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Temporal Change of Göksu River

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Abstract

Rivers meet the agricultural and energy needs of people and living things. In addition, it is the most important external factor and process in the shaping of the surface where we live. Turkey is a very rich country in terms of rivers and wetlands in general. Göksu River, which is located in the south of Turkey and is one of the important rivers of the region, has been selected as the study area. Göksu is a river flowing through the provinces of Antalya, Konya, Karaman and Mersin in Turkey with a length of 260 km and a basin area of approximately 10,000 km^2. Göksu originates from the Middle Taurus Mountains in two arms. The southern branch originates from the Geyik Mountains, and the northern branch originates from the Haydar Mountains and merges within the borders of the Mut District. From its confluence, the river takes the name Göksu, and then it empties into the Mediterranean Sea in the south of Silifke District. This study aims to investigate the temporal changes of Göksu River by using remote sensing methods. In the study, the Normalized Difference Water Index (NDWI) was used for the extraction of water bodies. In addition, the Normalized Difference Vegetation Index (NDVI) was used to study the temporal changes of forest and agricultural areas along the river line.

1. Introduction

Rivers provide water for irrigation, domestic supply, power generation and industry as well as a range of other ecosystem services and intrinsic and biodiversity values. Managing rivers to provide multiple benefits is therefore foundational to water security and other policy priorities. Rivers, which have become a religious symbol in some ancient societies, also play a big role in the vegetation changes around them. In this study, the temporal change of the Göksu River has been studied based on more than one year in recent seasons. In addition, the density of vegetation grown in the riparian region of the riversides and its change in time was studied.

1.1. Remote Sensing Data and Source

Remote sensing is the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance (typically from satellite or aircraft). The Landsat series is a joint USGS and NASA-led enterprise for Earth Observation that represents the world's longest running system of satellites for moderate-resolution optical remote sensing for land, coastal areas, and shallow waters. Landsat satellite data has important advantages in monitoring and evaluating long-term land changes (Gülci et al. 2019). After the launch of the first Landsat satellite (Landsat 1) in 1972, the series from 1 to 9 has followed until today. The Landsat 6 satellite was destroyed during launch. In this study, Landsat 4-5 TM C1 Level-1 data and Landsat 8 OLI/TIRS C1 Level-1 were downloaded freely from the USGS Earth Explorer site. Landsat satellite data can be downloaded from the EarthExplorer USGS site at no cost (Kayalık and Çorumluoğlu 2022). Land and scene cloud cover were chosen to be less than 3%. There are two types of image data available for the Landsat 4-5 satellite: MultiSpectral Scanner (MSS) and Thematic Mapper (TM). In addition to this, TM sensor with its seven spectral bands provides more radiometric information than the MSS sensor. TM, which has been used since 1984, has six bands with 30m resolution and Thermal Band with 120m resolution in the visible NIR and SWIR region. See Table 1.

Table 1. Landsat 4-5 TM band specifications.

TM Bands	Wavelength micrometers)	Resolution (meters)
B (Blue)	0.45 - 0.52	30
G (Green)	0.52 - 0.60	30
R (Red)	0.63 - 0.69	30
Near infrared	0.76 - 0.90	30
Mid-infrared	1.55 - 1.75	30
Thermal infrared	10.40 - 12.50	120
Mid-infrared	2.08 - 2.35	30

Landsat 8 OLI/TIRS carries two different devices: OLI (Operational Land Imager) and TIRS (Thermal Infrared Sensor). Besides the previous conventional bands, OLI (Operational Land Imager) includes a deep blue band for coastal/aerosol studies, a short-wave infrared band for the detection of sirrus clouds and a quality assessment band. The TIRS (Thermal Infrared Sensor) sensor has two thermal bands. These sensors provide a radiometric resolution of over 12bit of signal-to-noise radiometric performance. These 12 bits provides 4096 potential gray color levels compared to 256 gray level colors of 8 bit. The products are delivered in 16-bit. The Landsat 8 OLI/TIRS satellite, launched in 2013, has eight bands with a resolution of 30m, a PAN band with a resolution of 15m and 2 bands with a resolution of 100m. See Table 2.

Table 2. Landsat-8 OLI/TIRS band specifications

Bands	Wavelength (micrometers)	Resolution (meters)
Coastal aerosol	0.43 - 0.45	30
Blue	0.45 - 0.51	30
Green	0.53 - 0.59	30
Red	0.64 - 0.67	30
Near Infrared(NIR)	0.85 - 0.88	30
SWIR 1	1.57 - 1.65	120
SWIR 2	2.11 - 2.29	30
Panchromatic	0.50 - 0.68	15
Cirrus	1.36 - 1.38	30
Thermal Infrared(TIRS) 1	10.60 - 11.19	100
Thermal Infrared(TIRS) 2	11.50 - 12.51	100

In this study, multi-spectrum satellite images from Landsat-5 (TM) and Landsat-8 (OLI / TIRS) satellites were downloaded as time series data to detect water in riverbed and vegetation coverage in the riparian area of Göksu river in time. Therefore, starting from 2000, a total of 8 images were downloaded at intervals of two or three years until 2021. Eight images downloaded were selected from the season covering July, August, and September, but were downloaded from August in general. For the accuracy of the project, the cloudiness of the downloaded images was chosen to be less than 3%.

1.2. Study Area

The part where Göksu River flows into the Mediterranean Sea from within the borders of Mersin province was chosen as the study area. Due to many reasons, such as the amount of precipitation, underground resources, global warming, changes may occur in the river areas. In addition, it is considered that the Ermenek Dam, which is located close to the study area, may have an effect on the temporal change of the Göksu River. Ermenek Dam is located on the Göksu River and was opened in 2009. Geographical location of study area lies between 36° 12 to 36° 37 N and between 33° 12 to 34° 2 E. Location map was prepared for the determined are Fig. 1.

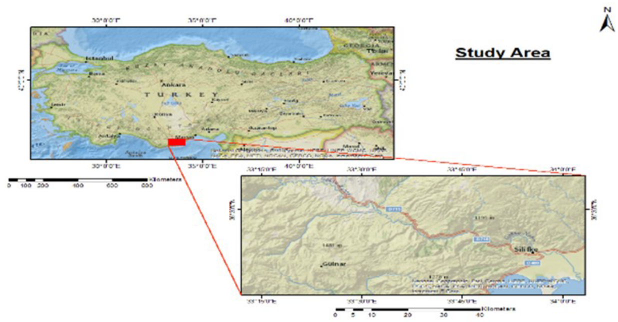

Figure 1. Location map of the study area

2. Material and Method

In the previous sections, the river area, the vegetation area and their indices were explained and some information about data acquisition is also given. In this section, information about the materials and methods used is explained. The temporal changes of the region (river for water area and river banks for vegatation cover), so riparian area of Göksu river selected as the study area is being studied. Images of the study area have been downloaded for free from the USGS Earth Explorer site, from the Landsat-5 and Landsat-8 satellites. Dark Object Subsraction (DOS) and Conversion of the Digital Number to Top of Atmosphere Reflectance (DN to ToA Reflectance) operations were applied to the downloaded data. NDWI-Normalized Difference Water Indexes were used for the river area extraction and NDVI-Normalized Difference Vegetation Indexes were used for the vegetation area extraction in yearly maner. Then, Unsupervised Classification was performed on the images with the indexes applied. After the classification, the temporal changes of the river and vegetation areas were examined, and then accuracy assessment was performed.

2.1. Image Processing

Landsat data has been used in change analysis studies for decades because of its relatively high spatial resolution covering long-term intervals. Change analysis with remote sensing techniques is the process of determining temporal differences between images. In this process, while electromagnetic radiation detected by various sensors travels from the earth's surface to the sensing sensor, gases, aerosols and other atmospheric components are exposed to atmospheric effects (such as scattering and absorption) by atmospheric components. Radiometric distortions occur due to the changes in the light falling on the images, the geometry of the view, atmospheric conditions and the response time of the sensor. Some atmospheric and radiometric corrections need to be applied to satellite images in order to minimize the resulting system errors and to eliminate the distortions caused by atmospheric particles.

2.1.1. Data Calibration

Thanks to data calibration, the differences in the data obtained in different systematic scenario situations at different times are eliminated in the form of digital records of a physical phenomenon, and comparable meaningful reflectance values are obtained. The formulas used in the calibration of the data are given below as indicated by Equation 1.a, 1.b, 2 and 3.

$$L_\lambda = ((L_{MAX\lambda}-L_{MIN\lambda})/(Q_{CALMAX}-Q_{CALMIN}))*(Q_{CAL}-Q_{CALMIN})+L_{MIN\lambda} \quad (1.a)$$

$$\rho_\lambda = (\pi * L_\lambda * d^2) / (ESUN_\lambda * \cos\theta_S) \quad (1.b)$$

$$\rho_\lambda' = M_\rho * Q_{cal} + A_\rho \quad (2)$$

$$\rho_\lambda = \rho_\lambda'/\cos(\theta_{SZ}) = \rho_\lambda' / \sin(\theta_{SE}) \quad (3)$$

Here, $L\lambda$ = ToA spectral radiation-radiance (Watts / (m^2 x srad x μm)), Qcal = Pixel values (DN), Mρ = Image channel specific multiplicative rescaling factor, Aρ = Image channel specific additive rescaling factor, ρλ = ToA reflectance value, θSE = Sun elevation angle, θSZ = Sun zenith angle ; θSZ = 90° - θSE.

2.1.2. Atmospheric Correction

Atmospheric correction is simply defined as the process of removing atmospheric effects from satellite images. Some atmospheric and radiometric corrections should be applied to satellite images in order to minimize the resulting system errors and to eliminate the distortions caused by atmospheric particles (Bektaş Balçık and Gölsel 2010; Liang 2004).

2.2. Normalized Difference Water Index (NDWI)

The normalized difference water index (NDWI) is a method developed to describe open water features and improve their presence in remotely sensed digital images. NDWI utilizes reflected near-infrared radiation and visible green light to highlight the spectral characteristics of water while removing soil and terrestrial vegetation features. This band ratio approach is calculated by Equation (5) given below (Xu 2022).

$$NDWI=Green-NIR/Green+NIR \quad (5)$$

Here, Green Band: 0.519 μ - 0.601 μ wavelength range for Landsat 5 sensor, 2nd band; For the Landsat 8 sensor, it has a wavelength range of 0.533μ - 0.590μ and corresponds to the 3rd band. NIR (Near Infrared): For Landsat 5 sensor, it is in the wavelength range of 0.772 μ - 0.898 μ, in Band 4; For Landsat 8 sensor, it is 0.851 μ-0.879 μ, corresponding to the 5th band.

2.3. Normalized Difference Vegetation Index (NDVI)

Normalized Difference Vegetation Index (NDVI) is a band ratio technique developed to estimate the size of vegetation biomass. NDVI is calculated using the formula given in Equation (6).

$$NDVI=NIR-Red/NIR+Red \quad (6)$$

Here, NIR (Near Infrared): For Landsat 5 sensor, it is in the wavelength range of 0.772 μ - 0.898 μ, in Band 4; For Landsat 8 sensor, it is 0.851 μ-0.879 μ to the 5th band; Red Band: For Landsat 5 sensor it has a wavelength range of 0.631 μ - 0.692 μ and corresponds to the 3rd band, for Landsat 8 sensor it is in the range of 0.636 μ-0.673 μ and corresponds to the 4th band.

2.4. Image Classification

Digital image classification is the process of clustering all the pixels belonging to the relevant image into classes in an assigned number. In a multiband optical image composed of pixels, each pixel defines the reflectance values of the part of the object associated with the pixel, obtained along the bands. Classifications made by determining only the number of classes are called unsupervised classification, while classifications made by determining the classes with the help of a training set are called supervised classification. As the classes assigned on the image can be determined by the user, it can also be done randomly by specifying only the number of classes (Lillesand et al. 2007). Unsupervised classification method was used in this study.

2.5. Accuracy Analysis

For the reliability of the images produced as a result of the classification, which performs the algorithms cyclically, the accuracy of the operations performed must be tested.

2.6. Change Determination

It is the process of comparing and interpreting the values obtained as a result of the analyzes performed on the satellite images.

3. Results and Discussion

In this part of the study, the results obtained as a result of the application of the techniques given in the previous section will be shared. First of all, necessary preprocessing steps were applied on the satellite images of the Göksu River area. The results obtained as a result of NDWI, NDVI and classification, which are evaluated within the scope of the study, will be shared on the satellite images prepared for analysis by applying preprocessing steps.

3.1. Image Preprocessing

Image preprocessing is a step that involves performing the necessary calibration processes for the data remotely sensed by a sensor and thus eliminating the systematic errors that occur. Many techniques have been developed to remove atmospheric distortions, including image-based dark object extraction (Chavez 1988) techniques. In this study, radiometric calibration and atmospheric correction processes were performed. From the images obtained within the scope of this process, first the brightness value and then the reflection value were obtained by using the data in the metadata file (data collection date, sun height, azimuth angle, etc.) in the satellite images. At the end of the processing steps, new images were produced covering the entire workspace, minimizing possible errors. The raw satellite image shown in Fig. 2, arranged in Fig. 3 is shown.

Figure 2. Raw Satellite Image

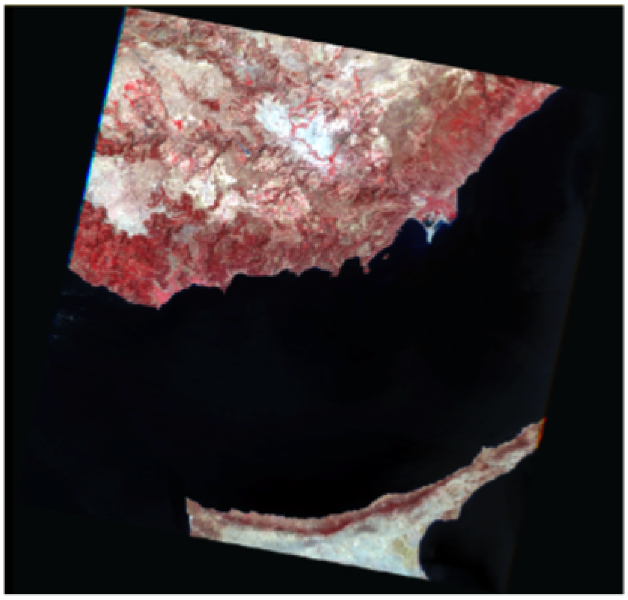

Figure 3. Processed Satellite Image

3.2. Normalized Difference Water Index (NDWI)

NDWI, which is calculated by incorporating satellite images into the analysis, is widely used in the detection and mapping of surface water bodies. The findings obtained as a result of the NDWI procedure are given in Fig. 4.

Figure 4. NDWI image of 26th July 2016

3.3. Normalized Difference Vegetation Index (NDVI)

Normalized Difference Vegetation Index (NDVI) was used to describe the surface vegetation of the regions. The NDVI is among the prosperous methods used for the extraction vegetation from satellite images. The findings obtained as a result of the NDVI procedure are given in Fig. 5.

Figure 5. NDVI image of 26th July 2016

3.4. Unsupervised Classification

It is the process of producing thematic maps with the help of images by gathering objects with the same spectral reflectance properties in the spectral reflectance feature space defined by bands under the same class (Doğan 2008). In the continuation of the processes, unsupervised classification was performed on the satellite images of the Göksu River. The maps of Göksu River Water class and vegetation class obtained as a result of classification are given in Fig. 6 and Fig. 7, respectively.

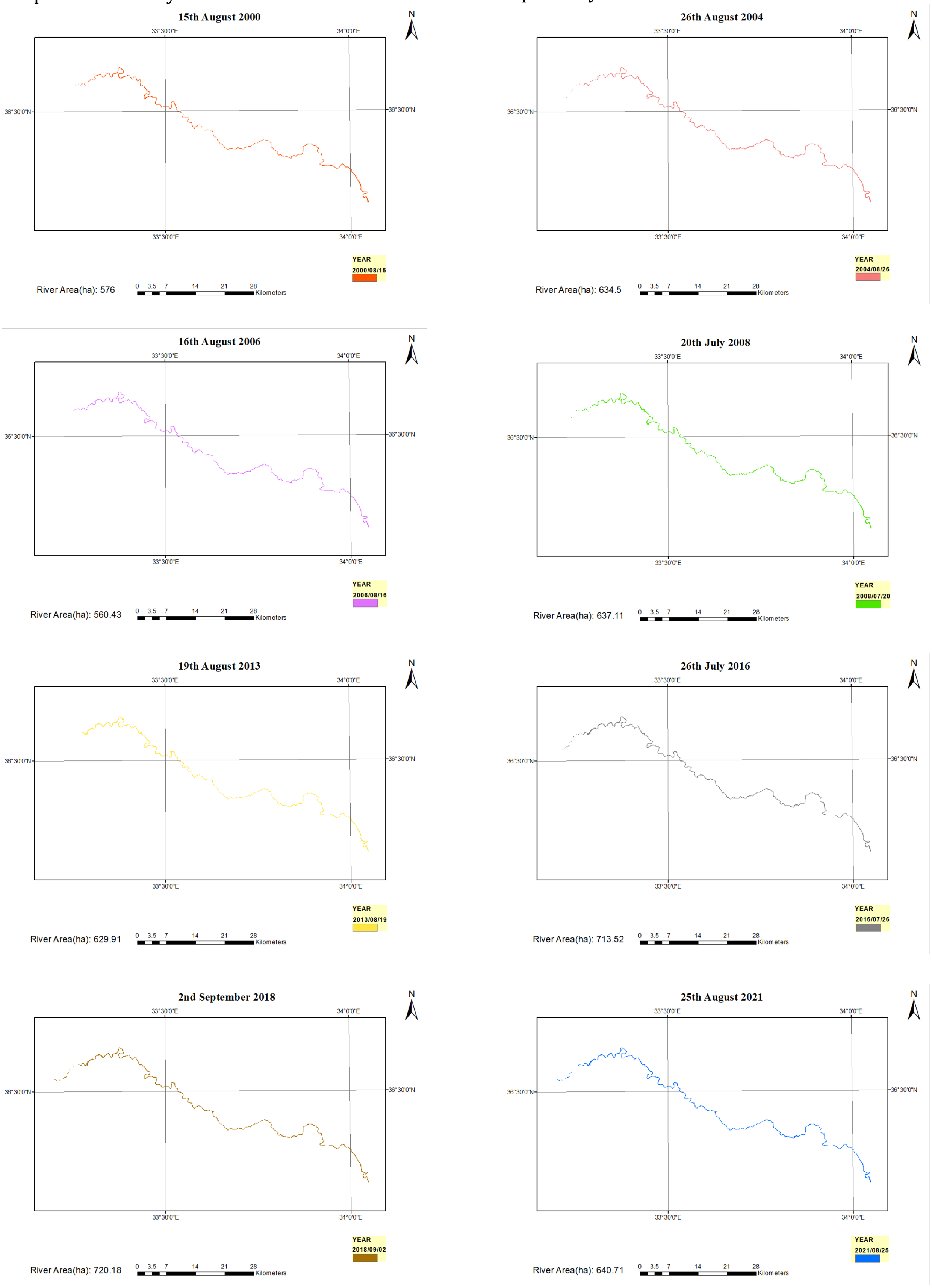

Figure 6. Classified Map of River Area

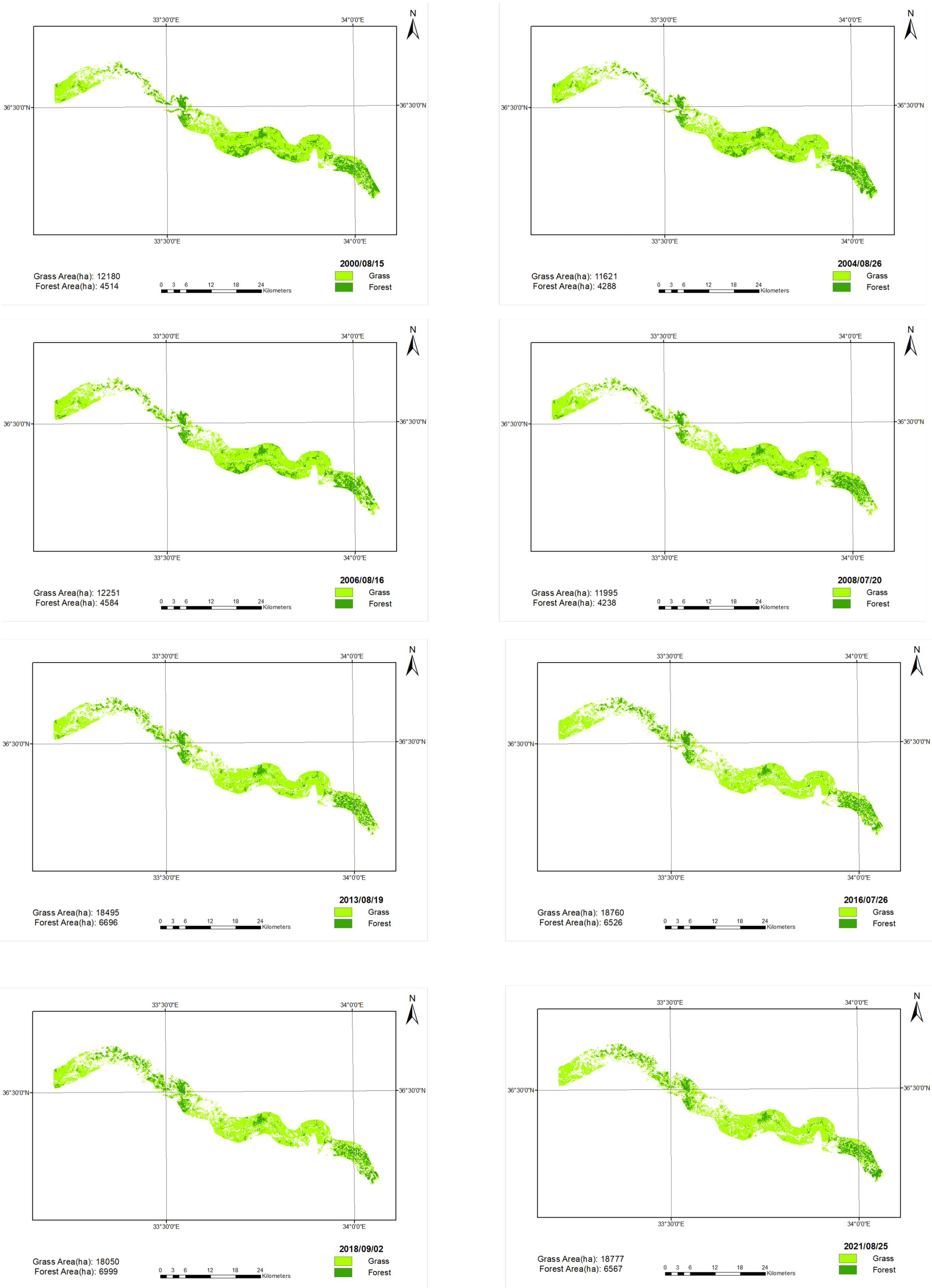

Figure 7. Classified Map of Vegetation Area

3.5. Accuracy Assessment

Determining the wavelength to be used in the unsupervised and supervised classification process, the sufficient accuracy and number of control areas, the classification algorithm and testing its accuracy are extremely important for the reliability of the actual study (Örmeci and Ekercin 2005). Testing the accuracy of the classification, the data produced It is based on the principle of statistically checking its accuracy. Accuracy analysis of the classification process applied to the Göksu River was carried out. Accuracy analysis was performed using the error matrix method. The findings obtained as a result of the analysis are as given in Table 3.

3.6. Change Determination

Within the scope of the study, satellite images of Göksu River were made comparable after all processing steps that would allow interpretation. Then, the changes of vegetation and river areas were determined. River Area changes are given in Fig. 8, Vegetation Area changes are given in Fig. 9.

Table 3. Accuracy Rate of River and Vegetation Region

Dates	Accuracy Rate of	
	River Region	Vegetation Region
15th August 2000	80.00%	87.00%
26th August 2004	84.00%	83.00%
16th August 2006	83.00%	87.00%
20th July 2008	85.00%	93.00%
19th August 2013	92.50%	88.00%
26th July 2016	93.75%	89.00%
2nd September 2018	97.50%	84.00%
25th August 2021	90.00%	82.00%

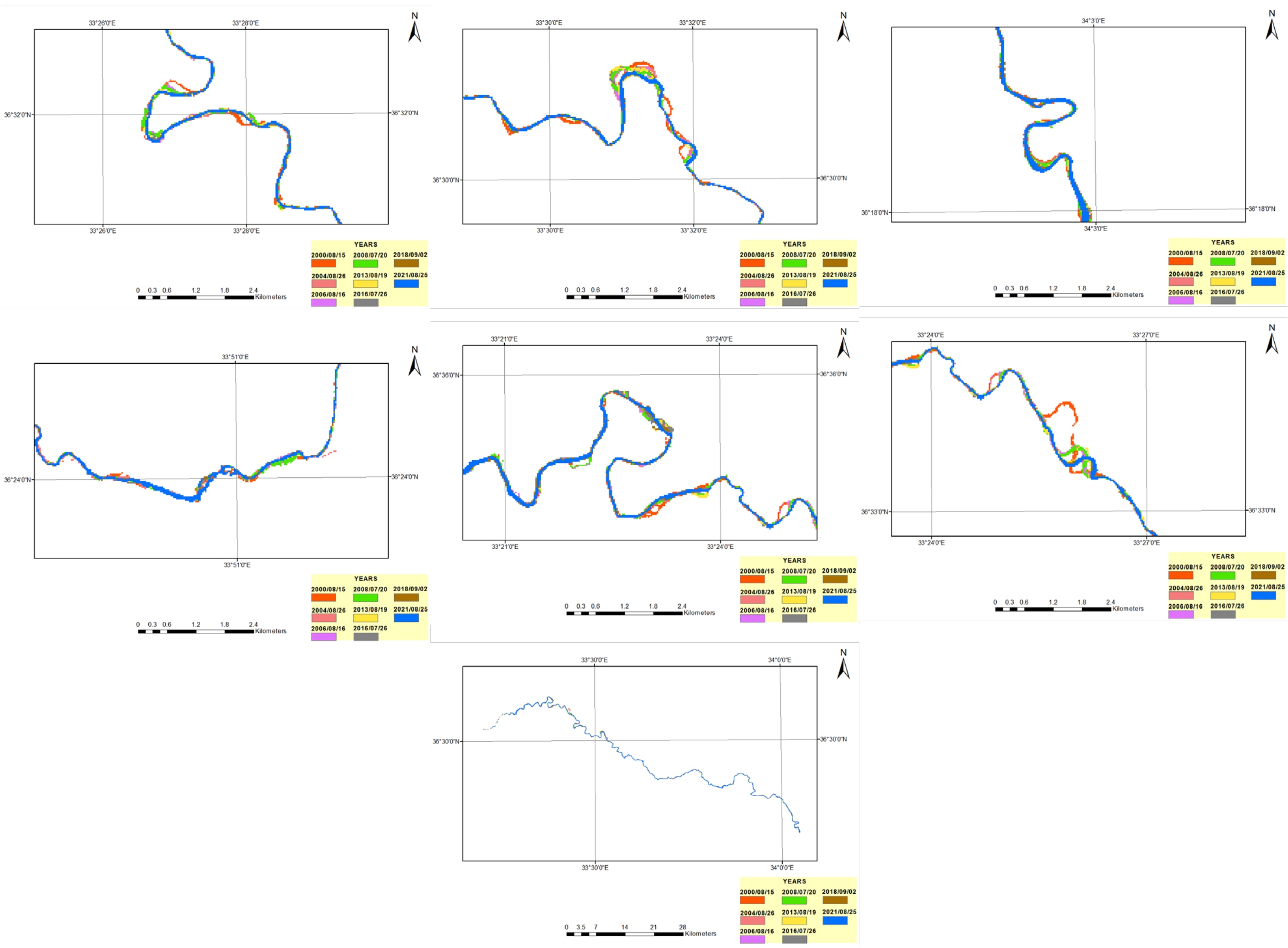

Figure 8. River Area Change Detection

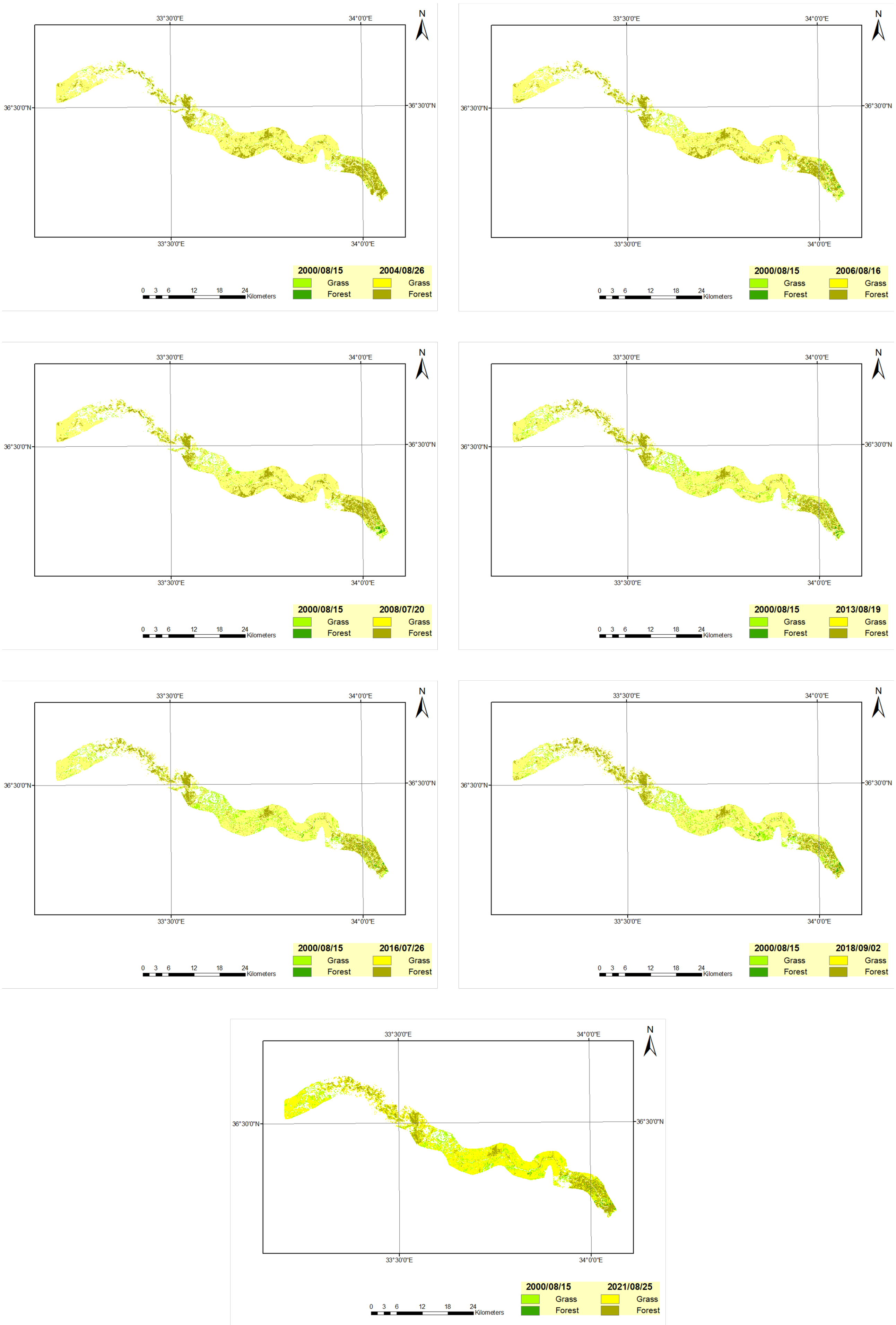

Figure 9. Vegetation Area Change Detection

As a result of the change analyzes applied, the change of the area of the river according to the years is given in Table 4 and Fig. 10.

Table 4. River Areas by years

Date	River Area(ha)
2000/08/15	576.00
2004/08/26	634.50
2006/08/16	560.43
2008/07/20	637.11
2013/08/19	629.91
2016/07/26	713.52
2018/09/02	720.18
2021/08/25	640.71

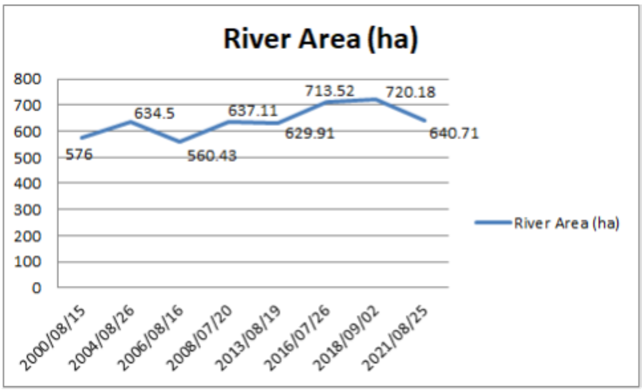

Figure 10. Graph of River Area by years

As a result of the change analyzes applied, the change of the area of the vegetation according to the years is given in Table 5 and Fig. 11.

Table 5. Grass and Forest Areas by years

	Grass Area(ha)	Forest Area(ha)
2000/08/15	12180	4514
2004/08/26	11621	4288
2006/08/16	12251	4584
2008/07/20	11995	4238
2013/08/19	18495	6696
2016/07/26	18760	6526
2018/09/02	18050	6999
2021/08/25	18777	6567

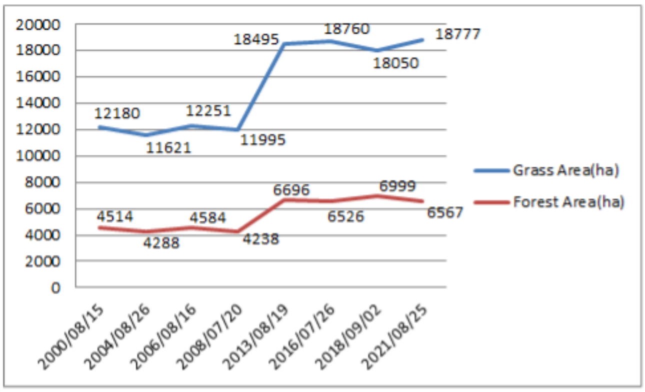

Figure 11. Graph of Grass and Forest Areas by years

4. Conclusion

In our country, remote sensing technology is widely used in monitoring wetlands and detecting changes over time (Özçalık et al. 2020). Monitoring lake areas is a relatively new science. Climate change, excessive water use, etc. For these reasons, the lakes are under the threat of drought (Kaplan et al. 2016). In this study, the 260 km long Göksu River, which is a river flowing through the provinces of Antalya, Konya, Karaman and Mersin and pouring into the Mediterranean in the south of Silifke district of Mersin province, was chosen as the analysis area. Analyzes were carried out using Landsat satellite images and multi-band satellite images recorded by satellite sensors were evaluated for the purpose of examining lake surface water. Satellite technologies, which provide spatial information about certain characteristics of lakes, offer services that can complement ground-based monitoring programs at lower cost (Cüce and Bakan 2009). Firstly, the satellite images, which were subjected to image preprocessing steps, were made ready for analysis after necessary corrections were made. The change of the Göksu River surface water over the years was examined through the satellite images that were prepared for analysis.

Data for the years 2000, 2004, 2006, 2008, 2013, 2016, 2018 and 2021 have been downloaded. The downloaded data are for the months of July, August and September. While downloading the data, it was preferred that the dates be close to each other in terms of day and month. NDWI, NDVI and unsupervised classification images were obtained with images cut from this data. The threshold value applied during the processing of the indices was chosen according to the pixel values of the water and vegetation in the image. Images with applied NDWI and NDVI indices were used for unsupervised classification. During unsupervised classification, images were divided into 2 classes to separate the river area and 5 classes to separate the vegetation area. Of these 2 classes, 1 was chosen as a river and 2 out of 5 classes was chosen as a vegetation area. Accuracy assessments and area calculations were made on the classified data. The accuracy rate for the river area has ranged from 80% to 97.50% over the years. For vegetation, it was between 82% and 93%. And these results are quite satisfactory for this project. It was determined that the reason for the low level of riverbed change in the southeast part of the study area was urbanization. Likewise, it was determined that the forest area in the same region was mostly the parcels where fruit and vegetable trees were grown. Apart from these, it is thought that one of the reasons for the change in the riverbed is the Ermenek Dam, which was opened in 2009.

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Author Contributions

Hakan Satılmış: Conceptualization, Methodology, Visualization, Investigation, Writing
Özşen Çorumluoğlu: Reviewing and Editing, Investigation
Elif Akyel: Writing-Original draft preparation, Data curation, Visualization, Writing-Reviewing and Editing.

Conflicts of Interest

The authors declare no conflicts of interest.

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