Innovative Technologies for Studying the Impact of Climate Change on River Basins in the Guba-Khachmaz Region of Azerbaijan

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Abstract. It is believed that multivariate analysis for water quality management of Guba-Khachmaz economic region, which includes Shabran, Khachmaz, Guba, Gusar and Siyazan districts in the northeastern part of the Republic of Azerbaijan, will be more useful in terms of interpreting quality data. It is possible to prepare a large database for forecasting by integrating accurate results of spatial image analysis into the GIS database from time to time. The application of this approach is recommended in studying the current environmental situation of Guba-Khachmaz economic region of the Republic of Azerbaijan and in analyzing the current and expected impacts of climate change. The application of modern trends and technological innovations is the most effective method to combat and prevent this global crisis. As a result of the studies, it was determined that the most effective way to obtain, collect and analyze information on the impacts of climate change in the territory of the Republic of Azerbaijan, including Guba-Khachmaz economic region, is the use of Geographic Information Systems (GIS). The general monitoring framework was applied to analyze changes in climate characteristics in large regions at different time scales. The study further shows that online approaches such as GEE combined with remote sensing datasets are useful for monitoring climate change impacts, especially in semi-arid and arid regions, to model dynamic climate changes. In summary, the results of this study are of great importance to water resource planners and managers and make a significant contribution to the advancement of GIS science through the application and identification of effective methods for mapping climate change impacts on water resources.

Keywords: Climate change, water resources, Google Earth engine, remote sensing, time series analysis

1 Introduction

The area of the Guba-Khachmaz economic district, which includes Shabran, Khachmaz, Guba, Gusar and Siyazan districts in the north-eastern part of the Republic of Azerbaijan, is

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7.66 thousand km^2 and covers 8.8% of the country's territory. The territory of the economic district is divided into 4 altitude zones: lowland, foothill, mid-mountain and high-mountainous zones , which differ from each other between 26 and 4,466 meters. Depending on these zones, the climatic conditions of the region are warm, cold-humid and cold. The region has a dense river network and abundant water resources [19].

From the middle of the 19th century , in addition to natural changes, anthropogenic factors have also influenced climate change for the first time. The reduction of water resources, which is one of the most important consequences of global warming and climate change, has reached such a magnitude that it can prevent the sustainability of life in addition to the ecological impact. Studies conducted on global warming show that climate change will play a limiting role on water resources [13].

The application of modern trends and technological innovations is the most effective method to combat and prevent this global crisis. As a result of the conducted research, it was determined that the most effective method for receiving, collecting and analyzing information on the effects of climate change on the territory of the Republic of Azerbaijan, including the Guba-Khachmaz economic region, would be the application of Geographic Information Systems (GIS).

Computer-aided data analysis and visualization tools, statistical methods, and especially GIS have become priority technologies in water resources protection, development, and management research, and GIS-based water quality management systems have been widely used in recent years. Despite the significant increase in the number of statistical programs implemented for water quality in the scientific literature, the GIS-based multivariate statistical analysis method has been used in a small number of studies.

GIS has the advantage of integrating multi-source data, surveys and statistics, spatial analysis and visualization into succinct space-based activities. The power of GIS is not limited to digital mapping but also helps in environmental impact assessment, data analysis, natural resource management and decision making by integrating many other important data. GIS plays an important role in the planned project by visualizing the collected and analyzed data on the map. GIS can enrich the data by absorbing data from IOT (Internet of Things) technology. A sensor-based wireless monitoring system is provided to the centers where software applications are used to analyze field data, feeding information from other sources such as weather conditions and spatial imagery into CWSI (Crop Water Stress Index) models to assess water requirements, and finally to create a unique water stress index for each area. In addition, remote sensing using developing space technologies is more effective in studying hydrological changes in water. With this method, it is possible to monitor changes in water bodies using space images and provide information that cannot be obtained by traditional methods.

2 Methods

In this study, a data-driven approach was used using the product called JRC-Global surface water mapping layer V1.4 on Google Earth Engine (GEE) to map and monitor the effects of climate change on surface water resources. Key climate variables affecting water bodies, including air temperature (AT), actual evapotranspiration (ETa), and total precipitation, were analyzed from 2000 to 2021 using the temperature-vegetation index (TVX) and Moderate Resolution Imaging Spectroradiometer (MODIS) products [4, 5]. The results, decreasing water surface area, highlight the significant influence of AT and ETa on controlling water surface area in the LUB (partial rho of − 0.65 and − 0.68, respectively). One of the data retrieval sources for the analysis was the Web of Science Core Collection (WoSCC), which includes the world's leading science and technology journals [6,8].

The first successful Earth orbiting meteorological satellite, the Infrared Observation Satellites (TIROS-1), launched by NASA on April 1, 1960, a new era of Earth observation was approaching (Wexler and Fritz, 1960). And after the 1990, with the popularization of remote sensing technology and methods, remote sensing was widely used in watershed management. During this period, related applications of remote sensing in hydrology and water resources research began. Remote sensing using developing space technologies is more effective in studying hydrological changes in water [10, 11]. Through this method, it is possible to monitor changes in water bodies using spatial images and provide information that cannot be obtained by traditional methods. GIS has the advantage of integrating multi-source data, surveys and statistics, spatial analysis and visualization into succinct space-based activities. The power of GIS is not limited to digital mapping, but also contributes to environmental impact assessment, data analysis, natural resource management and decision-making by integrating many other important data. GIS plays an important role in the planned project by visualizing the collected and analyzed data on the map. Lake Agzybir or Devechi Port is a freshwater marsh lake located on the coast of the Caspian Sea in the Shabran region of Azerbaijan. It used to be a port. Its area is about 1.5 km². The Shabran, Devechi and Takhtakorpu rivers flow into the lake. The Karadahna River (4 km long) flows from the lake to the Caspian Sea. During the hunting season, waterfowl and fish are hunted. There have been significant changes in the water surface area of the Agzybir from year to year (Fig. 1.), especially in the southern regions of the lake where the lake bed is sometimes exposed in summer and autumn. From 1984 to 2022, the minimum lake surface area was recorded, while 2014 saw the maximum lake surface area.

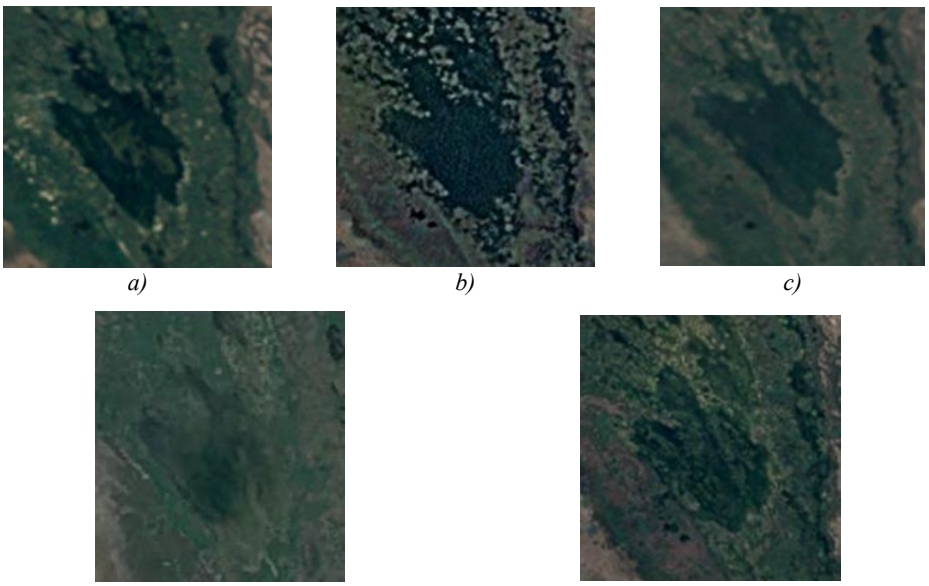

Fig. 1. Spatio-temporal changes in water areas of Lake Agzybir (a) spatial decline in water areas from 1984 to 2022 (b) spatial increase in water areas from 2015 to 2020, generated in ArcGIS 10.7.1 software (www.esri.com, and (c) temporal variation table of water areas, generated in Microsoft Office Excel 2023 (https://www.microsoft.com).

Lake Agzybir, located in the territory of the Guba-Khachmaz economic region, was studied with Google Earth images from 1984 to 2022.

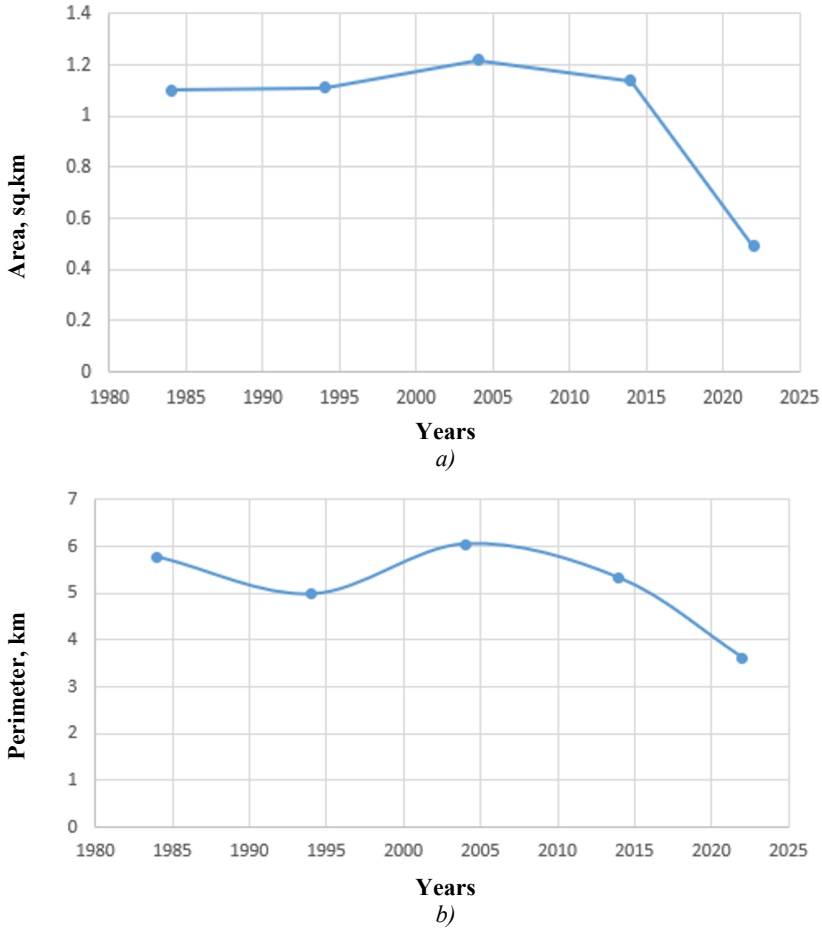

Fig. 2. a) Changes in the surface area of Lake Agzybir based on measurements made with Google Earth; b) the change of the perimeter of Lake Agzybir based on measurements made with Google Earth.

3 Results and discussions

This study applied an integrated approach involving remote sensing and GEE datasets to monitor the effects of climate change on water resources. Figures 1 show the results of water surface changes over the study area. Water was constantly present throughout this period, representing 0.99% of the area. This corresponds to an approximate area of 5.77 km^2 in contrast, the surroundings of the central parts have undergone significant changes in terms of water presence. Figure 1b gives an overview of the absolute change in water presence in 1994. The results reveal that there has been a significant change in the presence of water. Except for the dams and a small part of the UB in the northern part of the lake, the entire area has experienced such changes from 1984 to 2022. According to the figure 2 about 73.58% of the study area experienced an absolute change in water presence during the period 1984-2022.

In a small part of the lake in the northern region, there was a substantial change in the occurrence of surface water between 1984 and 2022, which illustrates the normalized occurrence change (Fig. 1 c). further supports this observation, indicating that approximately 66.29% of the study area within experienced a change in water occurrence during the period

1984 - 2022. Figure 1d provides an overview of the number of months when water was present in the study area from 1984 to 2022. The data presented in figure 1 d, indicate that January (10.82%) and December (56.08%) have a high level of water availability. Figure 1 e of this study displays the frequency of water return from one year to the next 2022. It indicates that the central parts of the region. The lake has the highest percentage of water return, suggesting that these areas have experienced more consistent water recovery over time. However, 28.99% of the permanent water was converted to seasonal water during this period. Further study 0.48% and 7.84% of the water resources were classified as permanent ephemeral and seasonal ephemeral respectively over the study area from 1984 to 2022.

The application of GIS and remote sensing techniques through Landsat satellite imagery is a mandatory and appropriate method to be used to estimate and assess the status of environmentally deteriorating areas when available data from ground monitoring stations are inaccessible, insufficient, deficient or missing. as is the case of the lake basin which is suffering from water surface retreat [15-17]. The maps prepared of the lake using Landsat satellite imagery throughout the study period helped to detect the changes in water area and variation in lake boundaries throughout the study period as the water area was decreasing significantly.

By correlating the few available and limited meteorological data on fluctuating rainfall that resulted in a severe drought that the lake basin has been witnessing recurrently until 2022, with the prepared maps, it was concluded that drought was the major contributor to the deterioration of Lake Agzybir throughout the study period, due to the significant impact on both the water inflow to the lake from the rivers feeding the lake and the recharge of groundwater aquifers, which was reflected in the prepared maps showing the resulting water withdrawal. lake area and fluctuation of lake boundaries from small to dry lake. Conversely, no significant relationship was found with rainfall and water area (partial rho of + 0.25). Notably, the study results indicate that over the last four decades, about 40% of the lake's water bodies have remained permanent. This suggests a loss of about 30% of permanent water resources, which have been transformed into seasonal water bodies, representing nearly 13% of the total. This research provides a comprehensive framework for monitoring surface water resource variations and assessing the impact of climate change on water resources. It contributes to the development of sustainable water management strategies and plans, supporting the preservation and efficient use of water resources.

4 Conclusion

In addition to climate change and global warming, which ultimately resulted in a period of severe drought, other factors have influenced the current state of Lake Agzybir, including the absence or inadequacy of integrated water resources management in the countries sharing the lake, unsustainable development programs, gaps in monitoring data sets due to the dilapidated state of meteorological monitoring stations, the prevailing security situation in the countries sharing the lake and in the immediate vicinity of the lake that has significantly reduced the level of their technical services, and the unavailability of most data resources on the lake. These factors together have made it difficult for policymakers or planners to adopt an ecologically based approach in the region and have encouraged researchers to use other, more adequate methods, such as GIS and remote sensing techniques, which can overcome these obstacles and facilitate ecosystem assessment and restoration in similar cases of environmental degradation in the areas [20, 21]. The application of remote sensing to study the impact of climate change on water scarcity requires efficient, effective and cost-effective technologies capable of analyzing large data sets. Therefore, this study was initiated to map

various influential climate variables and determine the impact of climate change on water resources.

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