Study of the landscape of the Hakari River in the climatic conditions of Azerbaijan

Banovsha Mekhtiyeva[1], and *Maya* Abdullayeva[2*]

[1]Water and Reclamation Scientific Research Institute Public Legal Entity, I. Dadashov 324, Baku AZ 1130, Azerbaijan
[2]Azerbaijan State University of Oil and Industry, Azadlig Avenue 20, Baku AZ1010, Azerbaijan

Abstract. The article investigates changes in landscape structure due to anthropogenic factors in the Karabakh region of Azerbaijan. The main part of the research object has been exploited for more than 30 years, and its forest-vegetation and soil cover have undergone significant changes. The uncontrolled and chaotic use of objects located in these areas has caused sharp changes in many ecological parameters. The purpose of the research is dedicated to investigating changes in landscape structure in the Hakaririver river basin of Karabakh as a result of anthropogenic impacts. The article uses Geographic Information System (GIS) technology to identify and analyze these changes. The research was conducted in 2 stages. In the first stage, changes in forest-vegetation cover in the Hakaririver basin between 2005 and 2024 were studied using the vegetation index (NDVI). In the second stage, changes in landscape structure in the research area between 1991 and 2021 were investigated and map-schemes were compiled. Using the NDVI index, it was possible to detect significant changes in the properties of soil and vegetation. With a normalized difference vegetation index value, it is possible to calculate certain empirical correlations on the land surface (including vegetation type and quality).

1 Introduction

The development of innovative technologies, the study and assessment of landscape components (forests, plants, soils, etc.) using satellite data have created great opportunities for effectively solving practical problems in the shortest possible time.To analyze the study area, a classification of various objects was carried out. Arc GIS software (Arc GIS 10.8) was used to determine the NDVI index values of natural objects in the Hakarı River basin. Satellite images of 2005 and 2021 Landsat 5 and Landsat 8, as well as NDVI values for various landscape components, were compared as initial data. The areas of total forest cover and vegetation cover in the section of the Hakarı River basin, passing through the Gubadli district, were compared, and a map and a diagram (1991 and 2021) were compiled. The landscape of the Hakarı River basin, the length of which is 113 km, was taken as the research area. The Hakarı River basin is one of the largest river basins of the Lesser

* Corresponding author: mayaabdullayeva@hotmail.com

Caucasus, flowing through the territories of the Lachin, Gubadli and Zangilan regions (Figure 1).

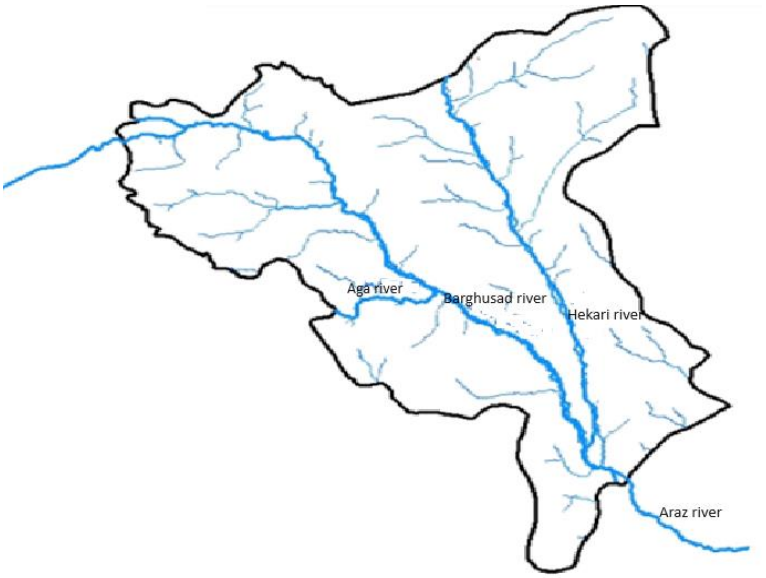

Fig. 1. Description of the Hakari River basin.

Natural vegetation belts are spread in this basin starting from 3600 meters. Modern tree and shrub plants include beech, oak-alder forests, orchards and vineyards. At an altitude of 2300-2500 meters above sea level, birch, pear, etc. formed a narrow strip 500 meters wide. Currently, this strip has disappeared, and subalpine meadows have replaced it.

The forest landscape in the Hakarı basin consisted of eastern oak and once formed a large strip 10-14 km wide. After the oak forests disappeared in the basin, meadows and meadow steppes took their place. On the eroded slopes, the jungles were replaced by oak forests. Currently, although few, Georgian oak forests remain in these areas. Now, arid forests can be found in the lower reaches of the Hakarı. On the modern vegetation map of the Hakarı basin, it is possible to see alpine and subalpine meadows, eastern oak forests, Liberian oak forests, etc. [1-3].

Satellite images of different times were used to assess the changes that occurred in the physiognomic components of the landscape.

2 Materials and methods

The digital image processing in the study was carried out mainly based on the Landsat 5 and Landsat 8 satellite database (based on data obtained from NASA).To identify and assess changes in the landscape of the Hakarı River basin, satellite images from 2005 and 2024 were compared (satellite images were taken from the open geoinformation portal Google Earth and matched in the Global Mapper program).

To study the current state of forest and vegetation cover in the Hakarı River basin, data were first collected using satellite data, multispectral images and the NDVI index. It is known that vegetation indices are used to assess forest vegetation parameters. The values of this index are affected by the type of forest and vegetation, the degree of sparseness, the angle of the surface, and the color of the soil cover.

As in various fields of science, aerospace photography is used to study the state of forest vegetation, increase the effectiveness of scientific research and solve practical problems. The study of these methods allows for more efficient data collection in the study area. Aerospace research can be used to determine changes in landscape components. It is known that multispectral images are images obtained in certain wavelength ranges of the electromagnetic spectrum. Thus, it becomes possible to detect changes in the geological environment in the study area and present them in different shades of color. It is considered appropriate to use vegetation indices when classifying and mapping landscape elements, water bodies and forest areas, which are easily observable components of the natural-territorial complex [4, 5]. NDVI mainly allows you to estimate the content of chlorophyll and green mass of plants. The classic NDVI index is used to calculate the presence of vegetation. This index changes depending on the amount of phytomass, takes a positive value and is calculated using the following formula:

$$\text{NDVI} = NIR - RED/NIR + RED$$

These indices are also used to obtain new information about plant health, photosynthetic activity and development stages, as well as in vectorizing satellite images, changes in the environment, etc. [3-6].

The vegetation index takes values from minus 1 to plus 1. It is attributed to vegetation cover from 0.2 to 0.7. Areas with sparse vegetation cover vary between 0.2 and 0.5. Areas with the highest values of 0.6 and 0.9 are attributed to tropical forests.

Using these normalized indices in agriculture and forestry, environmental monitoring, and climate research allows for more accurate measurements in the area, and also increases accuracy [7, 8].

3 Discussion of the result

In the surrounding areas of the Hakarı basin, succulent plants, shrubs, grasses, trees, etc. were observed in a strip pattern. In order to assess the forest and vegetation cover in the study area for a period of 19 years (during 2005-2024), it is considered appropriate to use remotely sensed data (RSD) to detect and determine changes in the environment.

To compare changes in the landscape structure of the Hakarı basin, NDVI (normalized differential vegetation index) was calculated, and the types of objects were determined. In order to detect and evaluate the changes that occurred here, first of all, the values of the vegetation indices for each component in the spectral ranges where various objects (hydrographic elements, vegetation cover, soil, etc.) are reflected were determined and calculated (Table 1).

Table 1. NDVI index values for various landscape components of the Hakari River basin (2005).

NDVI values	Forest cover	Dense vegetation	Sparse vegetation	Shrubs and grasslands
	Index range			
The Hakarı River basin passing through the Gubadli district (2005)	0.391-0.531	0.248-0.320	0.215-0.248	0.133-0.183
The Hakarı River basin passing through Zangilan district (2005)	0.517-0.721	0.369-0.517	0.216-0.369	0.093-0.216

Table 1 shows that the index values for forest cover indicators vary between 0.391-0.531 in the Hakari River basin passing through Gubadli district, while in the Hakari River basin passing through Zangilan district, these values are 0.517-0.721. Forest cover in Zangilan district is denser than in Gubadli district.

In Table 2, the value of the forest cover index varies between 0.291-0.531 in the Hakari River basin passing through the Gubadli district, but this value is 0.356-0.58 in the Hakari River basin passing through the Zangilan district. It can be concluded that a decrease in forested areas was observed in the Hakari River basin in 2021. This also occurred as a result of Armenia's military operations.

Table 2. NDVI index values for various landscape components of the Hakarı basin (2021).

NDVI values	Forest cover	Dense vegetation	Sparse vegetation	Shrubs and grasslands
	Index range			
The Hakarı River basin passing through the Gubadli district (2021)	0.291-0.531	0.248-0.020	0.183-0.148	0.103-0.131
The Hakarı River basin passing through Zangilan district (2021)	0.356-0.580	0.274-0.035	0.189-0.274	0.120-0.189

The satellite images we processed show that changes have occurred in the landscape structure over the past 19 years [9]. The vegetation cover of the forest ecosystem in the Hakari River basin, which passes through the Gubadli region, was analyzed and environmental indicators were assessed (Figures 2 and 3). The electronic map of the areas crossed by the Hakari River in 1991 was compiled as follows. It can be seen from the figure that a decrease in the areas with forest and vegetation cover is observed in these areas. The areas with bare soil cover have increased (based on normalized indices).

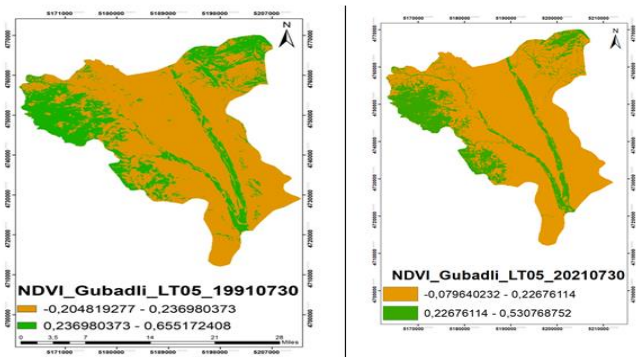

Fig. 2. Map scheme of the Hakari River basin (forest-vegetation and bare soil cover in Gubadli district were compared for 2 classes).

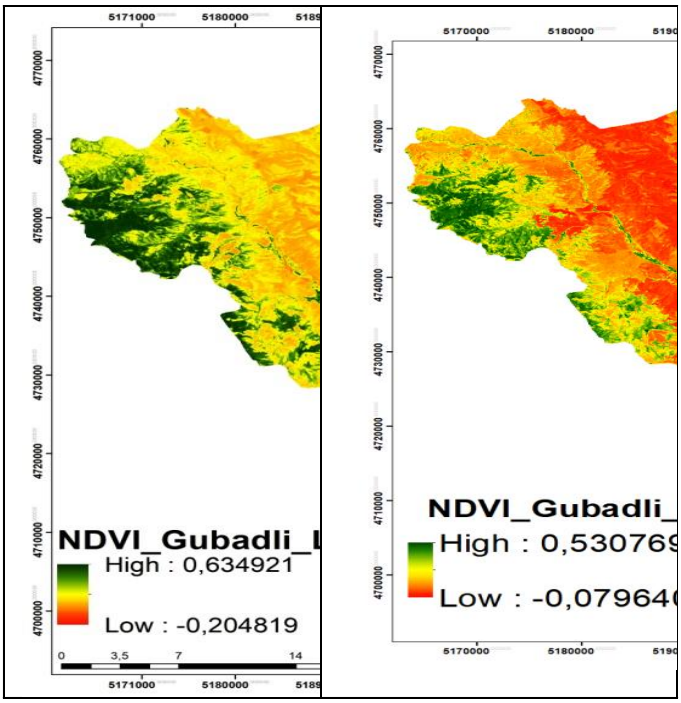

Fig. 3. Map of areas with total forest and vegetation cover of the Hakari River basin (Gubadli district) (1991 and 2021).

When comparing 1991 and 2021, the index values show that dense vegetation in the basin has been replaced by sparse shrubs and grasslands.

4 Conclusion

The article studies the changes in forest, soil and plant objects in the Hakari River basin using NDVI spectral indicators. It was found that the vegetation cover of the study area has undergone significant changes, and the amount of plants has decreased by approximately 24.55 percent.

Currently, restoration measures are being implemented in non-forest areas in the study area. In order to eliminate damage to the landscape structure, the current state of vegetation, soil and climatic conditions, and relief should be taken into account. Measures and recommendations should be developed by specialists to protect valuable forests.

In the liberated regions, great work has begun to be done in the field of solving environmental problems. Environmental protection, restoration of ecological balance, etc. issues are of particular importance for human health. The "Forest Fund Restoration Program for 2022–2026" was prepared, which provides for forest restoration measures in these regions. This program is intended to implement measures to restore forests in about thirty (30) thousand hectares of forest fund areas in the liberated and occupied Karabakh and East Zangezur regions.

During the Second Karabakh War, more than 54 thousand hectares of forest areas were destroyed during the occupation. Currently, a new program has been developed for the restoration of forests in these regions. This program will create new opportunities for the restoration of forests.

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