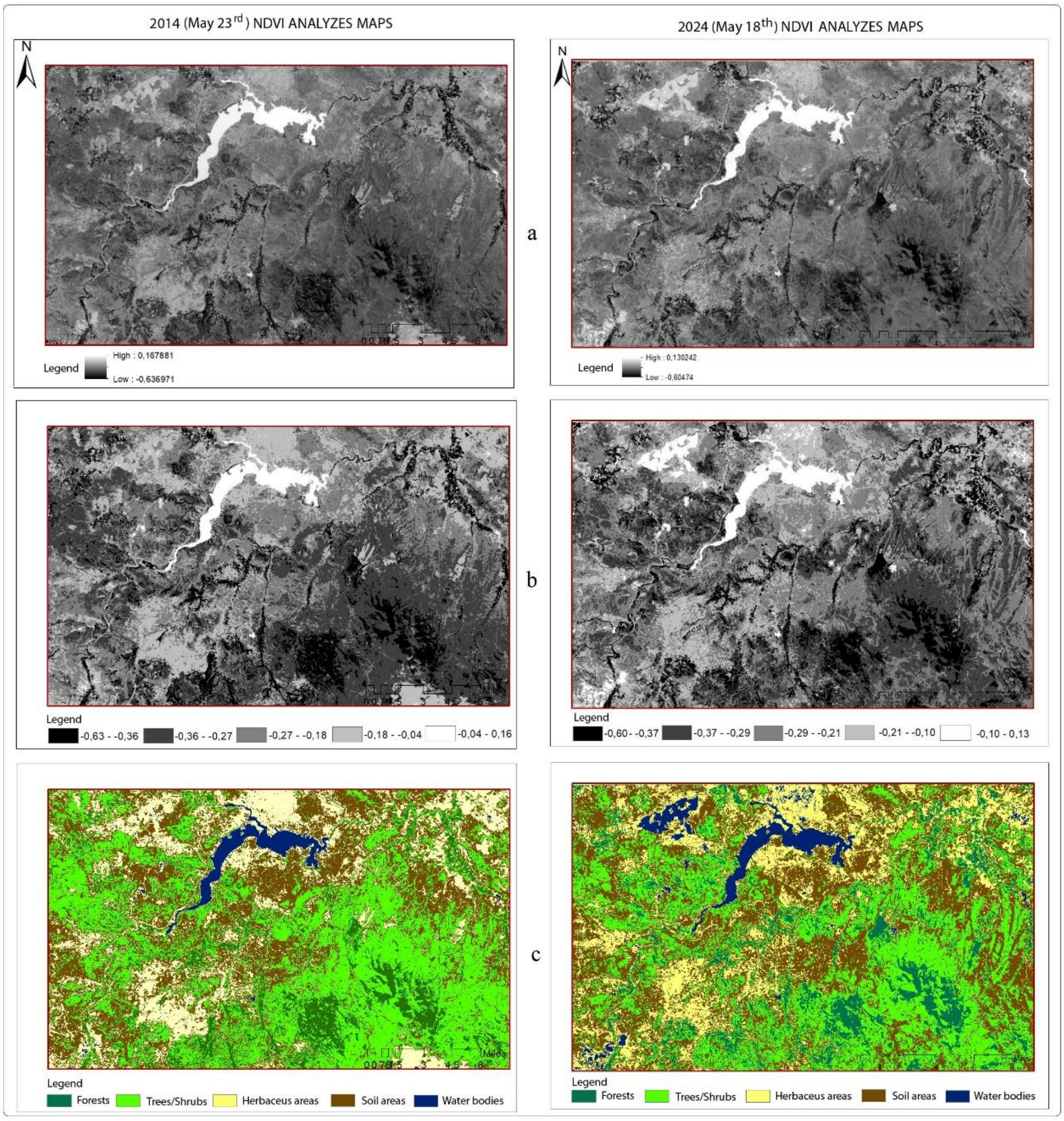

Figure 3. Results of normalized difference vegetation index (NDVI) analyses (2014 and 2024)(a. Maximum/minimum levels of reflection values, b. Classification of reflection values, c. Classification of plant cover and water bodies)

Table 1. Numeric values of plant cover and water bodies belonging to the research area

Categories	2014 (May, 23rd)	2024 (May, 18th)	Change (%)
Soil areas	30,966.00	30,130.45	-2.70
Herbaceous areas	17,202.20	18,158.13	5.56
Trees/Shrubs	34,285.61	33,854.94	-1.26
Forests	9,008.42	9,439.09	4.78
Water bodies			-5.87

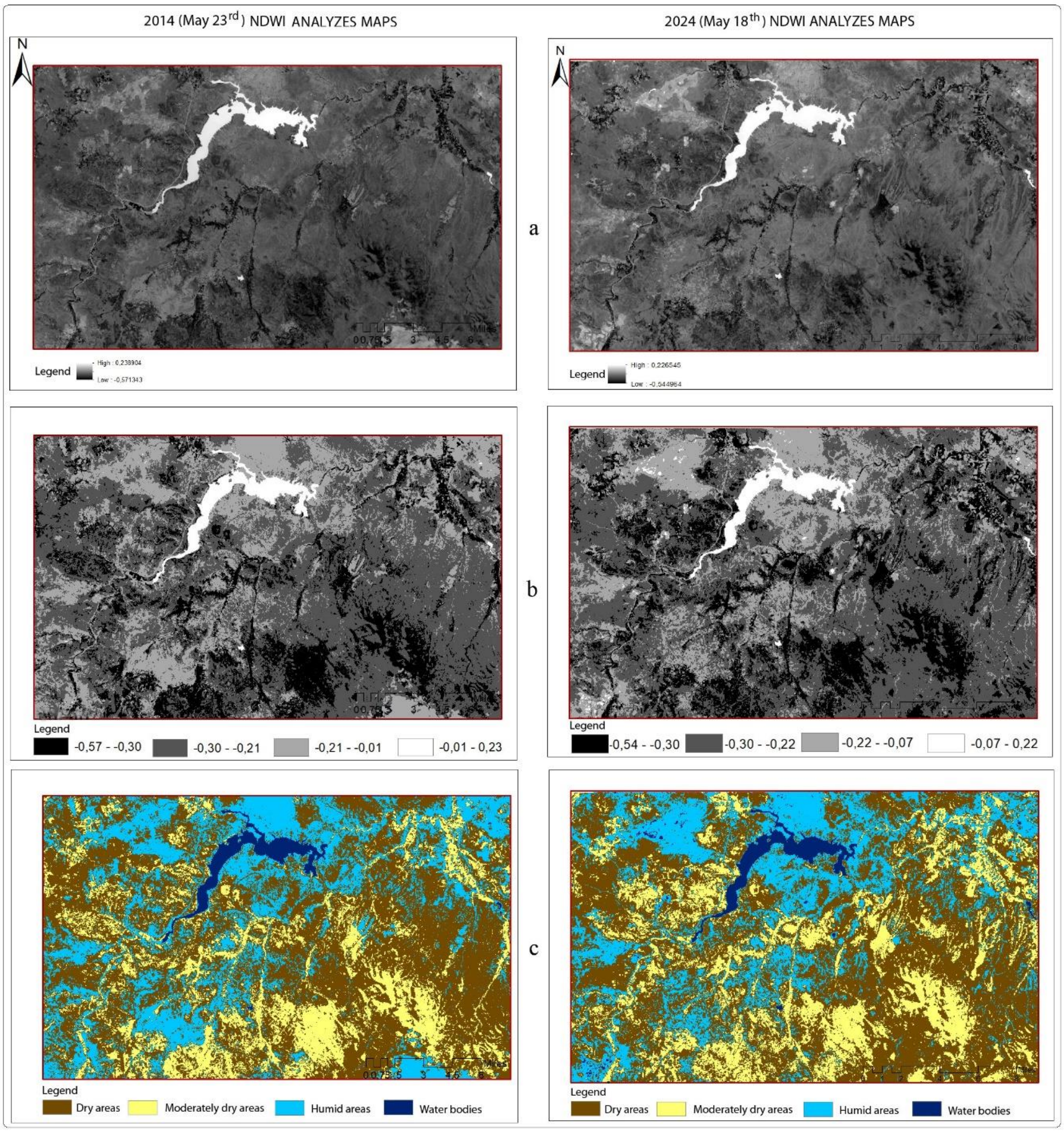

Figure 4. Results of normalized difference water index (NDWI) analyses (2014 and 2024) (a. Maximum/minimum levels of reflection values, b. Classification of reflection values, c. Classification of the areas in terms of water content)

Table 2. Numeric values of plant cover and water bodies belonging to the research area

Categories	2014 (May 23rd)	2024 (May 18th)	Change (%)
Dry areas	51,939.28	52,989.54	2.02
Moderately dry areas	16,423.67	18,198.48	10.81
Humid areas	23,099.28	20,394.59	-11.71
Water bodies	2,050.49	1,930.11	-5.87

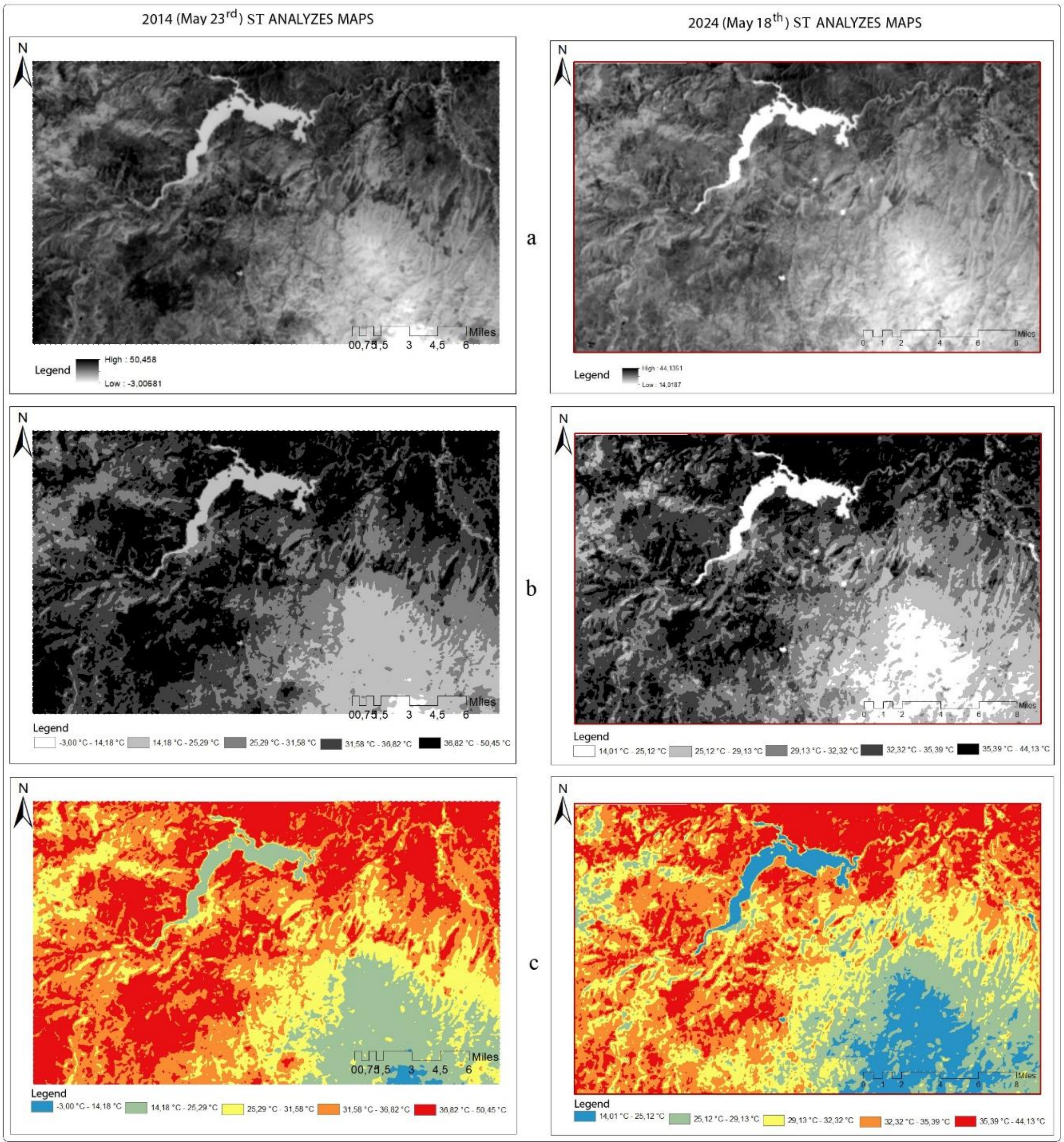

Figure 5. Results of surface temperature (ST) analyses (2014 and 2024) (a. Maximum/minimum levels of reflection values, b. Classification of reflection values, c. Classification of the areas in terms of surface temperature)

Table 3. Temperature spectrum and areas (ha**)**

2014 (May 23rd)		2024 (May 18th)	
Temperature Spectrum (^{0}C)	**Area (ha)**	**Temperature Spectrum (^{0}C)**	**Area (ha)**
-3.00 --- 14.18	446.31	14.01 --- 25.12	8,753.12
14.18 --- 25.29	12,649.16	25.12 --- 29.13	13,700.86
25.29 ---31.58	17,888.16	29.13 --- 32.32	21,557.71
31.58 --- 36.82	31,456.79	32.32 --- 35.39	28,851.77
36.82 --- 50.45	31,072.16	35.39 --- 44.13	20,649.26

warmer for the same period. It is thought that this situation occurred as a result of climate change [35, 36], as explained above.

In a study conducted in Tokat province, it was noted that the current state of the vegetation can be tracked using remote sensing methods, and the change in vegetation may be observed through future studies [21]. In this study, in addition to the vegetation of the Porsuk dam and its immediate surroundings, water content and surface temperature analysis were also carried out, taking advantage of the opportunities provided by technology, both today and 10 years ago, and the results were compared. In other words, temporal and spatial analysis was applied within the framework of the variables specified in the study area. We believe that this study will provide data for other studies to be carried out in the area in the coming years in terms of determining vegetation, water content and surface temperature, future planning, management and decision-making processes.

4. CONCLUSION

In this study, changes in the vegetation and water content of Porsuk and its immediate surroundings over 10 years were studied by performing NDVI and NDWI analyses. Additionally, the study was supported by surface temperature analysis. It was concluded that the presence of forests and areas with herbaceous vegetation increased over the 10 years, whereas soil, tree/shrub areas and the water body decreased. It was also concluded that dry and moderately dry areas increased, while water bodies and wet areas decreased. The results obtained have been associated with climate change and climate drift.

CONFLICT OF INTEREST

The authors stated that there are no conflicts of interest regarding the publication of this article.

CRediT AUTHOR STATEMENT

Kübra Günbey: Formal analysis, Investigation, Visualization, Resources, **Harun Böcük: C**onceptualization, Supervision, Investigation, Validation, Writing – Original Draft.

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