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Determining the Temporal Change in Tuz Gölü Between 2000-2020 by Remote Sensing

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A B S T R A C T

Changes in the landscape become extremely destructive and many heritage values and resources are irreversibly lost. The speed, frequency and magnitude of these changes in the landscape increased in the second half of the 20th century, especially with the impact of human activities. Remote sensing is the most widely used method for determining the change in the landscape. In the research, MNDWI, NDVI and NDMI techniques, which are frequently applied in remote sensing, were used in order to determine the landscape change in Salt Lake. Thus, the changes in the built area, water surface and land cover between the years 2000-2020 in Salt Lake were determined. According to the MNDWI and NDMI Analysis results, a decrease was observed in the water surface width and moisture content in Salt Lake between 2000 and 2020. In the steppe areas south of Salt Lake, the increase in tree cover due to the change in land use type was determined by NDVI analysis. Therefore, it is possible to say that there is an increase in the amount of moisture in these areas. In addition, it was determined that the increase in agricultural activities in the region caused a change in land use types and the amount of green space in the region changed at this rate. With the mentioned methods, negative changes in the landscape as a result of human activities on the landscape can be determined practically. Thus, it will be possible to predict the negative consequences of climate change and take precautions.

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Introduction

Intensive use of natural resources calls for increasingly detailed inventories of its components and an investigation of the changes which took place in the past (Aaviksoo, 1995). This is particularly important in fast, usually unplanned, changing areas, such as urban settlements in developing countries (Ramachandran, 1992; Bocco and Sanchez, 1995; Rodri´guez, 1995; López et al., 2001). Land cover change is one of the most important factors affecting the natural structure and functions of the landscape. Land-cover and land-use (LCLU) change analyses and projection provide a tool to assess ecosystem change and its environmental implications at various temporal and spatial scales (Lambin, 1997). In order to detect landscape change, many different remote sensing techniques such as "NDWI (Normalized Difference Water Index), MNDWI (Modified Normalized Difference Water Index), SAVI (Soil-Adjusted Vegetation Index), LTS (Land Surface Temperature), NDBI (Normalized Difference Built-up Index), NDMI (Normalized Difference Moisture Index), NDVI (Normalized Difference Vegetation Index)" can be used. In the study by Soydan (2020), landscape change of Akkaya Dam in Niğde was determined by using remote sensing method for 1999, 2009 and 2019. For this purpose, MNDWI and NDVI indices were used and water surface and vegetation changes between the specified years were obtained. In the study conducted by Turgut (2023), the temporal variation of the wetlands in the Batum Delta was determined. In addition, the relationship of this change with basic climate parameters such as average temperature and total precipitation has been revealed. For this purpose, the average temperature and total precipitation amount of the months of April, May, June, July, August and September in the period between 2016-2021 of the study area and the NDWI values of these time periods were determined. The aims of the study by Albarqouni (2022) are to extract water surface area and lake surface water temperature (LSWT), and to present long-term spatio-temporal analysis of these variables together with meteorological parameters. In this study, Google Earth Engine (GEE) cloud-based platform was used to determine the change between 2000 and 2021 for Burdur Lake, Eğirdir and Beyşehir lakes in the Lake District. The spatial changes of the water surfaces were determined with the NDWI index, and the temperature changes on the water surfaces were determined with the lake surface water temperature (LSWT) index.

Within the scope of the research, MNDWI, NDVI and NDMI techniques were used in order to determine the landscape change of Salt Lake and its surroundings between 2000 and 2020. MNDWI is a remote sensing technique used to separate water surfaces from soil and vegetation cover. With this technique, the difference between the green wavelength and the near-infrared wavelength is proportional to their sum, and values between -1 and +1 are obtained as a result of the analysis (McFeeters, 1996). NDVI is a standardized index allowing you to generate an image displaying greenness (relative biomass). This index takes advantage of the contrast of the characteristics of two bands from a multispectral raster dataset the chlorophyll pigment absorptions in the red band and the high reflectivity of plant materials in the near-infrared (NIR) band. The Normalized Difference Moisture Index (NDMI) is sensitive to the moisture levels in vegetation. It is used to monitor droughts as well as monitor fuel levels in fire-prone areas (ESRI, 2021). The purpose of choosing these techniques is to determine the negative effects of increasing drought due to climate change on water and vegetation. The negative changes in the landscape can be revealed as a result of the interventions on the landscape with the methods used within the scope of the study. This study makes it possible to anticipate the results of potential interventions and to eliminate the negative effects with the landscape planning studies.

Material and Method

The study area is the Salt Lake Basin in the Central Anatolia Region. In the scope of the research, numerical, verbal and visual data provided for collecting, analyzing and evaluating the data constitute the other materials of the study. These:

- Landsat 5 TM and Landsat 8 OLI / TIRS Satellite Images for July 2000 and 2020,
- National literature data on theoretical foundations, methods and research findings.

The stages of the study and the analyzes made are given in Table 1.

MNDWI (Modified Normalized Difference Water Index), NDVI (The Normalized Difference Vegetation Index), NDMI (The Normalized Difference Moisture Index) analysis carried out using Landsat 5 TM and Landsat 8 OLI / TIRS Satellite Images. Band features of Landsat 5 TM and Landsat 8 OLI / TIRS Satellite Images are given in Table 2 and Table 3.

The Modified Normalized Difference Water Index (MNDWI) uses green and SWIR bands for the enhancement of open water features. It also diminishes built-up area features that are often correlated with open water in other indices (ESRI, 2021).

The documented and default MNDWI equation is as follows:

MNDWI = (Green - SWIR) / (Green + SWIR)

SWIR = pixel values from the short-wave infrared band

The normalized difference vegetation index (NDVI) is a standardized index allowing you to generate an image displaying greenness, also known as relative biomass. This index takes advantage of the contrast of characteristics between two bands from a multispectral raster dataset—the chlorophyll pigment absorption in the red band and the high reflectivity of plant material in the near-infrared (NIR) band (ESRI, 2021). In this study, Google Earth Engine (GEE) cloud-based platform was used to determine the change between 2000 and 2020 for Tuz Gölü. The documented and default NDVI equation is as follows:

NDVI = ((IR - R)/ (IR + R))
IR = pixel values from the infrared band
R = pixel values from the red band

NDMI uses NIR and SWIR bands to create a ratio designed to mitigate illumination and atmospheric effects (ESRI, 2021). The documented and default NDMI equation is as follows:

NDMI = (NIR - SWIR1)/ (NIR + SWIR1)
NIR = pixel values from the near infrared band
SWIR1 = pixel values from the short-wave infrared 1 band

Study Area

Located in the Konya Closed Basin with an area of 5.3 million hectares (53,850 km^2), Salt Lake covers an area approximately 130 thousand hectares (1,300 km^2) and is the second largest lake in Türkiye in this respect. Salt Lake and its surroundings, which is one of the important wetlands with its large and small lakes and has a geological tectonic origin, is a "Class A" wetland according to Ramsar criteria. Salt Lake Specially Protected Environment Area, with an area approximately 741 thousand hectares (7,414 km^2) was determined and declared as a Specially Protected Environment Area (SPEA) with the Council of Ministers Decision dated 14.09.2000 and numbered 2000/1381 due to its natural, ecological and biological values (Ministry of Environment and Urbanization, 2014).

Salt Lake Specially Protected Environment Area, which is one of the most important natural areas in the world with its surrounding vegetation and species, also has the status of grade 1 Site Area, Important Plant Area (IPA), Important Nature Area (INA), Important Bird Area (IBA). Salt Lake and its surroundings, which home of many bird species due to its location on important migration routes, are also one of the largest and most important salty steppe habitats and wetlands of Türkiye. Salt Lake and its surroundings, which are biogeographically a small inland sea, are the only habitat of many plant and animal species that do not live anywhere else in the world. Mud islets, rocky areas, and salty shallow waters in the region are supply feeding, sheltering and breeding habitats for many different species (Ministry of Environment and Urbanization, 2014).

Table 1. Stages of the research

Stage	Scope	Explanation
1. Stage	Determination of the scope, purpose and scope of the research area	Salt Lake
2. Stage	Literature review and inventory collection	Compilation of data on theoretical foundations, methods and research findings
3. Stage	Determination of method	Determination of water surface change Determination of vegetation change Determination of moisture change
4. Stage	Production of geographic database	Height Model (DEM) Landsat 5 TM and Landsat 8 OLI / TIRS Satellite Images
5. Stage	Analysis	MNDWI (Modified Normalized Difference Water Index) NDVI (The Normalized Difference Vegetation Index) NDMI (The Normalized Difference Moisture Index)
6. Stage	Evaluation & Conclusion	Calculation of landscape change Development of landscape protection proposals

Table 2. Landsat 5 band features (USGS, 2021a)

	Bands	Wavelength (micrometers)	Resolution (meters)
Landsat 5 Thematic Mapper (TM)	Band 1 – Blue	0.45-0.52	30
	Band 2 – Green	0.52-0.60	30
	Band 3 – Red	0.63 – 0.69	30
	Band 4 – Near Infrared (NIR)	0.76 – 0.90	30
	Band 5 – Short Wave Infrared (SWIR)	1.55 – 1.75	30
	Band 6 – Thermal Infrared	10.40 – 12.50	120 (30)
	Band 7 – Short Wave Infrared (SWIR)	2.08 - 2.35	30

Table 3. Landsat 8 band features (USGS, 2021b)

	Bands	Wavelength (micrometers)	Resolution (meters)
Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)	Band 1 – Coastal aerosol	0.43-0.45	30
	Band 2 – Blue	0.45-0.51	30
	Band 3 – Green	0.53-0.59	30
	Band 4 – Red	0.64-0.67	30
	Band 5 – Near Infrared (NIR)	0.85-0.88	30
	Band 6 – Short Wave Infrared 1 (SWIR1)	1.57-1.65	30
	Band 7 – Short Wave Infrared 2 (SWIR2)	2.11-2.29	30
	Band 8 - Panchromatic	0.50-0.68	15
	Band 9 – Cirrus	1.36-1.38	30
	Band 10 – Thermal Infrared (TIRS) 1	10.60-11.19	100
	Band 11 – Thermal Infrared (TIRS) 2	11.50-12.51	100

Table 4. The amount of change in the water surface between 2000 - 2020

Satellite Image / Year / Month	Water Surface (>0)	Other Surface (<0)
Landsat 5 TM / 2000 / July	183351.2 ha	2563659 ha
Landsat 8 OLI/TIRS / 2020 / July	133361.5 ha	2613542 ha
Change	49989.7 ha (-)	49883.0 ha (+)

Table 5. The amount of vegetation change between 2000 - 2020

Satellite Image / Year / Month	Rock, sand or wasteland areas (-1 – 0.05)	Shrub and grassland (0.05 – 0.3)	Tree canopy (0.3 – 1)
Landsat 5 TM / 2000 / July	289691.5 ha	2364047 ha	93452.12 ha
Landsat 8 OLI/TIRS / 2020 / July	514644.7 ha	1984274 ha	247953.8 ha
Change	224953.2 ha (+)	379773 ha (-)	154501.7 ha (+)

Table 6. The amount of moisture changes between 2000 - 2020

Satellite Image / Year / Month	Very Dry	Dry	Medium	Wet	Very Wet
Landsat 5 TM 2000 / July	873.7463	1362099	1213111	107612.1	62810.66
Landsat 8 OLI/TIRS / 2020 / July	1.09574	1539072	1001858	199075.5	6859.004
Change	221.9 ha (+)	176973 ha (+)	211253 ha (-)	91463.4 ha (+)	55951.7 ha (-)

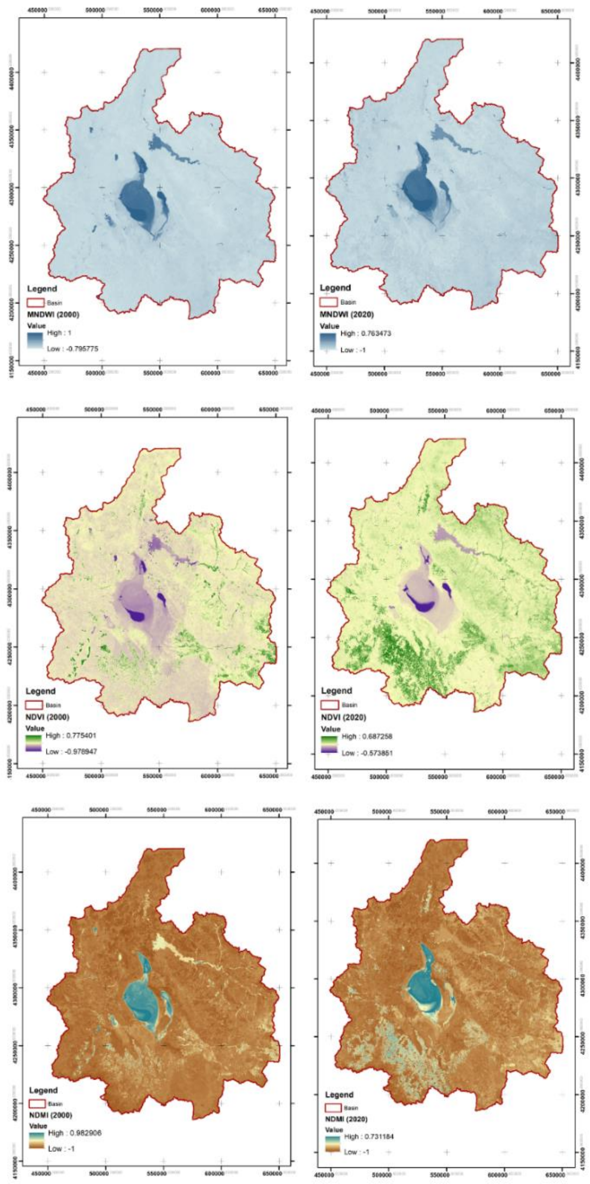

Figure 1. Landscape Change Analysis (MNDWI, NDVI, NDMI)

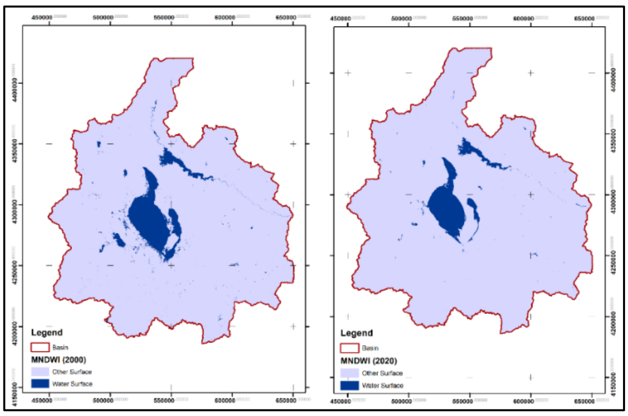

Figure 2. Maps of MNDWI 2000 and 2020

Result and Discussion

The total catchment area including Salt Lake is calculated as 2855116 ha. Within the scope of the research, MNDWI, NDVI and NDMI analyzes were performed in ArcGIS environment in order to determine the water surface, vegetation and moisture changes and the changes in the total basin area were calculated. Figure 1 shows the results of the analyzes.

Determination of Water Surface Change

The water surface maps produced with the MNDWI were prepared for July 2000 to 2020 (Figure 2 and Table 4). While the water surface width of the lake was 183351.2 ha in 2000, it decreased to 133361.5 ha in 2020. As a result of the calculations, it is possible to say that there has been a decrease in the water surface width of 49989.7 ha, that is, approximately 27% over the 20-year period.

Determination of Vegetation Change

Vegetation maps produced with NDVI were prepared for July of 2000 and 2020 (Figure 3 and Table 5). The change in the amount of vegetation that emerged due to drought and land cover change of the lake was calculated. Between 2000 and 2020, a decrease of 379773 ha in the bush and pasture cover in the lake, and an increase of 224953 ha in the bare area or soil area were detected. It was calculated that there was an increase of 154501 ha in the amount of tree cover. While a decrease in tree cover due to drought and climate change is expected, the opposite values were obtained as a result of the analysis. This is due to changes in land cover type. It is known that there is an increase in the amount of trees in the region due to the increase in agricultural activities and afforestation works.

Determination of Moisture Change

The maps, on the other hand, in which the moisture produced by NDMI are determined, were prepared for the month of July of the years 2000 and 2020 (Figure 4 and Table 6). When the moisture content of the lake due to drought is evaluated; Between 2000 and 2020, the width of very humid areas in the lake decreased by 55,951 ha, while a total of 177195 ha increased in “very dry” and “dry” areas. In “wet” areas, an increase of 91463 ha was detected. Therefore, it can be said that there is a decrease of 89% in the “very wet” areas in the basin.

Discussion

According to the drought analyzes made by the World Wildlife Fund (WWF) and the European Environment Agency (EEA) in 2006, it is seen that the basin that will be most affected by the global climate changes predicted to take place in the future is the Central Mediterranean countries, including Türkiye. In this context, Salt Lake Specially Protected Environment Area, which receives the least rainfall in Türkiye, is expected to be one of the regions that will be most affected by climate changes worldwide. While this situation reveals the necessity of optimum and sustainable use of water and water resources in and around Salt Lake, it makes it essential to protect water resources in particular. According to the report prepared by the WWF in 2010, Salt Lake, which spread over an area of 260,000 hectares 40 years ago, is now around 130,000 hectares covers the area. Therefore, the area of the lake has narrowed by 50% in 40 years, and the water level of the lake has decreased by almost 1 meter in the last 20 years (Ministry of Environment and Urbanization, 2014).

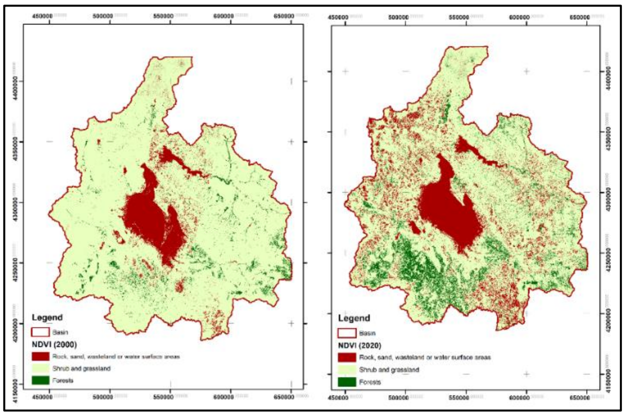

Figure 3. Maps of NDVI 2000 and 2020

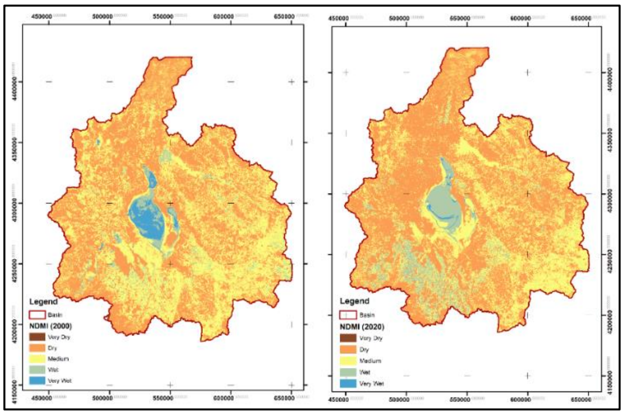

Figure 4. Maps of NDMI 2000 and 2020

It can be said that the reasons for this decrease in the amount of water surface are the decrease in the amount of precipitation due to climate change and drought. While the change in the amount of water was determined by the MNDWI analysis carried out within the scope of the study, the change in the amount of moisture due to drought was determined by the NDMI analysis. According to the results of the analysis, a correct relationship was determined between the water surface and the amount of moisture. Between 2000 and 2020, a decrease was observed in the width of the water surface and the amount of moisture in the reservoir area of the lake. However, the increase in tree covers due to the change in land use type in the steppe areas south of Salt Lake was also reflected in the values of the NDVI analysis. Therefore, it is possible to say that there is an increase in the amount of moisture in these areas and this has been confirmed by NDMI analysis. At the same time, increasing water consumption as a result of increased agricultural activities in the region causes a decrease in the amount of water in Salt Lake. It has been determined as a result of NDVI analysis that this increase in agricultural activities expressed also causes a change in land use types and the amount of green space in the region changes at this rate. It is possible to verify the change in land use types due to the increase in agricultural areas by comparing CORINE 2000 and CORINE 2018 data.

It has been determined that the underground waters in the Konya Closed Basin, which contains vital resources for Salt Lake and its surroundings, have decreased by an average of 14 m in the last 33 years. It is seen that many factors such as climate, geological, hydrogeological, agricultural structure of the region are effective in these changes observed in the aquifers in the region. For this reason, it is necessary to take urgent measures regarding the use of groundwater. Konya-Çumra Irrigation Project, which is among the water and irrigation projects that are important in terms of agricultural activities in and around Salt Lake, is the largest irrigation project. Farmers, who are excluded from the irrigation facilities provided by the General Directorate of State Hydraulic Works and Rural Services, obtain their water needs from drainage channels to irrigate their lands or drill wells to meet them from groundwater. Uncontrolled drilling of wells in and around Salt Lake causes the groundwater levels in the region to decrease. The amount of precipitation in the region is decreasing with each passing year. This situation adversely affects the hydrological structure of Salt Lake and its surroundings. Along with the decrease in the amount of precipitation, factors such as dam construction on the surface waters feeding the lake, excessive and unconscious consumption of underground waters reduce the water level in Salt Lake and dries the lake at the same time (Ministry of Environment and Urbanization, 2014).

If timely measures are not taken against climate change, which will make its impact more felt in the coming years, and if the process is not managed effectively, irreversible results may occur. The changes in the landscape function as a result of remote sensing techniques applied within the scope of the study, the negative effects of climate change and human interventions have been determined. The indexes used in this study can be a guide in predicting the possible consequences of potential human interventions in rural landscape areas and determining landscape changes in these areas. On the other hand, it is possible to say that this study is a practical and applicable method in terms of including these changes in important natural areas in the planning process instead of post-planning research.

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