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SPATIAL CHANGES OF THE COASTLINE OF DOJRAN AND PRESPA LAKES USING GIS AND LANDSAT IMAGERY

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ABSTRACT
Spatial changes of coastline of Dojran and Prespa Lakes using GIS and Landsat Imagery
The spatial changes that occur in natural lakes have a different features, from a hydrological character (change in lake level, surface, coastline) to microbiological level (flora and fauna in lake waters) as well as water quality. In this paper, we will mainly focus on physical-geographical changes, primarily on the surface of the lake and the displacement of the coastline and the volume of water. The main objective of this paper is understanding of the integrated application of various GIS techniques in monitoring numerous natural objects and their changes through space and time. Also, in this paper, the monitoring of the spatial condition of the Prespa and Dojran lakes during the period from 1985 to 2022, i.e. a period of 37 years, is covered. It is important to note that Dojran Lake has a history of long oscillations in the lake level and a drastic shift of the coastline and return to previous position. In contrast, the situation with Prespa lake is alarming because, in the last decade, the water level of the lake has been in continuous decline, and since it is mainly a shallow lake, the spatial changes, especially in the shifting of the coastline, are dramatic. This drastic change is a potential threat to the survival of one of the oldest lakes in the Republic of North Macedonia and Europe.

KEY WORDS
GIS, coastline, remote detection, Landsat, Prespa Lake, Dojran Lake.

1. Introduction

Water resources in the environment are under constant pressure from anthropogenic influences and climate changes. Lakes are an integral part of the water resources in the environment, and also they are water bodies conditioned by the formation of lake basins, where in geological history they are one of the water bodies and were formed in different parts of the Cenozoic era (Radevski 2021). In the past, lake observation methods were carried out directly on site, with sampling and measurement, which took a lot of time, laboratory materials, financial and human resources. With the application of Geographical Information Systems and techniques used such as Remote Sensing, they provide a new dynamic basis for the study of hydrographic objects, the changes that occur in space, which further facilitates the process of data collection, processing, execution of spatial and statistical analyzes and presentation of the processed data (Bao et al. 2011). Geographical Information Systems represent computer systems that enable input, export, analysis, and manipulation of spatial and associated non-spatial data (Delaney and Van Niel 2007). Geospatial and remote detection analyses are widely used for water body monitoring and the results can be helpful for decision-making and mitigating drought impacts (Elkollaly et al. 2017), investigation of the surface area of lakes and marches from satellite images (Dawood et al. 2018) and digitized on-screen from the satellite images for better accuracy (Valeyev 2019).

Unlike other large bodies of water such as oceans and seas, lakes, especially those that are naturally formed, are located inside the land, and they are filled with water from streams and rivers that flow into the lake and in areas where there is melting of the snow caps on the mountains.Therefore, the application of GIS and its techniques are of great importance for continuous monitoring of changes in the earth's surface over time (Kaplan et al. 2019). In addition to climatic factors, anthropogenic activities related to the change of water bodies, primarily on lakes, are represented by agricultural activities, construction of dams, and withdrawal of water for energy purposes and the population. The spatial change occurring in the lakes can be recorded by processing the satellite images or orthophotos, recorded in different periods. Following the change that occurs with the help of photogrammetry, Remote Sensing measurement is much more practical compared to classical topographical measurements. All of this allows all environmental and other physical-geographical problems to be observed step by step so that it is possible to quickly and efficiently calculate the dimensions and effects of the change of the lakes, (Temiz and Durduran 2016), precipitation distribution (Radevski et al. 2013), the parameters of Stage Frequency Analysis of the lakes (Radevski and Gorin 2014) and annual water level changes for lakes (Bonacci et al. 2014), which have enormous implication on the spatial changes of the lake coastline.

2. Study area

This paper covers the spatial changes that have occurred in the Prespa and Dojran Lakes in North Macedonia during the period from 1985-2022 year. They are natural lakes with a tectonic character, created by the tectonic-morphologic development of the terrain in the geological past (Figure 1). Prespa Lake is the second largest tectonic lake, located in the southwestern part of N. Macedonia, in the Prespa Basin between Baba Planina in the east and Galichica Mountain in the west, Suva Gora Mountain in the south and Gladno Pole in the southeast. Gladno Pole separates the Great from the Small Prespa Lake, while in the north the flat Resensko Pole limits the basin. In the southwestern part of the lake is the border between N. Macedonia, Albania, and Greece, so the lake is divided between these three countries. Prespa Lake occupies an area of 274 km^2, of which the N. Macedonia owns 176.8 km^2, Albania 49.4 km^2, and Greece 47.8 km^2. To the south of the Great Lake stretches the Little Prespa Lake. It has an area of up to 41.6 km^2, which nearly the entire lake belongs to neighboring Republic of Greece. The Prespa Lake it is filling with water from the Brest River, the Surlov River, and the Toplec spring in the northwestern part of the lake (Stojmilov 2011) (Figure 2a and Figure 2b).

The Prespa Lake was formed during the Tertiary period in the Pliocene when the The Prespa ridge was created along two almost parallel faults from the meridian direction and according to their character it represents a typical asymmetric trench and filled with water. The Prespa Lake subsided in four stages and today it expands to a height of 853 m, creating two lakes: The Great and the Small Prespa Lake. Prespa Lake has an elongated shape in the north-south direction. At 850 m. a.s.l. the length of the lake in the north-south direction is 28.5 km, and the greatest width is 16.9 km. A lower depth, in contrast to the neighboring Lake Ohrid, characterizes the lake since the central plain before the submergence had the characteristics of a karst field. Thus, the average depth of the lake is 18.8 m, and the largest is located in Golubina bay and is 54 m, and the length of the coastline is 100.1 km (Gramatnikovski 1975). The catchment area of Prespa Lake is 1,363.7 km^2, of which N. Macedonia has 761 km^2, while the remaining 602.71 km^2 are divided between Albania and Greece (MOEPP 2021). The Prespa Lake receives water from a large number of small tributaries such as the river Istok and Golema or Stara Reka, which flow into it from the north, and Pretorska, Kranska, and Brajchinska rivers and others. In the year 1963, the volume of water in the Great Prespa Lake was 4.86 km^3 and area of 287.5 km^2 (MOEPP 2021) a value that has not been changed until 1985, when the lake's shrinking trend started.

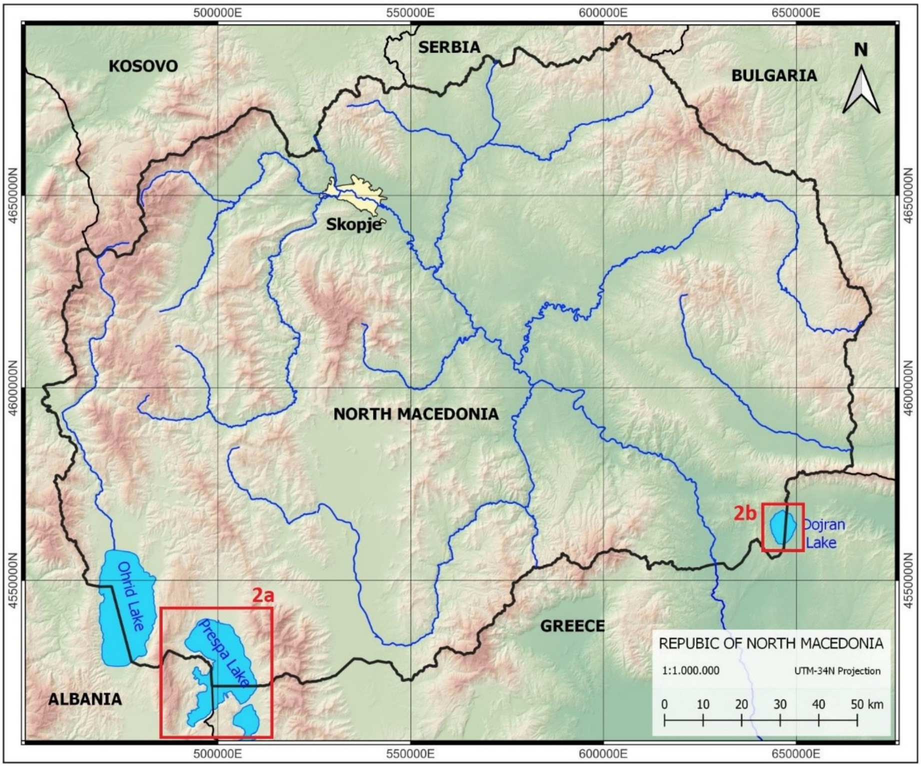

Figure 1: Geographic locations of Prespa Lake (2a) and Dojran Lake (2b)

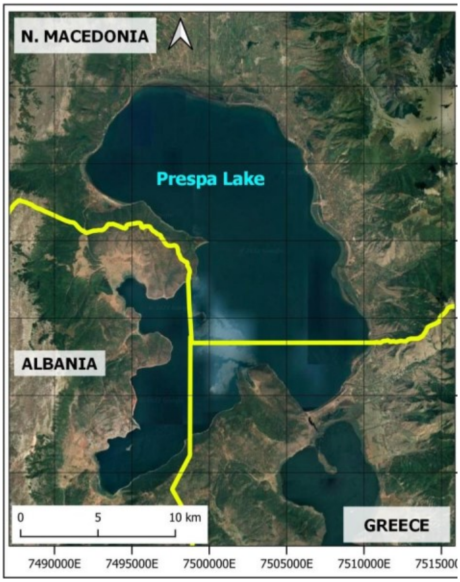

Figure 2a. Satellite image of Prespa Lake

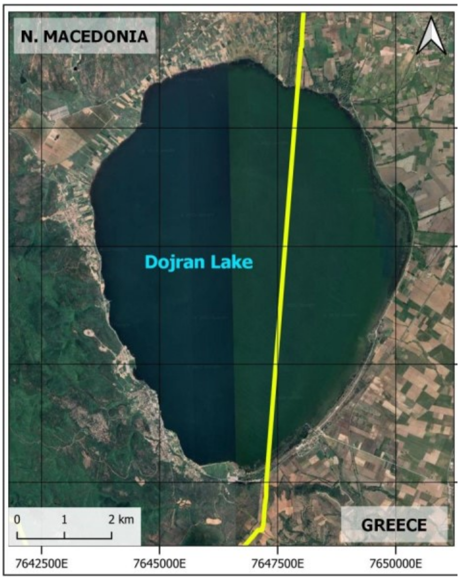

Figure 2b. Satellite image of Dojran Lake

Dojran Lake is formed in small and shallow lake basin, which is located in the Southeastern part of N. Macedonia. It spreads in the Dojran valley, created by the tectonic movement of land between Belasica, Krusha, and Kara Bali mountains, which created its basin. The creation of Lake was during the Pleistocene epoch, and at that time, with its size, shape, and depth, it stood out markedly from the terrain. The current Dojran Lake is a remnant of the once large Peon Lake (Stojmilov 2011), which up to today's level of 148 meters, covers a typically elliptical shape with an area of 43 km^2 (at a level of 148 m absolute height), of which in the territory of N. Macedonia are 27.4 km^2, and Greece 15.6 km^2. The greatest length in the north-south direction is 8.9 km, and the greatest width, in the east-west direction, 7.1 km. According Stojmilov (2011), the maximum depth of the lake is 10.4 m, and the average depth is 6.7 meters. Nearly 262 million m^3 of water has accumulated in the shallow lake basin (Bonnaci et al. 2008). The coastline length of Dojran Lake is 26.5 km, of which N. Macedonia have 15 km of the coastline, while 11.5 km of the coastline is in neighboring Greece. The total area of the catchment area is 271.8 km^2, of which 32% belong to N. Macedonia and 68% to neighboring Greece (Popovska et al. 2005).

3. Materials and methodology

Remote Sensing has an imminent detection in monitoring changes in space, before rounding up to coastal changes (Klemas and Yan 2014) observed the changes that occurred in the coastlines using variety of remote sensing different Remote technics with spatial, spectral, radiometric, and temporal resolution, while monitoring the changes of Lake Urmia, based of Landsat imagery (Srokhabi 2021) was proceed. The more recent series of Landsat 8 satellite images, with the better-represented sensors, were used in the study of the extraction of the coastal zones of the Bodrum Peninsula, in Turkey (Colak et al. 2019). In this paper, in order to investigate the changes in water bodies and the dynamics of shifting of the coastline, satellite images used for the territory of Dojran and Prespa Lakes, in the period from 1985 to 2022, a period of 37 years. Landsat 4-5 TM satellite images used for 1982 and 1992, Landsat 7 ETM+ for 2002 and 2012, while for 2022, Landsat 8 OLI/TIRS series satellite images were used. The previously mentioned series of satellite images were downloaded from the United States Geological Survey (USGS). Landsat 4-5 TM imagery is achieved at 30m resolution, while Landsat 7 ETM+ satellite imagery has 30 m and 15 m resolution; Landsat 8 OILI/TIRS have 30 m and 15 m resolution. The time series of the satellite images are selected in similar or very close time frames, in order to have a closer uniformity between the spaces, since it is still a matter of two different paths of images. In order to avoid covering the satellite images with clouds, the strips of months when the cloudiness in that period of the year is the least were selected (Tables 1 and 2).

Table 1: Satellite series for Prespa Lake.

Satellite Images for Prespa Lake						
Year	Satellite	Sensor	Resolution	Path	Row	Projection/Date
1982	Landsat 4	MSS	30	185	32	UTM / WGS-84
1992	Landsat 5	TM	30 (120)	185	32	UTM / WGS-84
2002	Landsat 7	ETM+	30 (15)	185	32	UTM / WGS-84
2012	Landsat 7	ETM+	30 (15)	185	32	UTM / WGS-84
2022	Landsat 8	OLI/TIRS	10 (20)	185	32	UTM / WGS-84

Table 2: Satellite series for Dojran Lake.

Satellite Images for Dojran Lake						
Year	Satellite	Sensor	Resolution	Path	Row	Projection/Date
1982	Landsat 4	MSS	30	184	31	UTM / WGS-84
1992	Landsat 5	TM	30 (120)	184	31	UTM / WGS-84
2002	Landsat 7	ETM+	30 (15)	184	31	UTM / WGS-84
2012	Landsat 7	ETM+	30 (15)	184	31	UTM / WGS-84
2022	Landsat 8	OLI/TIRS	10 (20)	184	31	UTM / WGS-84

The further procedure includes the application of the GIS software QGIS 3.16.14 LTR, where by applying the Normalized Difference Water Index (NDWI), converting the raster data set into vector data (polygons), on-screen digitalization of the coastline and software calculation of the surface of the lakes. All data is prepared and processed in UTM projection and WGS-84 geodetic datum. The cartographic interpretation and visualization of the data are performed on the previously mentioned GIS software QGIS 3.16.14 LTR.

4. Results and discussion

4.1. Prespa Lake

According to processed data from the satellite images of the Landsat series for Prespa Lake in GIS, it is recorded that Prespa Lake is characterized by significant spatial changes from 1985 to 2022, that is, the studied period of 37 years. According to the obtained data, it is noted that there is a trend of continuous reduction of the lake in relation to its condition in 1985. The calculated changes are shown in Table 3. where the surface and the perimeter, and the total length of the coastline, which is divided between North Macedonia and the neighboring countries Greece and Albania, are shown.

Table 3: Calculated statistic for Prespa Lake.

Year	Lake Prespa				
	Area_ha	Area_km^2	Perimeter_km	Length_km	Width_km
Year 1985	27,385	273.85	113.84	12.87	14.48
Year 1992	26,627	266.27	110.96	21.89	14.35
Year 2002	25,883	258.83	107.86	21.51	14.22
Year 2012	25,950	259.50	109.12	21.46	14.25
Year 2022	25,017	250.17	106.12	21.42	14.02

The level of Prespa Lake fluctuated a lot in the past (UNDP 2009). Thus, at the end of the 20th and the beginning of the 21st century, it was lower by 13-14 meters. In the middle ages, there was a medieval town of Prespa on the shores of Little Lake. According to the hydrological parameters of the lake measured on July 15, 1963, Prespa Lake, at an elevation of 851.53 meters, covered an area of 278.5 km^2 (MOEPP 2021). Twenty-two years later, in 1985, the lake covers an area of 273.85 km^2, the coastline is 113.8 km, the width is 14.5 km, and the length of the lake is almost 13 km. In the following seven years, there is a significant reduction of Prespa Lake by 7.58 km^2 resulting in a shift of the shoreline as much as 520 meters from its position in 1985 on the northern shore. The negative dynamic of reduction of the Prespa Lake is intensively recorded in the next ten years as well.

In year 2002, the lake occupies an area of 258.8 km^2, and the length of the coastline is reduced to 107.8 km. In the next ten years, stagnation is observed in the reduction of the lake, both in the surface of the lake and the level of the water level. In 2012, a slight increase in the surface of the lake by 0.7 km^2 was recorded, while the length of the coastline was 109.1 km. In the period from 2012 to 2022, a continuous drop in the lake level, a decrease in surface area, and a drastic change in the shoreline characterizes Prespa Lake by about 230 meters from its position in 2012. This change can also be observed with the data from the Ministry of Environment and Spatial Planning of the Republic of N. Macedonia published in a Report and analysis of the situation with Prespa Lake (MOEPP 2021). In 2022, from the processing of satellite images from Landsat 8, it is recorded that Prespa Lake occupies an area of 250.17 km^2 and a coastline of 106.12 km (Figure 3).

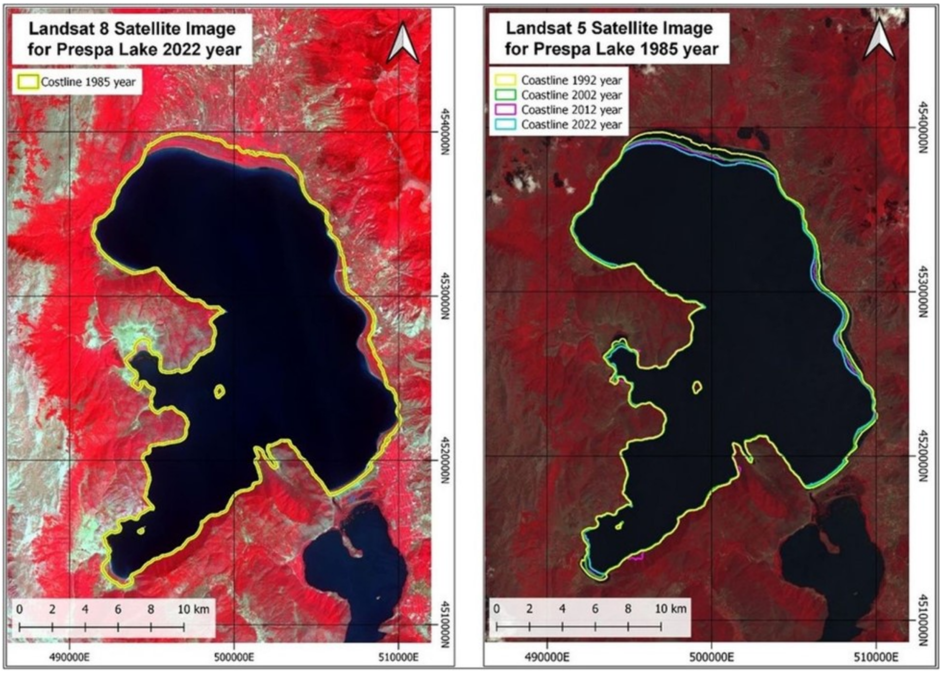

Figure 3: Comparison of situation between year 2022 (left) and year 1985 (right) through Landsat images and vector lines of the lake coastline.

In the period between 1985 and 2022, the shrinking trend results in a reduction of its surface by 23.7 km^2, a reduction in the length of the coast by 7.7 km. The reduction also results in shift of the coastline by about 1275 meters in the northern shore in near the village of Dolno Perovo, and for about 900 meters in the eastern coast near the village of Nakolec. In addition, if the data from 1963 are also taken into account, the surface of the lake has decreased by 28.3 km^2. The aforementioned spatial changes also affect the height of the water level. It should also be noted that in this paper, the spatial changes are analyzed using satellite images from the Landsat series, and that the calculated results are compared with published results for the lake levels of the Great Prespa Lake and Dojran Lake. In 1963, at 850 m. a.s.l. the accumulated amount of water in Great Prespa Lake is 4.86 km^3 (MOEPP 2021), a level that has not been much changed until 1985.

Using the formula for volume calculation for lakes, in 1992, at 847 m. a.s.l. the accumulated water was 4.05 km^3 or that is, a calculated loss of 810 million cubic meters of water.As we can see in the results in previous Table 3. an additional drop in the lake level was observed, and thus a decrease in the volume of the lake. In the year 2002, the water level was 844 m. a.s.l. with volume of 3.26 km^3 a further loss of 0.79 km^3 of water in just 10 years. In the year 2012, there is a partial stabilization of the lake, an increase in the level of the lake by one meter and an increase in volume by 0.260 km^{3}at 3.52 km^3, thus increasing the surface of the lake and thereby moving the shoreline of the lake (Figure 4). Then there is a significant trend of a drop in the level of the Prespa Lake by three meters, as a result of which its surface area decreases, and thus the volume of the lake decreases by an additional 0.76 km^3, reaching a volume of 2.76 km^3 in 2022.

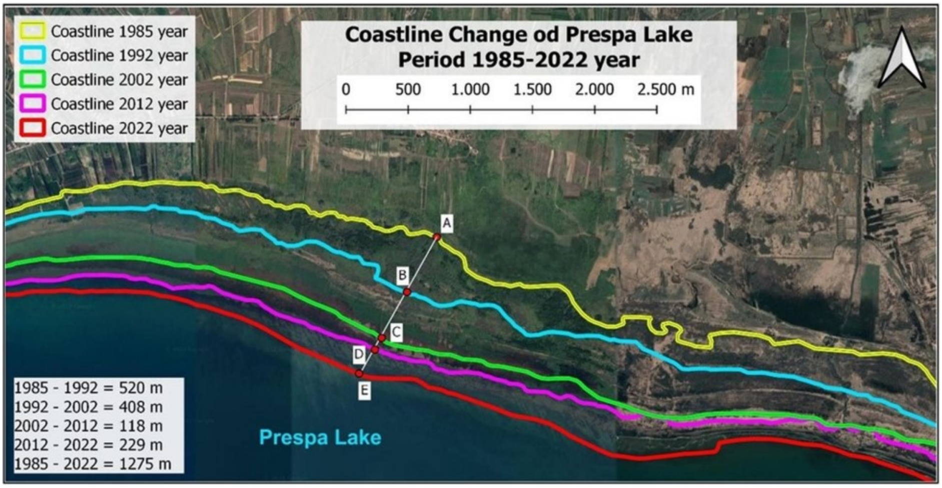

Figure 4: Comparison of northern coastline of Prespa between 1985 and 2022.

According to the processing of the satellite images, (Landsat images with a resolution of 30 meters and 15 meters for the panchromatic band), the level of the lake has decreased by 8 meters, while in terms of the calculated volume, and the lake has a loss of 2.10km^3 over a period of 37 years. According the Report and Analysis on The Situation of Prespa Lake, published in 2021 by Ministry of Environment and Physical Planning, thelake has shrunk by 9 meters, which represents a deviation of 1 meter on the lake level between two results.According to the Report on the State of the Environment for 2013, published by the Ministry of Environment and Physical Planning, as the year closest to 2012, the average annual water level of Prespa Lake is 844.56 meters, while the calculations from the analyzed satellite images give us a result of 845 meters, that is, an allowance of 34 centimeters. While according to the report on the state of the environment for 2021, the average annual water level of Prespa Lake is 842.14 meters, while calculations from satellite images give us a result of 842 meters.

4.2. Dojran Lake

According to the calculated results from the processed satellite images from the Landsat seriesof Dojran Lake in GIS, it can be noted that Dojran Lake is characterized by significant spatial changes from 1985 to 2022, that is, the studied period of 37 years. The calculated changes are presented in Table 4. where the surface and perimeter, i.e. the length of the coastline, are on both sides of the border between the Republic of Greece and the Republic of North Macedonia.

Table 4. Calculated statistics for Dojran Lake.

Year	Lake Dojran				
	Area_ha	Area_km^2	Perimeter_km	Length_km	Width_km
Year 1985	3,897.5	38.97	24.17	8.42	6.57
Year 1992	3,693.1	36.93	23.63	8.33	6.27
Year 2002	3,180.6	31.80	24.38	7.93	5.55
Year 2012	3,762.3	37.62	24.55	8.45	6.36
Year 2022	4,114.1	41.14	25.66	8.77	6.78

In 1985, the lake covered an area of 39 km^2, while seven years later, the lake decreased to 37 km^2. Towards the end of the 90s of the 20th century, the largest reduction of the Dojran Lake occurs. The most critical year of Dojran Lake is 2002 when its surface is 31.8 km^2, the perimeter of the coastline is 24.38 km long and it is characterized by the smallest width of only 5.55 km. These data coincided with the data from the project called “Spas on Dojransko Ezero”, where the water level in year 2002 (at zero elevation of 144.93) was 141.13 meters (Matlievska 2012), the lowest recorded elevation since the beginning of the level measurement on the lake. Due to the extremely low critical level of the lake, since it is still a shallow lake with an estimated depth of 6.7 meters, there was a possibility of the complete loss of a natural lake and the occurrence of an ecological disaster. Then, the authorities started the project for "Spas na Dojransko Ezero" (Rescue for Dojran Lake), with one main basic goal, providing additional quantities of water for Dojran Lake. In 2003, as part of the project, the hydro system "Gjavato" started working, and during the following years, there was a gradual stabilization of the level of the lake, which stopped the possibility of an ecological disaster (Matlievska 2012).

The repeated increase in the water level can be seen according to the data in Table 4, wherein the observed period, in 2012, the Dojran Lake covers an area of 37.62 km^2, i.e. an increase of 5.82 km^2, while the length of the coastline is 24.55 km. It can also be noted that the length of the ridge line in 2002 is similar to 2012, because in the extreme southeastern part of the lake, at the border crossing of Dojrani, during 2002, with the reduction of the lake, there was a greater spreading of the lake, that is, the creation of more shores towards the interior of the lake. In 2022, the lake has returned to the level of the 1980s, the lake area is 41.14 km^2, the coastline is 25.66 km, the maximum width is 6.8 km, and the length is 8.8 km (Figure 5).

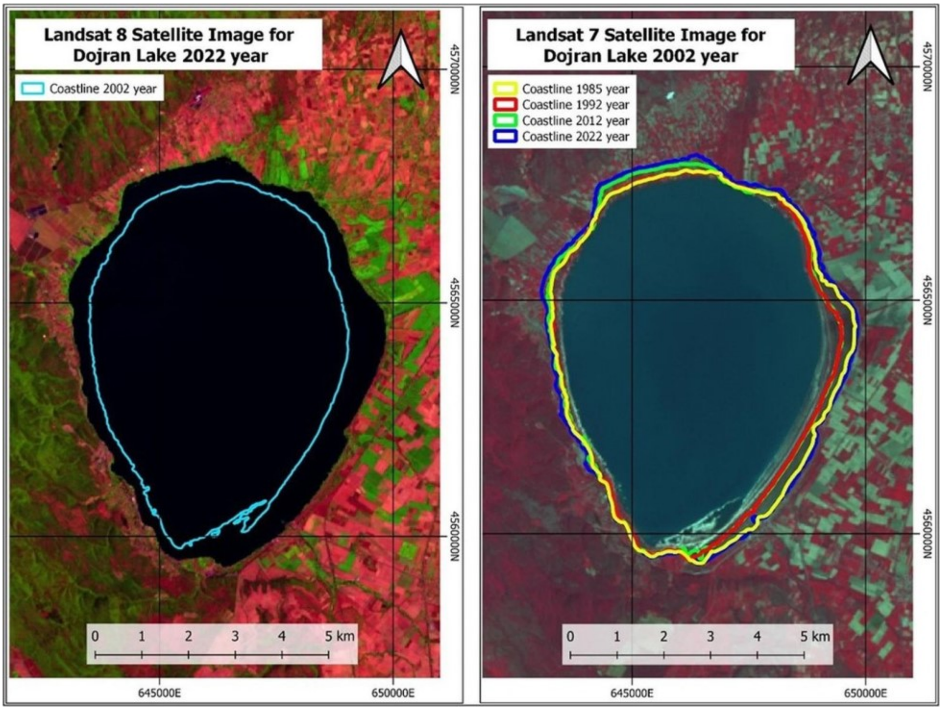

Figure 5. Comparison of situation between year 2022 (left) and year 2002 (right) through Landsat images and vector lines of the lake coastline.

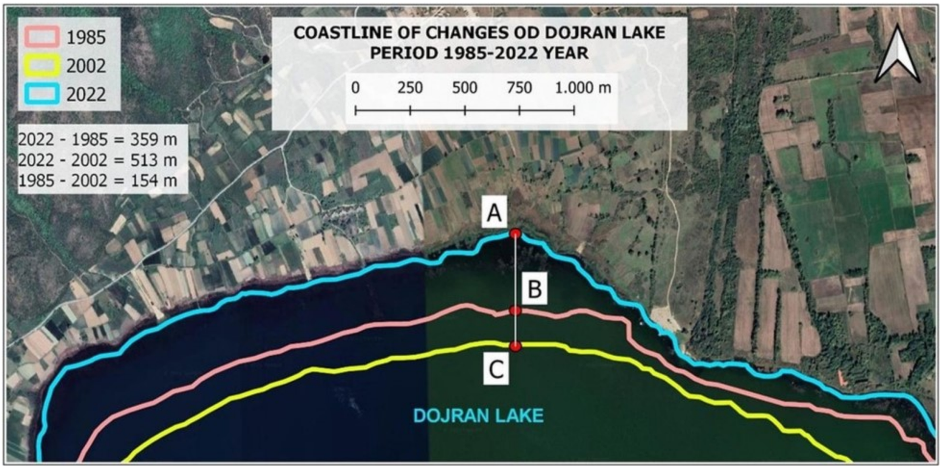

Figure 6. Comparison of northern coastline of Dojran between 1985 and 2022.

As can be seen (Figures 5 and 6), the spatial changes of Dojran Lake occur along its entire coastline, especially a noticeable trend of movement of the coastline is observed in the northern, eastern, and southern parts of the lake, where in certain places, the difference in the non-coastal location, the difference greater than 500 meters, and the reduced volume of Dojran Lake during the studied period. In 1985, at the lake level, Dojran Lake has a volume of 0.262 km^3. Seven years later, the level of the lake decreases by 3 meters and with it a drop to a volume of 0.148 km^3, that is a decrease of 0.114 km^3 (43.5%). According to the data from Table 4, the Dojran lake recorded an even more drastic retreat, the lake level dropped to 141 meters, while the volume was 0.0795 km^3 (a drop of 53.7% since 1992). After the launch of the hydro system "Givato" from the project "Spasna Dojransko Ezero", an increase in the lake level, an increase in the lake area, and an increase in the length of the coastlines (Table 4 and Figure 5) can be observed. According to the calculated data, the level rises to 145 meters, and the volume is 0.218 km^3 (an increase of 276.4%).Between 2012 and 2022, the level of the lake rises to 147 meters, surpassing the level of 1985, the surface of the lake increased to 41.14 km^2, and the volume increased to 297.3 km^3 (36.18% growth). This shows the significant fluctuation of the Dojran lake.

For comparison, according Bonnaci and Popovska (2008), the water level has decreased from 0.262 km^3 to 0.080 km^3 volume in 2002, the lake level has decreased from 146 m. a.s.l. in 1985 to 141.69 meters in 2002, while according to Panov (2004), the lake volume was little over 0.070 km^3. According to published data from the report on the state of the environment for 2003, 2013, 2021, from the Ministry of Environment and Physical Planning, the water level of the Dojran lake is 144.94 m.a.s.l. (year closest to 2002), 144.80 m. a.s.l. (year closest do 2012) and 146.96 for 2021 respectively.

5.Conclusion

This study aimed to investigate the historical trends and temporal changes of the coastlines, lake surface area, and rate of lake change, without delving deeper into the causes of decline and mechanism of lake change, by applying Landsat series satellite images and their processing in the software package QGIS 3.16.14 version. For the Prespa Lake, the results of the analysis showed a continuous trend of decreasing the lake in the last 37 years. The surface of the lake decreased from 274 km^2 in 1985 to 250 km^2 in 2022 (a loss of 8.75%), which resulted in drastic changes in the shoreline of about 1275 meters (period 1985-2022). These changes in the coastlines are also a result of the fact that the lake is shallow, so these changes in the level of the lake and its uneven surface affect the spatial arrangement of the coast itself. For the volume of water in Prespa Lake, a continuous decrease in the volume of water has been registered, from 4.86 km^3

in 1985 to 2.76 km^3 in 2022, i.e. a decrease of 2.10 km^3 for a period of 37 years, i.e. a decrease of 56.77% of the volume compared to year 1985. The results of the analysis of the recordings showed that the surface of Dojran Lake decreased from 39 km^2 in 1985 to 31 km^2 in 2002 (a loss of 20.5%), while in the period from 2002 to 2022, there is a repeated increase in the level of the lake and increasing its surface to 41 km^2 (growth of 32.25%) compared to 2002. The drastic spatial changes of the lake affected the shifting of the lake's coastlines. Since Dojran Lake is a shallow lake (average depth of 6.7 meters), small changes in depth result in large changes in the shoreline that vary up to several hundred meters compared to the previous state. Regarding the volume of the Dojran lake, significant fluctuations were measured in the period 1985-2022, where in 1985 we have 0.262 km^3, but in 2002, which was the most critical for the survival of the lake, the volume was 0.0795 km^3 (30.35 % of the situation in 1985). In 2022 we have a significant increase in the level of the lake, and thus the volume of the lake which reached 297.3 km^3 of water, which exceeds the level measured in 1985 by 13.47% more volume.

The monitoring of hydrographic objects, especially natural lakes, is of great importance to the ecosystem and the environment, which makes it possible to observe the spatial changes occurring in the space. Spatial changes can be analyzed using satellite images, which are an integral part of Remote Sensing, as an integrated technique for processing images with vector data in GIS, and the data gathered from the Landsat Satellite Imagery have an enormous impact in studying the hydrographic objects.

6.References

Bao, Y., H., Zhang, X. 2011: The study of lakes dynamic change based on RS and GIS - Take Dalinor Lake as an example. Third International Conference on Environmental Science and Information Application Technology (ESIAT 2011), Procedia Environmental Sciences 10 (2011) 2376 – 2384.

Bonnaci, O., Popovska, C., Geshovska, V. 2014: Analysis of transboundary Dojran Lake mean annual water level changes. Environmental Earth Sciences, Springer.

Bonnaci, O., Poposka, C. 2008: Ecohydrology of Dojran Lake.Part of the NATO Science for Peace and Security Series book series (NAPSC)

Colak. T. I., Senel, G., Goksel, C. 2018: Coastline Zone Extraction Using Landsat-8 OLI Imagery, Case Study: Bodrum Peninsula, Turkey. Fifth International Conference on Geoinformation Science – GeoAdvances, Casablanca, Morocco.

Dawood, A., Kalaf, Y., Abdulateef, N., Falih, M. 2018: Investigation of surface area of lakes and marshes from satellite images by using remote sensing and geographic information system integration in Iraq, MATEC Web of Conferences 162, 03016.

Delaney, J., Van Niel, K., 2007: Geographical Information System. Second Edition, Oxford University Press.

Elkolally, M, S., Khadr, M., Zeidan B, A. 2016: Meteorological Drought Analysis in the Eastern Nile Basin Using the Standardized Precipitation Index. Third International Environmental Forum, Environmental Pollution: Problem & Solution, Tanta University, Egypt.

Gramatnikovski, V. 1975: Natural-geographic, demographic and property characteristics of the Prespa Valley. Annual Proceedings, Book 21, Institute for Geography, Faculty of Natural Science and Mathematics, Skopje.

Kaplan, G., Avdan Z, Y., Avdan, U., Jovanoska T. 2019: Remote Sensing Techniques for Monitoring Shared International Waters; Study Case - Dojran Lake. Conference: International Disaster and Resilience Congress, Turkey.

Klemas, V., Yan X. 2014: Remote Sensing Techniques for Studying Coastal Ecosystems: An Overview. Seventh International Conference: Remote Sensing for Marine and Coastal Environments.

Landsat Satellite Imagery sourceUnited States Geological Survey: USGS Earth Explorer web site: https://earthexplorer.usgs.gov/

Matlievska, M. 2012: Overview of the Project "Save the Dojran Lake", University of Goce Delcev, (In Macedonian)

Ministry of Environment and Physical Planning (MOEPP): 2021: Report and Analysis on The Situation of Prespa Lake, (In Macedonian)

https://www.moepp.gov.mk/wp-content/uploads/2020/12/PRESPANSKO-EZERO_29.11.2021.pdf

Ministry of Environment and Physical Planning (MOEPP): Report on the State of the Environment for 2003, 2013, 2021. (In Macedonian)

Panov, N. 2004: Spasot na Dojransko Ezero. Vistina za proektot Gjavachko Pole. Selektor, Skopje (In Macedonian)

Popovska, C., Gesovska, V., Ivanoski, D. 2005: Ecological and Hydrological State of Dojran Lake. Vodoprivreda 0350-0519, 37 (2005) 216-218 p. 175-180

Radevski, I. 2021: Hydrology. University textbook, Ss. Cyril and Methodius University of Skopje, Faculty of Natural Science and Mathematics, Skopje. (In Macedonian)

Radevski, I., Gorin, S., Markoski, B., Dimitrovska, O., Todorovska,S. 2013: Spatial Precipitation Distribution In Prespa Basin (Republic Of Macedonia). Hilly-Mountain-Areas Problems and Perspectives, Ohrid, 12-15 IX 2013.

Radevski, I., Gorin, S. 2014: Stage Frequency Analysis on the Great Prespa Lake. 14th International Multidisciplinary Scientific GeoConference SGEM 2014.

Regional Environmenatl Center, Prespa Park, UNDP, 2009: Lake Prespa Transboundary Diagnostic Analysis. https://iwlearn.net/resolveuid/161dcb8b-3aa1-44f2-a67f-fb3e8c617c02

Sorkhabi, O., M. 2021: Changes in the area of Lake Urmia based on Landsat Image. Preprint, University of Isfahan.

Stojmilov, A. 2011: Geography of the Republic of Macedonia. Ss. Cyril and Methodius University of Skopje, Faculty of Natural Science and Mathematics and University of Tourism and Management, Edition 2011, Skopje (In Macedonian)

Temiz, F., Durduran, S, S. 2016: Monitoring Coastline Change Using Remote Sensing and GIS Technology: A case study of Acıgöl Lake, Turkey. World Multidisciplinary Earth Sciences Symposium (WMESS 2016),IOP Conf. Series: Earth and Environmental Science 44 (2016) 042033.

Valeyev, A., Karatayev, M., Abitbayeva, A., Uxujbayeva, S., Bektursynova, A., Sharapkhanova, Z., 2019: Monitoring Coastline Dynamics of Alakol Lake in Kazakhstan Using Remote Sensing Data. Journal Geosciences 2019, 9, 404.