Investigation of Meteorological Effects on Çivril Lake, Turkey, with Sentinel-2 Data on Google Earth Engine Platform

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Abstract: Lakes and reservoirs, comprising surface water bodies that vary significantly seasonally, play an essential role in the global water cycle due to their ability to hold, store, and clean water. They are crucial to our planet’s ecology and climate systems. This study analyzed Harmonized Sentinel-2 images using the Google Earth Engine (GEE) cloud platform to examine the short-term changes in the surface water bodies of Çivril Lake from March 2018 to March 2023 with meteorological data and lake surface water temperature (LSWT). This study used the Sentinel-2 Level-2A archive, a cloud filter, the NDVI (normalized difference vegetation index), NDWI (normalized difference water index), MNDWI (modified NDWI), and SWI (Sentinel water index) methods on lake surfaces utilizing the GEE platform and the random forests (RFs) method to calculate the water surface areas. The information on the water surfaces collected between March 2018 and March 2023 was used to track the trend of changes in the lake’s area. The seasonal (spring, summer, autumn, and winter) yearly and monthly changes in water areas were identified. Precipitation, evaporation, and temperature are gathered meteorological parameters that impact the observed variation in surface water bodies for the same area. The correlations between the lake area reduction and the chosen meteorological parameters revealed a strong positive or negative significant association. Meteorological parameters and human activities selected during different seasons, months, and years have directly affected the shrinkage of the lake area.

Keywords: remote sensing; water surface area change; Sentinel-2; meteorological parameters; Google Earth Engine; Çivril Lake; Turkey

1. Introduction

Wetlands constitute the wealthiest and most productive ecosystems on earth. Wetlands, which have an essential place in the lives of the people living in the immediate vicinity, contribute to the region’s economy, the country, and the natural habitat. It has an essential and different place among other ecosystems in terms of protecting the natural balance and biological diversity. Wetlands play a vital role in water collection, irrigation, and wastewater management or water availability for flood protection, biodiversity conversion, fish stocks, safe drinking water supply, and water quality improvement. In addition, since wetlands are used as a food supply by birds and terrestrial animals, many bird species live in these areas [1]. Climate change and human activities may dramatically affect seasonal and annual variations in surface waters, which may also highly affect the resilience of the ecosystem and the long-term economic and social development of the lake and its surroundings [2,3]. With the decrease in water in wetlands, most aquatic plants stay out of the water, and fishing becomes impossible [1]. Therefore, a detailed mapping of the water surface area is required. Monthly, seasonal, and annual observations can be made in extracting the water surface area. As far as is known, monthly analyses have only been considered by [4–9], seasonality analyses have been evaluated by [7,10–18], and annual analyses have been assessed by [2,3,11,19–25].

The most important environmental problems in Çivril Lake, which is located in the Çivril District of Denizli Province, one of the critical wetlands of Turkey, and one of the
lake systems rich in aquatic plants, are the opening of the wetlands to agriculture [26] and the deterioration of the water budget balance due to incorrect water use [27], the use of intensive agricultural fertilizers and pesticides [28], and erosion and alluvium carried by rivers [27]. In addition, the decrease in organic matter and plant diversity coupled with an excessive increase in the number of individuals, namely the density of aquatic plants and invasive fish species (such as Israeli carp), are among the most critical problems in these lakes [27].

The release of water from Çivril Lake, which is a dam lake, and the evaporation in the summer months cause a decrease in the water budget in the lake. If some measures are not taken, it is predicted that the water level in the lake will decrease to the drying level, and the lake ecosystem will deteriorate. In the project supported by GEKA (Güney Ege Kalkınma Ajansı) in 2015, a feasibility study was carried out to prevent the lake’s drying, restore its biological diversity and make it sustainable, and contribute to the region’s economic development and the public’s benefit from the lake [28]. At the same time, some studies need to be conducted to have sustainable agriculture. These studies are to regulate agricultural activities and prevent the opening of new agricultural areas for a sustainable conservation–utilization balance in this geography, where climate change, dry periods, and water shortages will be experienced in the future [29]. It is essential to determine whether the lake surface area has decreased due to the inadequacy of the measures taken or the climate change affecting the world. If the measures taken are insufficient, the measures should be increased by meeting with the local managers, and the problems should be found and corrected.

A few studies have been conducted on the surface area of Lake Çivril [30,31]. One of these studies presented a new country-wide database to show the spatio-temporal changes in natural lakes over 20 km\(^2\). To extract the database of natural lakes in Turkey, the long-term lake water surface areas of Lake Van, Salt Lake, Burdur Lake, and Beyselhir Lake, and the short-term lake water surface areas of Sapanca Lake, Manyas Lake, Tersakon Lake, and Çivril Lake were determined. The long-term evaluation was performed with Landsat data in spring and fall at 5-year intervals from 1985 to 2020. The short-term evaluation was performed with Sentinel-2 images between March and September 2016 and 2020. According to the study, it is essential to recognize that each lake has unique properties influenced by various factors. Therefore, each lake should be studied on an individual basis. Long- and short-term assessments of lakes should be paired with meteorological data (temperature, precipitation, and evaporation) covering the years of inquiry to comprehend the cause-and-effect relationship [30]. In another study, Landsat data of 10 lakes in Turkey and trend analysis of their surface areas were examined. The analysis reviewed ten lakes in Turkey’s Lakes Region, specifically Acigol, Burdur, Aksehir, Yarisli Isikli, Beyselhir, Egirdir, Ilgin, Salda, and Karatas. NDWI was determined for each Landsat satellite image, and the water surfaces were removed using Otsu’s threshold technique from other details. The investigation discovered that all lakes’ F1-score values and overall accuracy were computed to be above 90%. Additionally, a correlation analysis was conducted to examine the connection between the variations in the surface areas of the lakes [31]. The seasonal and annual changes in Çivril Lake were examined, and it was determined that the causes of the decrease in the lake water surface area were both meteorological and human-induced.

However, all the available articles have relied on analyzing a few images to determine any decrease in the area. While determining the water surface areas, deciding on the suitable periods [30] for each year and the images with the same date in other years is complicated because sometimes no cloud-free images or images can be obtained. For this reason, the problems mentioned above can be avoided by using all available images during the year [3]. At the same time, in the seasonal evaluations, no evaluation was performed that included all four seasons in a whole year. In the seasonal evaluations, spring and summer months were considered [30,31]. However, it is essential to have a more detailed and frequent monitoring system to accurately capture the subtle monthly changes in water bodies. Monthly time-series analyses are needed to determine the change in water surface
area within and between years. In the monthly satellite-based monitoring of water surface areas, meteorological data should be included in the study [16]. Studies on the changes in water surface area should also consider surface water temperature (SWT), a crucial variable that affects numerous environmental processes and the global energy balance [2]. The temperatures of lakes worldwide are increasing at an alarming rate, which is expected to adversely affect aquatic ecosystems [32]. Several studies have been conducted on the temperature of the lake’s water [2,33].

Due to this, a comprehensive study is needed to determine the effect of meteorological data on the variation in water surface areas using a sufficient number of satellite images taken over several seasons and years. More cloud cover and haze might decrease the number of usable images, which leaves inadequate data for monthly dynamic mapping. Consequently, the Sentinel-2 constellation’s potential application in water-body monitoring and dynamic analysis is an eagerly awaited exploration [16]. The Sentinel-2 mission is a highly effective and advanced project that utilizes multispectral imaging to capture high-resolution images over vast areas of Europe. The mission supports various services and applications, such as climate change, land monitoring, emergency management, and security. According to their entire mission specification, the twin satellites, which are in the same orbit but phased at 180°, are intended to provide a high revisit frequency of 5 days at the Equator [34]. With a resolution of 10 m, Sentinel-2 can accurately extract water distribution on land surfaces [16,35–39]. In studies to be carried out after 25 January 2022, the harmonized collection of Sentinel-2 is used. Sentinel-2 scenes with a processing baseline of ‘04.00’ or higher had their DN (value) range changed by 1000 after 25 January 2022. Therefore, the harmonized collection was chosen in its place. The harmonized collection changed the data range of more recent scenes to match earlier scenes [40]. The success of the harmonized Sentinel-2 image in determining the water surface area is a matter of curiosity.

All processes to determine the water surface area were carried out on the GEE. As the amount of geographic data grows, storage systems and the cloud have been developed to process the data. The Google Earth Engine (GEE) is a tool that facilitates geoprocessing and has attracted great interest from the academic and research world [41]. At the same time, the GEE platform has gained popularity in remote-sensing applications due to its ability to access many free satellite platforms and analyze large amounts of data [42]. The GEE platform offers support for both JavaScript and Python languages. It offers several advantages, including computing, analytical operations, data analysis, and the capacity to make maps and export these maps [43].

Currently, various machine-learning (ML) algorithms, such as decision trees (DT) [18], support vector machines (SVM) [44,45], and random forests (RFs) [12,23,46], have been utilized for wetland information extraction research. In the ref. [47] study, five ML algorithms were compared: K-nearest neighbor, RFs, maximum likelihood, SVM, and DT. The results showed that the RFs method had a high degree of accuracy and was particularly useful for classifying wetlands with remote sensing.

This study aims to examine the spatial and temporal changes in the water surface areas of Çivril Lake in the short-term from March 2018 to March 2023. The GEE cloud computing platform was used to extract and analyze the seasonal variation in the water surface area of Lake Çivril. This was performed by using the time series of harmonized Sentinel-2 imagery. To increase the classification accuracy, the NDVI, NDWI, MNDWI, and SWI indices related to water were used to determine the areas with and without water using the RFs method. Another purpose is to investigate the relationship between changes in lake water surface and LSWT with meteorological parameters (precipitation, evaporation, and temperature) to make it easier to comprehend what causes changes in surface water. This study presents and evaluates the statistical relationship (correlation matrix) between climatic variables, LSWT, and the reduction in lake area.
2. Materials and Methods

2.1. Study Area

This study is related to Çivril Lake, located in the Çivril district, the largest district of Denizli, in the southwest of Turkey. It is used for irrigation purposes, covering an area of 7028 hectares according to SAYBIS data. Işıklı (Çivril) Lake (38°14′ K, 29°55′ D) is one of the largest freshwater lakes in Turkey (Figure 1). Considering the region’s climate, summers are hot and dry, and winters are cold and rainy. Although Çivril Lake is a natural lake with a karstic structure, it has been converted into a dam lake to protect residential and agricultural areas from flooding. Çivril Lake has been given the status of Class A Wetland by the International Ramsar Convention and was registered as a “Wetland of National Importance” on 10 June 2016 [48]. Many sources, such as Kufi and dinar water, are moved into Çivril Lake. The lake’s waters are transferred to the Büyük Menderes River, located in the southwest. In this state, the lake acts as a regulator [29].

Figure 1. Study Area.

At the same time, this lake has been declared an important bird area as it provides a critical habitat and a spawning, hatching, and migration environment for waterfowl. However, natural life in the lake is seriously endangered due to the proximity of the lake to significant cities and the fact that hunters hunt all seasons without following the rules. In addition, groundwater is consumed unconsciously due to the drilling of boreholes around the lake without permission. At the same time, the lake water has been dramatically reduced due to the irrigation performed by randomly releasing the lake water to the fields. This decrease in the lake level has significantly increased the proportion of aquatic plants. Today, it is still used as a reservoir area for irrigation purposes. For all these reasons, it is essential that the lake does not dry out and its habitats are protected [27,49].

2.2. Datasets and GEE

Sentinel-2 is a wide-swath (290 km), high revisit time (10 days at the equator with one satellite and five days with two satellites under cloud-free conditions, resulting in 2–3 days at mid-latitudes), high-resolution multispectral mission that is polar-orbiting (consists of a constellation of two polar-orbiting satellites placed in the same sun-synchronous orbit,
phased at 180° to each other). Sentinel-2A launched on 23 June 2015, and Sentinel-2B launched on 7 March 2017. Each satellite is equipped with a cutting-edge, broad-swath, high-resolution multispectral imager with 13 spectral bands for a fresh viewpoint, such as observing interior waterways and coastal areas and observing plant, soil, and water cover (Table 1). From sci-hub, the Sentinel-2 L2 data are downloaded [32,50].

### Table 1. Band information of the Sentinel-2 Level-2A data.

<table>
<thead>
<tr>
<th>Band Name</th>
<th>Pixel Size (Meters)</th>
<th>Band Description</th>
<th>Band Name</th>
<th>Pixel Size (Meters)</th>
<th>Band Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>60</td>
<td>Aerosols</td>
<td>B8</td>
<td>10</td>
<td>NIR</td>
</tr>
<tr>
<td>B2</td>
<td>10</td>
<td>Blue</td>
<td>B8A</td>
<td>20</td>
<td>Red Edge 4</td>
</tr>
<tr>
<td>B3</td>
<td>10</td>
<td>Green</td>
<td>B9</td>
<td>60</td>
<td>Water vapor</td>
</tr>
<tr>
<td>B4</td>
<td>10</td>
<td>Red</td>
<td>B11</td>
<td>20</td>
<td>SWIR 1</td>
</tr>
<tr>
<td>B5</td>
<td>20</td>
<td>Red Edge 1</td>
<td>B12</td>
<td>20</td>
<td>SWIR 2</td>
</tr>
<tr>
<td>B6</td>
<td>20</td>
<td>Red Edge 2</td>
<td>QA60</td>
<td>60</td>
<td>Cloud mask</td>
</tr>
<tr>
<td>B7</td>
<td>20</td>
<td>Red Edge 3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This study uses the GEE cloud platform. The workflow of the methodology is shown in Figure 2. GEE provides programming, cloud storage, and graphical interfaces for remote-sensing studies [16]. It creates and runs scripts using a web-based integrated development environment (IDE). Furthermore, this integrated development environment (IDE) visualizes geographical research via the JavaScript application programming interface (API). One could utilize GEE libraries to construct programs in both JavaScript and Python. Satellite imagery is stored in a public data archive by Earth Engine, which includes historical earth images from the last forty years. These images are ingested daily and can be accessed for global-scale data mining. A helpful tool for studying spatial data is Google Earth Engine [31]. All the processing tasks were conducted in the GEE platform. Sentinel-2 data Level-2A products available at GEE were used; radiometric measurements per pixel in surface reflection were provided to convert them to radiation with all parameters [52]. This product does not need atmospheric correction [53]. The applications presented in this study focus on Çivril Lake. ALOS World 3D—30m (AW3D30) has been used to eliminate errors caused by the mountain’s shadow. It is a global digital surface model (DSM) dataset with a roughly 30 m horizontal resolution. In the Sentinel-2 Level-2A data is a QA60 band. Poor-quality images that were the result of cirrus and opaque clouds were removed from each image using the QA60 bitmask band with cloud information. Spectral criteria are used to calculate opaque and cirrus clouds [54]. The study collected Sentinel-2 Level-2A images with <10% cloud cover. A low cloud cover threshold (10%) was chosen to obtain high-quality images, which reduces the inclusion of omission errors in cloud/cloud shadow identification.

A lake’s surface water temperature, LSWT, determines its hydrology and biogeochemistry. Studying the temperature patterns of the lake over time can offer valuable information about the impact of climate change on the region. A correlation is established between the decrease in the lake surface area and the increase in LSWT measurements [55]. One of the most extensively used types of remote-sensing data is Landsat imagery, which is frequently used in (Land Surface Temperature) LST research. Using the Landsat 8 OLI/TIRS thermal bands, this study produced LSWT data for the lake [56].

The average surface temperature of the world has risen during the previous century. Therefore, it is predicted that climate change will negatively affect water systems. There is a relationship between the decrease in water surface area and meteorological parameters that is either positive or negative [3]. This study looked at possible relationships between water surface area and LSWT with meteorological variables, such as temperature, evaporation, and precipitation, using the ERA5-Land and CHIRPS Pentad monthly satellite datasets. Monthly precipitation data were collected from the “CHIRPS Pentad: Climate Hazards Group Infrared Precipitation with Station Data (Version 2.0 Final)” system, a system that
includes ground-based observations and satellite data [57]. Evaporation and temperature data were also taken monthly from the ERA5-Land Monthly Aggregated—ECMWF Climate Reanalysis [58].

Figure 2. The workflow of the methodology.

In this study, Sentinel-2 images were evaluated annually, seasonally, and monthly for 5 years. Taking into account the Northern Hemisphere’s meteorological seasons, the timeline of the obtained data was divided into four seasons. These are spring (March, April, and May), summer (June, July, and August), autumn (September, October, and November),
and winter (December, January, and February) [59]. The annual map covers four quarterly datasets starting in March.

2.3. Spectral Indices

In analyzing digital images of a geographic area, mathematical operations, such as addition, subtraction, and multiplication, can be carried out on the pixel data of two or more spectral bands [60]. These mathematical operations, called the water index, are also used to extract the water fields. The water index can be combined with other remote-sensing indices to accurately distinguish water from non-water with precision water extraction [2]. This study used spectral indices with a near-infrared (NIR) band, which reduces water reflection, and a green band, which increases water reflection. As in the study area, wetlands may have muddy and shallow water bodies, especially after rainfall. In addition, vegetation indices can prevent shadow effects [61] and cause the misclassification of vegetation [11] when determining water areas. Except for their greater reflectance in the VIS bands, ice and snow show a similar spectral trend to water bodies (from VIS to NIR and SWIR). Therefore, the blue band (>0.5) is utilized in mountainous places to eliminate ice and snow cover [16].

Each time-series image collection image in the study had four spectral indices added to it. Table 2 shows a list of the indices, including the NDVI [62], NDWI [63], MNDWI [64], and SWI [65]. The new composite image was created with these four indices. The GEE platform conducted all the pre-processing tasks of building the composite image.

<table>
<thead>
<tr>
<th>Water Indices</th>
<th>Literature</th>
<th>Bands</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDWI</td>
<td>[63] (McFeeters, 1996)</td>
<td>B8, B4</td>
</tr>
<tr>
<td>MNDWI</td>
<td>[64] (Xu, 2006)</td>
<td>B3, B8</td>
</tr>
<tr>
<td>NDVI</td>
<td>[62] (Rouse et al., 1974)</td>
<td>B3, B11</td>
</tr>
<tr>
<td>SWI</td>
<td>[65] (Jiang et al., 2021)</td>
<td>B5, B11</td>
</tr>
</tbody>
</table>

2.4. Random Forests

RFs are a standard ML algorithm. Its use in data classification has been reported by Breiman [66]. This method is based on the principle that many individual decision trees form a decision forest by integration. The algorithm combines random features or a combination of random features to create a tree. The bagging method is used to create training samples. At the next stage, after the bagging method, each selected feature is randomly drawn by changing N samples. N is the size of the original training set. The final prediction outcome is determined by voting after the predictions from various decision trees have been integrated [67].

2.5. Evaluation Metrics

The RFs method was used to classify the new composite image created with the four indices on the GEE platform. Approximately 100 points were randomly selected yearly, seasonally, and monthly for the classification method. The accuracy points were compared to the lake’s NDWI image to determine the water’s location. This comparison confirms the effectiveness of the lake water area extraction method and the accuracy of the extracted lake area data. Standard metrics, including user’s accuracy (UA), producer’s accuracy (PA), overall accuracy (OA), and Kappa, were used to evaluate the performance of the classification method used to determine the lake area. The Kappa coefficient measures the variances between the data expected and observed rates. It is well recognized that a coefficient more significant than 0.8 implies adequate confidence in the model’s performance [68,69].

2.6. LSWT (Lake Surface Water Temperature)

It provides a GEE code that enables the LST derivation from the Landsat Collection 1 Level-1 thermal infrared bands [56]. The statistical mono-window (SMW) technique was the foundation for the LST method, which was used. The Climate Monitoring Satellite
Application Facility (CM-SAF) developed this technique to retrieve LST climate data records from Meteosat First- and Second-Generation satellites [70]. The method only uses one thermal infrared band (specifically, band 10 for Landsat 8) to achieve consistency across all Landsat series. This strategy uses the ASTER Global Emissivity Dataset (GED) database and a Landsat NDVI-based vegetation cover correction method [55]. MODIS LST data were used to validate the LSWT results due to the lack of a ground station at the test site.

3. Results

3.1. Extracted Lake Surface Accuracy Assessment

In this study, the water surface areas of Çivril Lake were obtained annually, seasonally, and monthly from Sentinel-2 Level-2A images. To demonstrate the accuracy of the findings, the data extracted from the study region-based Sentinel image segment were compared point-by-point with the NDWI images for water surface area maps. The range of the NDWI scale is \(-1\) to \(+1\) with NDWI > 0 denoting water and NDWI < 0 denoting no water. Sentinel-2 images from March 2018 to January 2023 were used. The study started in March 2018 because Level-2A products have been systematically produced in the ground segment throughout Europe since March 2018 [71].

Table 3 shows the lake area’s accuracy values for UA, PA, OA, and Kappa. Five years of calculating a confusion matrix for the lake’s water surface area yielded results with an OA of more than 98% and PA and UA of more than 94% for the water areas. In addition, the Kappa coefficient values are close to 1 and represent complete compliance. The OA of the results in the seasonal evaluation for the water areas was greater than 96% with the PA being 95% and the UA being greater than 94%. The values of the Kappa coefficient exceed 91%. The OA of the results in the monthly evaluation for the water areas was greater than 95% with the PA being 90% and the UA being greater than 91%. The values of the Kappa coefficient exceed 90%. All the parameters used in the accuracy assessment were calculated with an accuracy of over 90%, which indicates that the RFs method successfully extracted the water surfaces.

<table>
<thead>
<tr>
<th></th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake Area (km²)</td>
<td>32.11</td>
<td>31.23</td>
<td>28.77</td>
<td>26.72</td>
<td>23.73</td>
</tr>
<tr>
<td>OA</td>
<td>1</td>
<td>0.98</td>
<td>0.98</td>
<td>0.98</td>
<td>1</td>
</tr>
<tr>
<td>UA</td>
<td>1</td>
<td>0.94</td>
<td>0.96</td>
<td>0.98</td>
<td>1</td>
</tr>
<tr>
<td>PA</td>
<td>1</td>
<td>0.98</td>
<td>0.98</td>
<td>0.98</td>
<td>1</td>
</tr>
<tr>
<td>Kappa</td>
<td>1</td>
<td>0.96</td>
<td>0.97</td>
<td>0.96</td>
<td>1</td>
</tr>
</tbody>
</table>

3.2. Areas of Extracted Lake Surface

This study utilized the Sentinel-2 Level-2A archive; applied a cloud filter; calculated the NDVI, NDWI, MNDWI, and SWI; and applied the RFs method to extract the water surface area on the GEE platform. Due to the cloud filter, it has been found that Sentinel photos occasionally have ten images in a month. Other times, there are no images for several months because of a temporal resolution of 2–3 days. There are no images for January 2019, March 2021, and February 2022. However, the data on water surfaces evaluated between March 2018 and March 2023 were sufficient to show the general trend of changes in the lakes’ water area. The annual, seasonal (spring, summer, autumn, and winter), and monthly changes in water areas were identified. Figure 3 displays the annual change graphs for the lake’s surface area. While the lake area was 32.11 km² in 2018, it decreased to 23.73 km² in 2022. It is observed that the lake area decreases a little more each year. Since the lake’s surface area is small, the changes in the seasonal transitions are becoming more radical.
However, the data on water surfaces; 2022

Figure 4. Seasonal Lake Area.

The trend and temporal fluctuation in the lake area between March 2018 and March 2023 are displayed in Figure 5. When analyzing Figure 5, it was observed that September has the lowest monthly lake levels. On the other hand, February and March have the highest monthly lake levels in the area. When the five-year lake level is examined, it is observed that there is a general decrease.
Figure 5. Monthly Lake Area.

3.3. Relationship between Meteorological Parameters, LSWT, Spectral Indices, and Lake Surface Area

To comprehend each variable’s behavior in the presence of other factors, the relationship between the NDVI, NDWI, MNDWI, and SWI spectral indices employed in the classification of the lake region was investigated (Figures 6 and 7). Considering the correlation between the spectral indices used in the classification method, it was observed that there was a 0.92 relationship between MNDWI and NDWI, a 0.74 relationship between SWI and NDWI, and a 0.85 relationship between SWI and MNDWI. There is a negative relationship between NDVI and the other indices (p-value < 0.01). This negative relationship between NDVI and the other indices shows that while NDVI increases, other indices decrease. For this reason, it is observed that there is a strong relationship between NDVI and the other indices. This result showed that it is appropriate to use the NDVI index, one of the indices used to increase classification accuracy. The classifications for NDVI and the other indices shows that while NDVI increases, other indices decrease. For this reason, it is observed that there is a strong relationship between NDVI and the other indices. This result showed that it is appropriate to use the NDVI index, one of the indices used to increase classification accuracy. The classifications for

<table>
<thead>
<tr>
<th>Month</th>
<th>NDVI</th>
<th>NDWI</th>
<th>MNDWI</th>
<th>SWI</th>
</tr>
</thead>
<tbody>
<tr>
<td>March 2018</td>
<td>1</td>
<td>0.92</td>
<td>0.74</td>
<td>0.85</td>
</tr>
<tr>
<td>June 2018</td>
<td>0.9</td>
<td>0.5</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>September 2018</td>
<td>0.6</td>
<td>0.2</td>
<td>0.1</td>
<td></td>
</tr>
</tbody>
</table>

Tables 4 and 5 list the correlation matrix for the coefficient of correlation.
Correlation analyses between LSWT and water surface area and meteorological factors, such as temperature, precipitation, and evaporation, were performed, as observed in Figure 8, to show the effect of climatic effects on the time-series data. Correlation analysis was performed with LSWT and annual–seasonal–monthly water surface area and meteorological data (evaporation, precipitation, and temperature). The LSWT was compared with the water surface area obtained from Landsat satellite images, and R was estimated to achieve this goal. In addition, the meteorological data for the lake were collected from the ERA5-Land and CHIRPS databases. Only two of the 50 available variables in ERA5-Land (temperature above 2 m and total evaporation) were used in the research. Precipitation data were obtained from the CHIRPS database.

Based on the data from Figure 9, there appears to be a strong correlation of 0.96 between the monthly LSWT values and temperature. The relationship between LSWT and temperature values was found to be 0.98 seasonally and 0.86 annually.

Precipitation and evaporation are the other crucial meteorological variables. Çivril Lake has higher evaporation and lower precipitation, according to the statistics for these parameters for the lake (Figure 10). Based on the data from Figure 10, there appears to be a low negative correlation of −0.40394 between the monthly evaporation values and precipitation. The relationship between evaporation and precipitation values was found to be −0.53 seasonally and 0.69 annually. These results also demonstrate the importance of statistics, LSWT, temperature, and precipitation when analyzing the water surface area data.
A monthly correlation study analyzed data on water surface area, LSWT, and various climate variables, such as temperature, precipitation, and evaporation. Table 6 includes the R values obtained from the correlation analysis. The R values were classified as $1 > R > 0.8$ extremely high, $0.8 > R > 0.6$ strong, $0.6 > R > 0.4$ moderate, $0.4 > R > 0.2$ low, and $0.2 > R > 0$ very low. To determine the relationship between the parameters, a 2-tailed statistical significance test was conducted. The $p$-value (probability value) is commonly used to determine statistical significance. Calculating the $p$-value can determine whether there is a significant statistical correlation between the two given variables. A $p$-value of less than 0.05 is typically regarded as statistically significant, while one less than 0.01 is typically regarded as very statistically significant. The relationship between LSWT and water surface area values was found to be $-0.61$ monthly, $-0.58$ seasonally, and $0.32$ annually. A robust statistical correlation ($p < 0.01$) was found between the lake’s water surface area and LSWT every month, every year, and every season. During the monthly correlation analysis, it was determined that there was a strong relationship between LSWT and evaporation by 0.90 and an even stronger relationship between LSWT and temperature by 0.96. The seasonal correlation analysis also showed a 0.93 relationship between LSWT and evaporation and a 0.98 relationship between LSWT and temperature. The annual correlation analysis also showed a 0.87 relationship between LSWT and evaporation and a 0.86 relationship between LSWT and temperature. The monthly and seasonal analyses revealed a low to moderate negative correlation between the lake area and temperature, evaporation, and precipitation data. Temperature and evaporation show a highly statistically significant ($p < 0.01$) association with LSWT for the lake. The annual correlation analysis also showed a 0.75 relationship between lake area and temperature, a 0.74 relationship between lake area and evaporation, and a 0.33 relationship between lake area and precipitation.

Table 6. Annual, Monthly, and Seasonal correlation analysis.

<table>
<thead>
<tr>
<th></th>
<th>LSWT (°C)</th>
<th>Evaporation (mm)</th>
<th>Temperature (°C)</th>
<th>Precipitation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake Area (km²)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSWT</td>
<td>0.323351</td>
<td>0.738169</td>
<td>0.74871</td>
<td>0.332416</td>
</tr>
<tr>
<td>Monthly Correlation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lake Area (km²)</td>
<td>$-0.60633$</td>
<td>$-0.36548$</td>
<td>$-0.55065$</td>
<td>0.498379</td>
</tr>
<tr>
<td>LSWT</td>
<td>1</td>
<td>0.903352</td>
<td>0.964479</td>
<td>$-0.50364$</td>
</tr>
<tr>
<td>Seasonal Correlation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lake Area (km²)</td>
<td>$-0.579663$</td>
<td>$-0.329132$</td>
<td>$-0.470574$</td>
<td>0.5994775</td>
</tr>
<tr>
<td>LSWT</td>
<td>1</td>
<td>0.9330413</td>
<td>0.9795878</td>
<td>$-0.731416$</td>
</tr>
</tbody>
</table>
Figure 9. Annual, seasonal, and monthly relationship of temperature and LSWT.

To further understand how climatic variables affect the lake surface area, Table 6 provides correlation matrices on a monthly, seasonal, and annual basis between each variable and the lake surface area. When seasonal and monthly correlation data are examined, it is revealed that evaporation does not affect the lake area. When the temperature, precipitation, and LSWT values were examined, it was concluded that there was a moderate relationship. All data between March 2018 and March 2023 were analyzed, except for the cases where no data were in the study, to determine the surface water in the lake area precisely.
The monthly relationship between LSWT and evaporation and precipitation.

4. Discussion

This study evaluated the RFs algorithm on lake water surface areas on the GEE platform. Studies in the literature have shown that the RFs algorithm can reliably classify wetlands with an OA of over 80% [72,73]. The results of this study show that, using the RFs approach, the water pixels can be retrieved successfully with an overall accuracy of more than 95% for the lake area, which is in line with the literature. It is thought that the reason for obtaining OA classification results above 95% in this study is the four indices used.

The evaluations of the size of Çivril Lake show a downward trend, which is in line with the literature [27,29–31]. In one of these studies, spatiotemporal statistical analyses of water area changes of ten lakes in Turkey, including Çivril Lake, were performed using Landsat satellite imagery, considering the meteorological variables. As a result of these analyses, the lake area in 1985 was 4411.61 ha, and the lake area in 2022 was 3133.42 ha [29]. In this manuscript, the lake surface areas were found to be 32.11 km$^2$ in 2018, 31.23 km$^2$ in 2019, 28.77 km$^2$ in 2020, 26.72 km$^2$ in 2021, and 23.73 km$^2$ in 2022 using harmonized Sentinel-2 satellite imagery. It can be claimed that these results confirm one another given that the spatial resolution of Sentinel satellite imagery is 10 m and that of Landsat satellite imagery is 30 m. In another study, the lake area water changes in six lakes in Turkey, including Lake Çivril, were examined at 5-year intervals with Landsat satellite imagery for 35 years with long-term, 7-month intervals with Sentinel satellite imagery for 5 years. In parallel with this manuscript, the lake water areas were found to decrease. Unlike this manuscript, long-term evaluations were performed by considering the spring and autumn periods, while short-term evaluations were performed by considering the months of March–September. Since the lake change between March and September is examined in this study, the lake water change in other months is unknown. In addition, they did not consider the meteorological data for Çivril Lake, which they examined in the short-term in their studies, and could not fully reveal the reason for the decrease in the lake area [30]. In this manuscript, the lake water exchange was determined in detail with all the data obtained during the year. In this way, unlike the other studies, the behavior of the water surface area change in Çivril Lake in different seasons and months has been determined in detail. In another study, the change in EUNIS habitat classes for Çivril Lake and Gölgöl for the years 1990, 2000, 2012 and 2018 was determined using the remote-sensing method. The increased agricultural lands between 1990 and 2018 and the resulting increased water demands put pressure on the wetlands of Çivril and Gölgöl, leading to decreased lake surface area and increased reeds [29]. In another study, the effect of the expansion of the agricultural fields around Çivril Lake was explained. Landsat TM images were obtained to examine the change in land cover of the lake between 1985 and 2010. Uncontrolled classification was applied to the August 1985 and 2010 images in the GIS environment. Accordingly, between 1985 and 2010, the irrigated agricultural areas around the lake increased by 100%. The
increase in irrigated agricultural areas caused the narrowing of Çivril Lake, according to the data in this manuscript, and triggered the increase in aquatic plants [27].

Among the reasons for the decrease in water surface areas are excessive water withdrawal due to the water supply to streams and even lakes themselves, using lakes for industrial purposes in salty lakes, and partly the effects of climate change on lakes of various natures. The observed decreases in the lake water area were mainly based on human-caused activities and meteorological effects. The significant decrease in the lake’s size has caused a severe decline in wetland habitats, drying out shallow areas crucial to waterfowl. At the same time, the increase in irrigated agricultural areas has caused the narrowing of Çivril Lake and has triggered the increase in aquatic plants [27]. It is noticed that the water surface area significantly increases during the winter and spring seasons, while the most significant decrease occurs during autumn. Analyzing the data every month may lead to some gaps, but it can help detect the visible changes in hydrology with greater accuracy in terms of time [16]. This study revealed that each lake has unique characteristics depending on various factors, and each should be examined separately. An individual study of the lakes reveals that many factors affect the well-being and sustainability of the lakes and natural conditions such as climatic conditions. To understand the reasons for the change in the lake, annual, seasonal, and monthly lake areas must be combined with meteorological data covering the years of the study (temperature, precipitation, and evaporation). To better investigate the cause of water losses in the lake, it is necessary to examine the meteorological data of the lake as well. This is to determine whether the water losses are due to climatic or human-caused activities.

In light of these studies, annual, seasonal, and monthly lake areas should be combined with the meteorological data (temperature, precipitation, and evaporation) that cover the years of the study to understand the causes of the change in the lake. This is an essential indicator for determining whether the water losses are due to climatic or human-induced activities. These mentioned human-induced causes are cutting the trees around the lake and transforming them into agricultural lands, increasing the settlement areas, establishing ponds in the upper parts of the lakes, and irrigating for agricultural purposes [29]. The investigated Çivril Lake is a dam reservoir lake with different conditions than natural lakes. Therefore, fluctuations in the water level are expected. The meteorological factors examined in this study affect the seasonal and annual variability of the reservoir surface. However, it can be said that human-induced effects affect the lake surface area change as much as meteorological factors.

5. Conclusions

From the results discussed above, we can express the following conclusions:

1. Water surface areas can be extracted using harmonized Sentinel-2 images.
2. Classification results with 95% OA were obtained using NDVI, NDWI, MNDWI, and SWI spectral indices and the Rfs method.
3. There is a negative correlation between NDVI and the other spectral indices. In the seasonal and monthly analyses, there is an extremely high relationship between NDVI and NDWI, a strong relationship between NDVI and MNDWI, and a strong relationship between NDVI and SWI in the seasonal analyses and a moderate relationship in the monthly analyses.
4. A strong and extremely high correlation relationship was found between LSWT, temperature, and evaporation in all analyses.
5. It was revealed that there is a negative but moderate correlation between the lake area and the LSWT in the seasonal and monthly observations. As a result, it was concluded that the LSWT variable affected the lake area change in the opposite direction.
6. There was a strong relationship between the lake area and evaporation in the annual analysis and a low correlation in the monthly and seasonal analyses. This result shows that the evaporation variable related to the lake area change is somewhat related.
7. There was a strong relationship between the lake area and the temperature in the annual analysis and a moderate relationship in the monthly and seasonal analyses. This result shows that the temperature variable related to the lake area change is related.

8. There was a low relationship between the lake area and precipitation in the annual analysis, moderate relationship in the monthly analysis, and a strong relationship in the seasonal analysis. This result shows that the precipitation variable related to the lake area change is related.

9. In small lakes such as Çivril Lake, which act as both a reservoir and a regulator, it was concluded that the lake water surface area should be determined by considering the meteorological data.

6. Recommendations

Decision-makers who want to develop sustainable agricultural and industrial water consumption policies must consider the conclusions of this research. These policies will help preserve water resources and prepare for possible climate changes.

For a sustainable conservation–utilization balance in this geography, where there will be climate change, dry spells, and water shortages in the future, it is vital to restrict agricultural activities and avoid the development of new agricultural areas.

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Conflicts of Interest: The author declares no conflict of interest.

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