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The Impact of Glacia Degradation on the State of the Agricultural Sector in the High-Mountain Territories of Tajikistan

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ABSTRACT

Glaciers, which occupy about 6% of the territory of Tajikistan, significantly affect the formation of runoff. Under the conditions of climate change (+1.5°), which has been occurring over the past 100 years, directly affecting the volume of glaciers - sources of food and water content of rivers, up to 10-20% feeding the flow of large rivers, and in dry and hot years, the contribution of glaciers to the water resources of individual rivers in the summer can reach up to 70%, leading to their annual melting. It is expected that the effects of climate change, leading to the degradation of glaciation, on water resources will have a cumulative effect on many sectors of the economy, including agriculture (increased demand for irrigation or forestry).

One of the main sectors of the Tajik economy that is vulnerable to climate change is agriculture. Its economic, social and political features determine the potential for adaptation to climate change and, as a result, are the main factors determining the state of the economy, focused mainly on agriculture.

A significant source of livelihood for the rural population, remote mountainous areas of Tajikistan, is agro-pastoral farming. At the same time, the bulk of the population is oriented towards subsistence farming, which actually provides for their need for food. At the same time, the area of arable land is limited here, and the productivity of the agricultural sector is very low. It should be noted that in of the country's land area is Tajikistan, in general, less than 7% suitable for growing crops.

Water, despite the abundance of water resources in the country, remains the main problem for farmers in the mountainous areas of Tajikistan. It should be noted that in the Eastern Pamirs, due to the high altitudes and arid climate, animal husbandry is the only type of agriculture, and the western part of the Pamirs is characterized by the presence of conditions for growing on the coastal part of the rivers, using irrigation, wheat, potatoes, tomatoes and cucumbers.

Based on the analysis and monitoring of existing fund materials, in this work, the choice of the research object was made - the basin of the lower left tributaries of the Muksu River (the left tributary of the Surkhob River), a glacier (No. 815) located on the territory of the Lakhsh district, the Republic of Tajikistan.

Research by Hugonnet R. (using the geodetic method) established that due to the decrease in the surface of the glacier in the middle part and the increase in its height in the tongue part, as well as taking into account its active downward movement, the structure of the object is destroyed, which leads to active degradation of the glacier (No. 815). At the same time, it was revealed that the advance of the frontal part of the glacier was 130 meters.

Analysis and assessment of the state of irrigated lands located in the study area was carried out by calculating vegetation indices, for example, the Normalized Difference Vegetation Index (NDVI) - the implementation and monitoring of changes in the nature of vegetation, the degree of its degradation, etc. Obtaining information about vegetation and calculating the vegetation index NDVI is implemented using data from satellite images Landsat 5-7 and Sentinel 2

In particular, based on the study of the dynamics of the area of agricultural land, it was found that not only the sown area has changed, but both the sowing cycle and the timing of harvesting have also been violated.

Thus, the main factors for ensuring the stable development of the agricultural sector in mountainous areas are the development of measures to adapt to climate change, the improvement and use of water-saving irrigation technologies, as well as the search for alternative water sources.

KEYWORDS: *Tajikistan, glaciers, degradation, climate change, agriculture, GIS technology, remote sensing, vegetation index, adaptation.*

1. INTRODUCTION

Global climate change and its impact on the environment is one of the most serious problems of our century. In this regard, the adaptation of agriculture acquires a special role, since this industry is the most vulnerable and dependent on natural and socio-economic metamorphoses. Today it is extremely important to study and predict the response of the agricultural sector to climate change, to develop effective ways of its adaptation.

The first statement about the threat of global climate change was published by the World Meteorological Organization (WMO) in 1976. Then the World Climate Conferences made it possible in 1979 and 1990. to form scientific programs for the development and adoption by the world community in 1992 of the UN Framework Convention on Climate Change and the preparation of the Kyoto Protocol [4].

In the context of global warming and the growth of the world's population, there is a shortage of water resources everywhere, and Tajikistan is no exception. In recent years, there has been an intensive reduction in the area of glaciation in the world, especially glaciers, less than 0.1 km2, and this is confirmed by many researchers, for example, in the study of T. Bolkh in the Ala-Archa valley in the Northern Tien Shan from 1964 to 2010, glaciers were continuously shrinking and lost 18.3±5.0% of the total area [12]. Also, measurements of the Earth's surface temperature indicate its annual increase, especially in recent decades [6]. According to WMO data, the hottest years for the entire period of instrumental observations were 2010-2020.

After the collapse of the USSR, starting from the 1990s, due to the inaccessibility of objects and the high cost of research, activities to study glaciation in Tajikistan, unfortunately, declined sharply, including scientific and expeditionary work, and the last available data on our object dates back to the 60s years of the XX century.

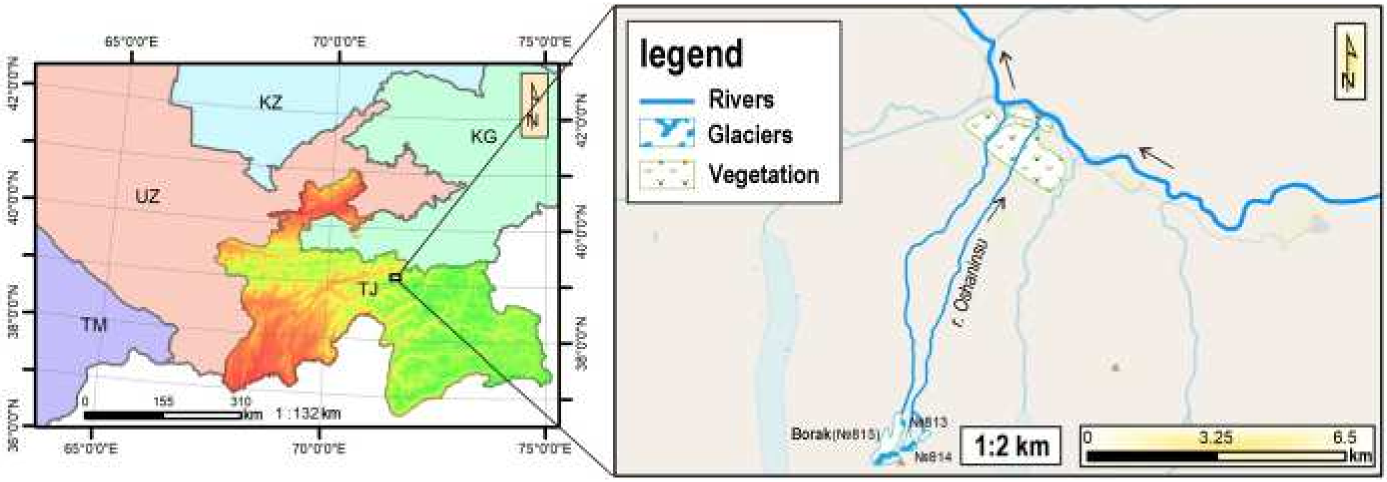
The first route studies of glaciers in the study area were carried out in 1897, and V.I. Lipsky discovered glacier No. 815, which was named "Borak", and the local population called the river flowing from the glacier "Obishain". In 1913, members of the German-Austrian expedition gave the glacier the name "Oshanin" and under this name it was included in the catalog of glaciers by N. L. Korzhenevsky, and the Obishain River, in turn, was renamed "Oshaninsu" [5].

By 1966, when compiling the Catalog of Glaciers of the USSR, it was found that the Borak glacier had already broken up into three glaciers, with a total area of 1.4 km2, which, under numbers No. 813-815, were included in the catalog. [5]. Modern remote sensing data made it possible to establish that the area of these glaciers is only 0.7 km2, i.e. for 55 years, the area of the glacier has halved, confirming its degradation for almost 100 years. It should be noted that such an intense melting of the glacier is not typical for this area. Global warming and an increase in air temperature will contribute to further melting of glaciers and this process, unfortunately, is accelerating and, as a result, the territory of our study will be subject to water shortages, especially during the growing season. Consequently, the solution of the issue of adaptation to such a development of events becomes even more relevant.

The purpose *of this study is to establish the degree of glacier melting and its impact on the water supply of irrigated lands in the village of Mok, Lakhsh district of the Republic of Tajikistan.*

2. Research object.

The study area is defined in the basin of the following tributaries of the Muksu River (left tributary of the Surkhob River), located in the Rasht valley, in the Lakhsh region, which is administratively part of the regions of republican subordination of Tajikistan and on the northern border with the Batken region of Kyrgyzstan, in the west with the Rasht region, in the south with Tajikabad and Sangvor districts, in production with the Chon-Alai district of the Osh region of Kyrgyzstan and the Murgab district of the GBAO of Tajikistan (Fig. 1).



Rice. 1. Place of study.

Based on the obtained images (September 1, 2018, at the end of the growing season), the object of research, using the normalized difference vegetation index (NDVI), it was found that the total area of agricultural land in the lower reaches of the Oshaninsu River is 170 ha (Fig. 2).

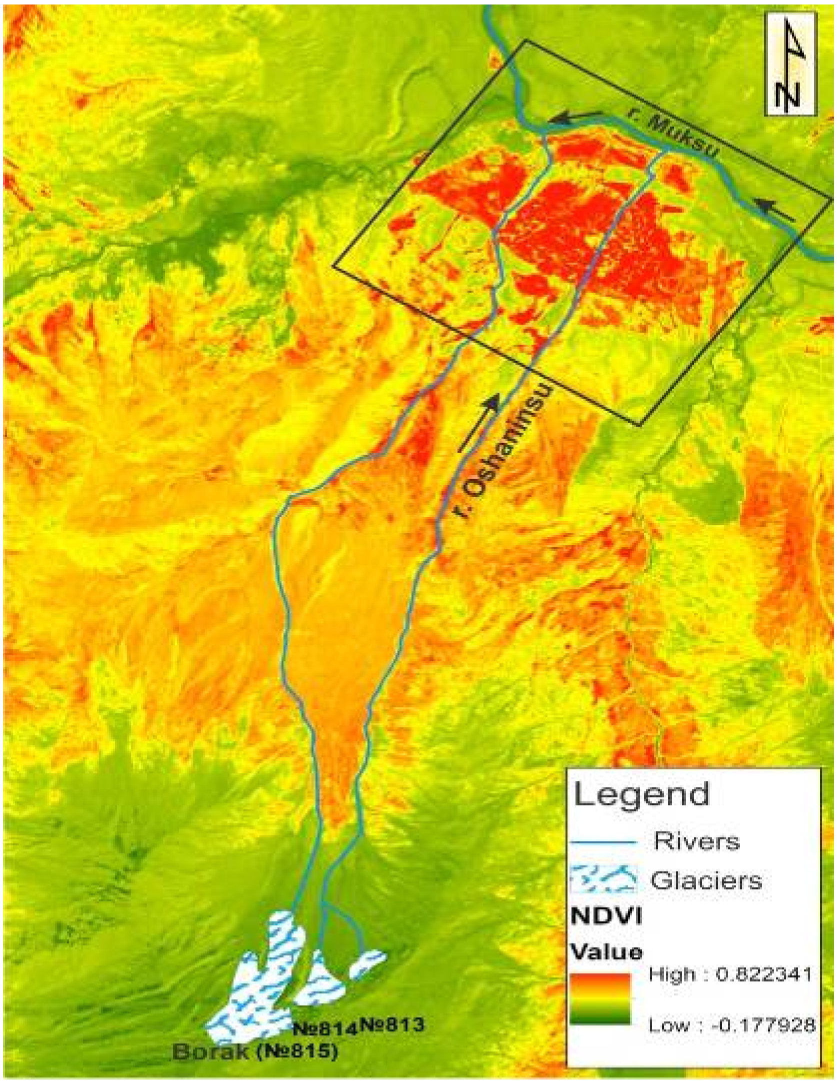


Fig.2. Research area Sentinel 2 snapshot, Normalized Difference Vegetation Index (NDVI).

3. Methodology.

Research methodology for determining the area of the glacier for the period from 2000 to 2022. included the use of satellite images Landsat 5-7 and Sentinel 2 [11] as well as geographic information systems and was implemented in the ArcGIS 10.5 program using SWIR, NIR, RED spectral channels [1]. The channels used made it possible to clearly identify the boundaries of the glacier, and with the help of a manual expert method, the contour of the glacier was obtained, which made it possible to obtain the areas of the glacier for the years under study.

NDVI is a standardized index showing the presence and condition of vegetation. This index uses the contrast characteristics of two bands from multispectral raster data. Negative values correspond to areas without vegetation. Very low values correspond to areas with little or no vegetation. Moderate values correspond to grassy and shrubby areas, while high values indicate lush vegetation. In ArcGIS 10.5, using the classification tool, features were extracted from images.

The use of the NDVI method [8,7,10] made it possible to obtain the dynamics of the area of agricultural land in the study area over the past seven years (Fig. 3 A). In ArcGIS 10.5, using a classification tool, objects were extracted from images created using an image segmentation process, where pixels that are in close proximity and have similar spectral characteristics are grouped and represent real objects on the surface (Fig. 3 B).

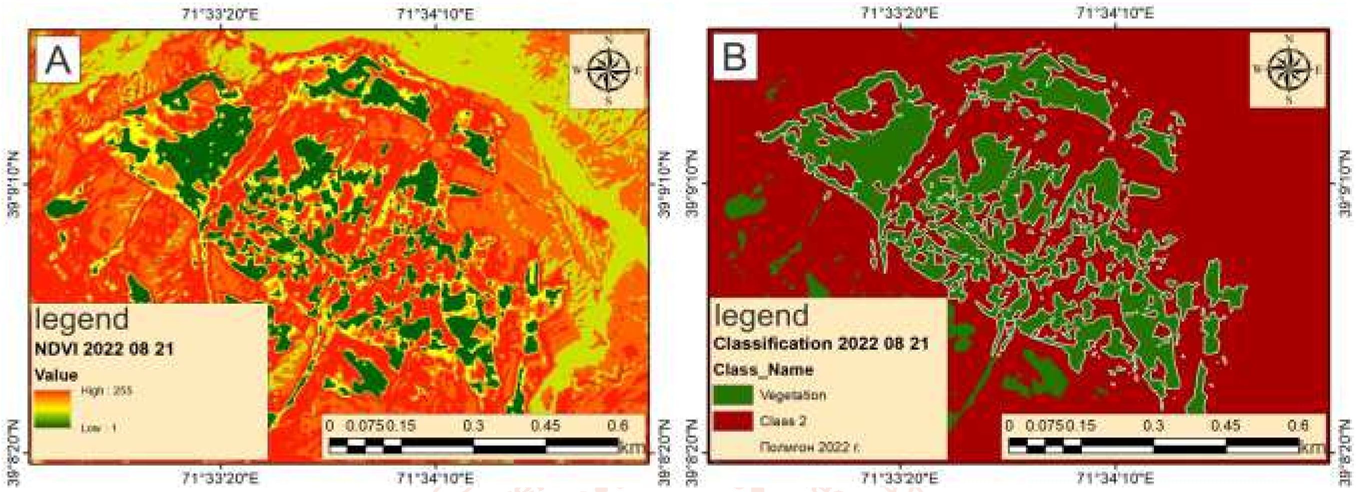


Fig.3. Agricultural land (green). A) using the NDVI method, B) using a classification tool

To determine the dynamics of the glacier surface, publicly available data on the mass loss of glaciers were used, where changes in surface height for all glaciers in the world were determined using a geodetic method using archives of high-resolution satellite images [12]. Using the above methods, results were obtained on the dynamics of the glacier, changes in the frontal part of the glacier, as well as the dynamics of irrigated lands.

4. Results.

The results obtained made it possible to establish that the frontal part of the Borak glacier (No. 815) slid by 130 meters, and the area of advancement at the same time amounted to 41820 m2, which is 7% of the total area of the glacier (580458 m2) compared to its state in 2000. Comparative An analysis of the glacier area data from 2000 to 2022 revealed that the total glacier area remained almost unchanged and in 2000 it was 580458 m2 and in 2022 it was 580067 m2 (Fig. 4). Compensation for the increase in the frontal part of the glacier occurred due to a decrease in the lateral parts of the glacier and from the surface of the accumulation zone.

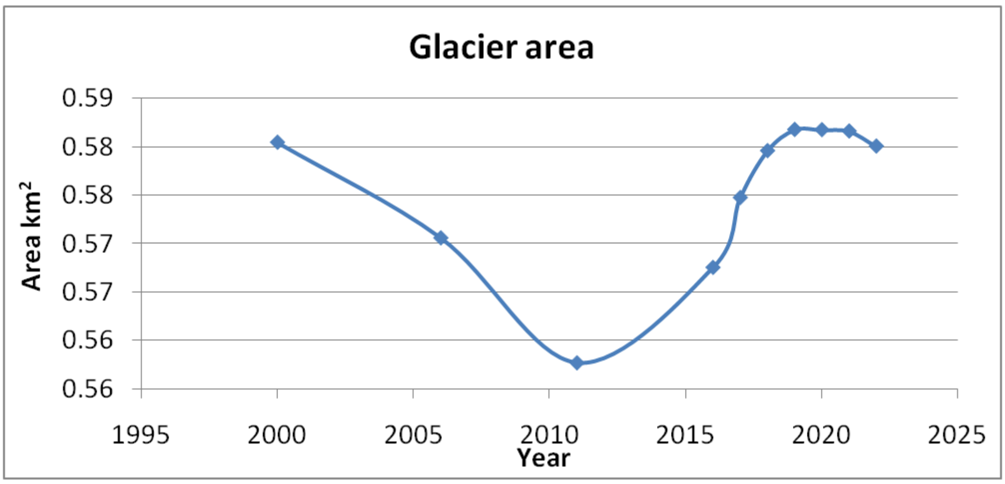


Fig.4. Dynamics of the area of glacier No. 815 from 2000 to 2022

Based on the analysis of the results obtained during the processing of satellite images using NDVI, as well as the extraction of objects using classification, it was found that the area of agricultural land in 2016 was 2.324 km2, in 2017 it decreased and amounted to 2.024 km2. Despite the fact that all processed images were obtained on fixed dates with a difference of 2 to 5 days, the area of irrigated land changed annually, throughout the entire period from 2016 to 2022. In the images processed using NDVI, zones with both dense and poorly developed vegetation were identified. At the same time, the predominance of the area with dense vegetation was revealed (Fig. 9A).

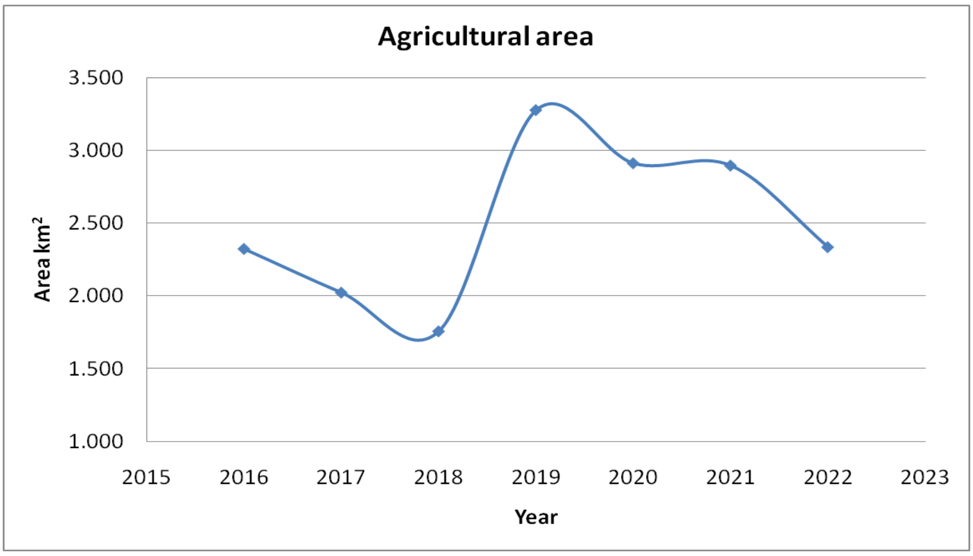


Fig.5. Dynamics of the area of agricultural land

5. Discussion

According to the results obtained, it was revealed that the glacier in the period from 2016 to 2022. moved forward by 130 m and this is not typical for such small glaciers (Fig. 6). According to experts (3), there is often a widespread retreat of the tongue parts of glaciers. Based on a detailed analysis of the process of the glacier moving forward and determining the speed of its movement, we found that the tongue part moves at an average speed of 20 meters per year. The received data is confirmed by Sentinel 2 satellite images, the resolution of which is 10 meters. Based on the processing of annual images, it was visually established that the movement begins from the middle part of the glacier.

As you know, the movement of glaciers is a common phenomenon, when the mass of ice from the accumulation zone moves down under the force of its gravity. But in this case, during the movement of ice, the thickness of the glacier surface decreased, with the exposure of individual parts of the rock on the sides of the glacier, which was revealed on satellite images. Thus, it is possible to confirm the thesis that in the course of moving forward the tongue part of the glacier is not an increase in its mass, but is the transfer of ice mass from the upper part of the glacier down. Thus, the glacier loses the mass that slides down as it descends below the glaciation line and this leads to the rapid melting of ice that has moved down.

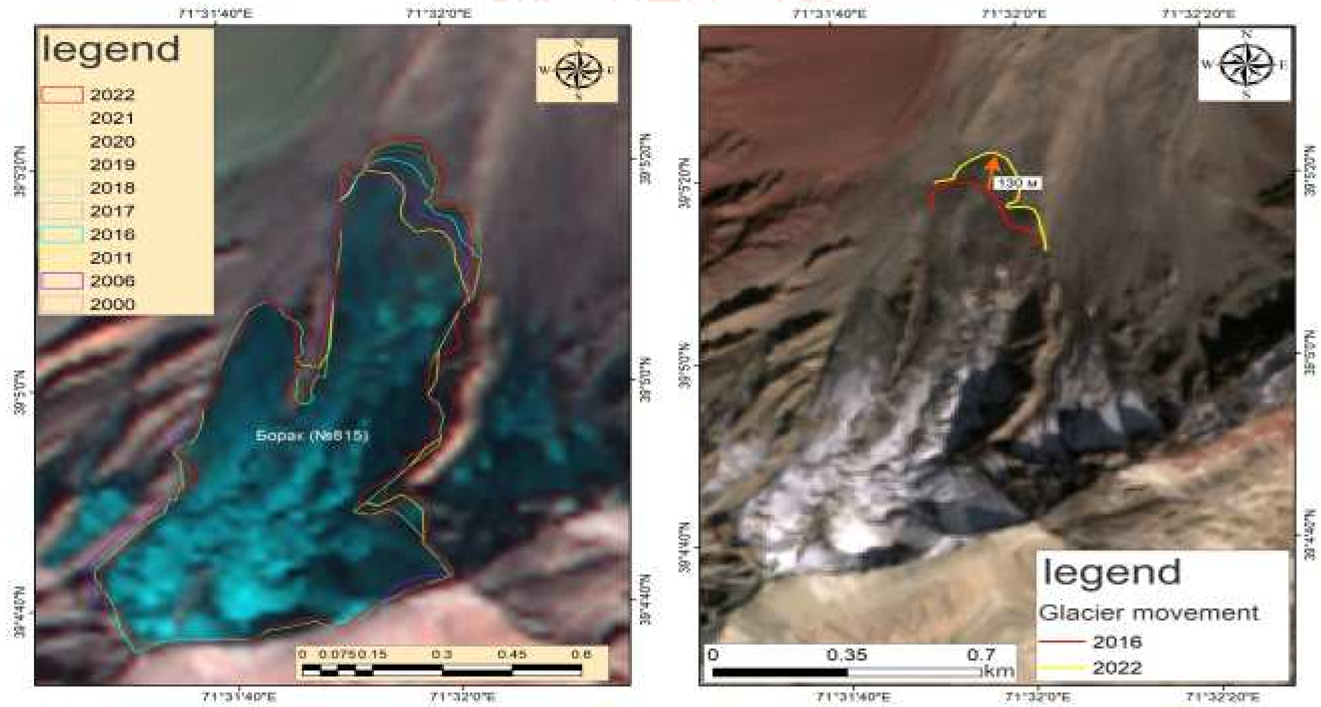


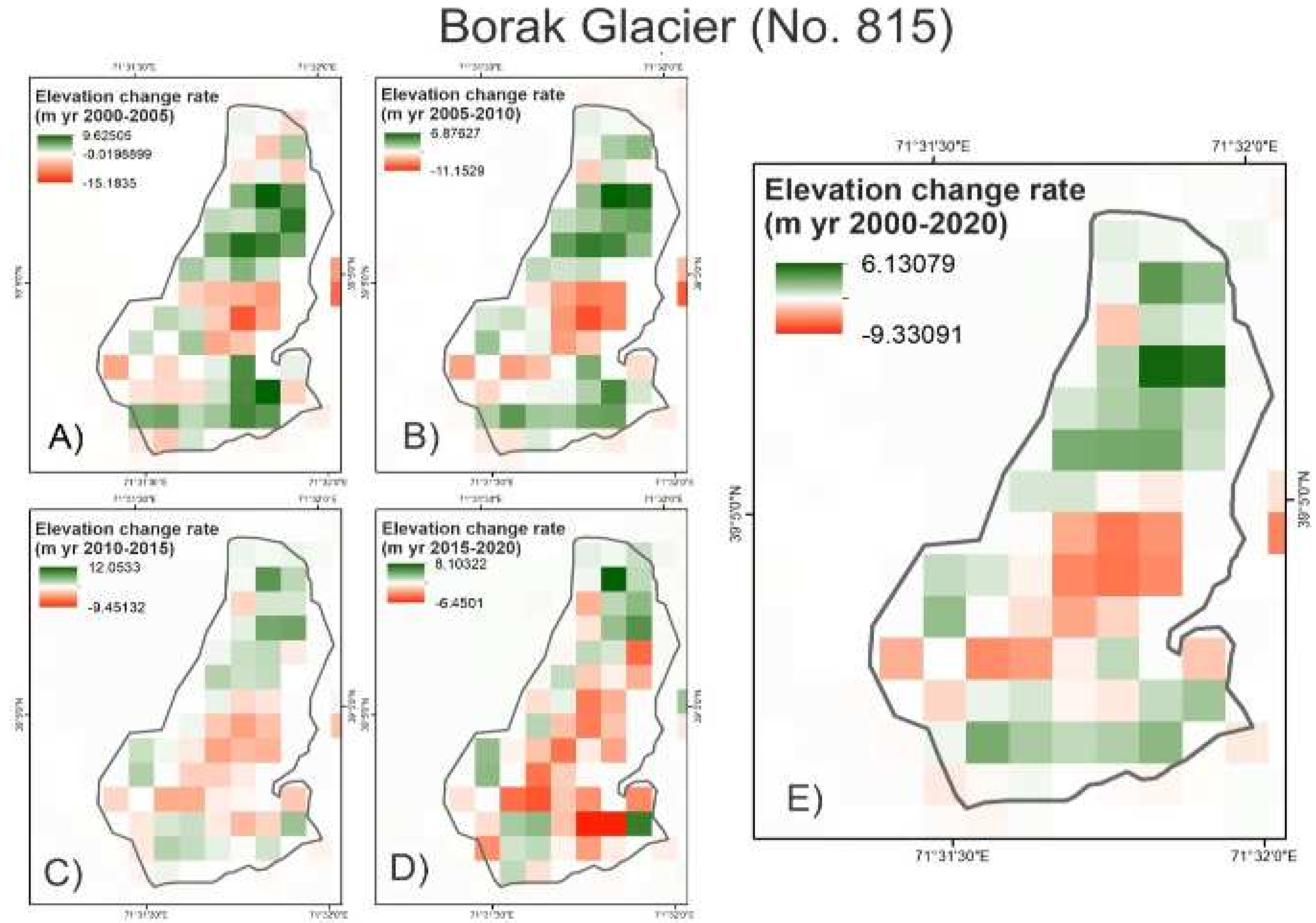
Fig.6. Bork glacier (No. 815), A) glacier contours from 2000 to 2022 B) glacier movement from 2016 to 2022

To confirm the reliability of the research results, publicly available data (13) were used and using the well-known geodetic method (2), the dynamics of changes in the surface of glaciers from 2000 to 2020 was determined.

At the same time, a decrease in surface elevations in the middle part and an increase in its height in the tongue part were recorded by the geodetic method on the studied glacier (Table 1, Fig. 7). In particular, it was found that in the process of changing the surface of the glacier from 2000 to 2020. the studied glacier in its middle part decreased by 9.3 meters (per year), and in the lingual part the maximum increase was 6.1 meters.

Table 1 Changes in the surface of the glacier.

Years	Maximum decrease in the middle part m/year	Maximum increase in lingual part m/year
2000-2005	-15	9.6
2005-2010	-11	6.8
2010-2015	-9.5	12
2015-2020	-6.5	8.1



Rice. 7. Change in the surface of the glacier (meter per year).

The results obtained confirm the fact of the rapid melting of the investigated glacier, sliding from the upper part to the lower and subject, due to rapid movement, to complete destruction. This trend can lead to rapid degradation of the glacier and its disappearance.

In connection with the above, it can be noted that the results obtained during the processing of satellite images for a fixed period using the NDVI methodology show that the area of irrigated land is not stable (Fig. 5) and is in constant dynamics, which in turn leads to a possible violation of the cycle of sowing and harvesting. On fig. 9. shows the annual measurements of the area of agricultural land for a fixed date.

Climate change and its impact on agricultural land can have both positive and negative effects. An earlier start of spring processes and a longer growing season may be positive, but this may lead to an increase in the frequency and duration of heat wave intensity, with possible frosts during the flowering period. An increase in the heat supply of crops can also be positive, but this can lead to the emergence of new pests and diseases of agricultural crops, and an increase in the duration of the stubble period can lead to a lack of moisture supply during the growing season and an increase in water demand (9).

The degradation of the studied glacier, which provides water resources to the population and irrigated areas of agricultural crops, can provoke a problem with irrigation water, which will naturally affect both the state of the agricultural sector and the quality of life of people living in this area. One of the negative consequences of such a process may be the migration of the population to other territories, which is not the best way out in this situation.

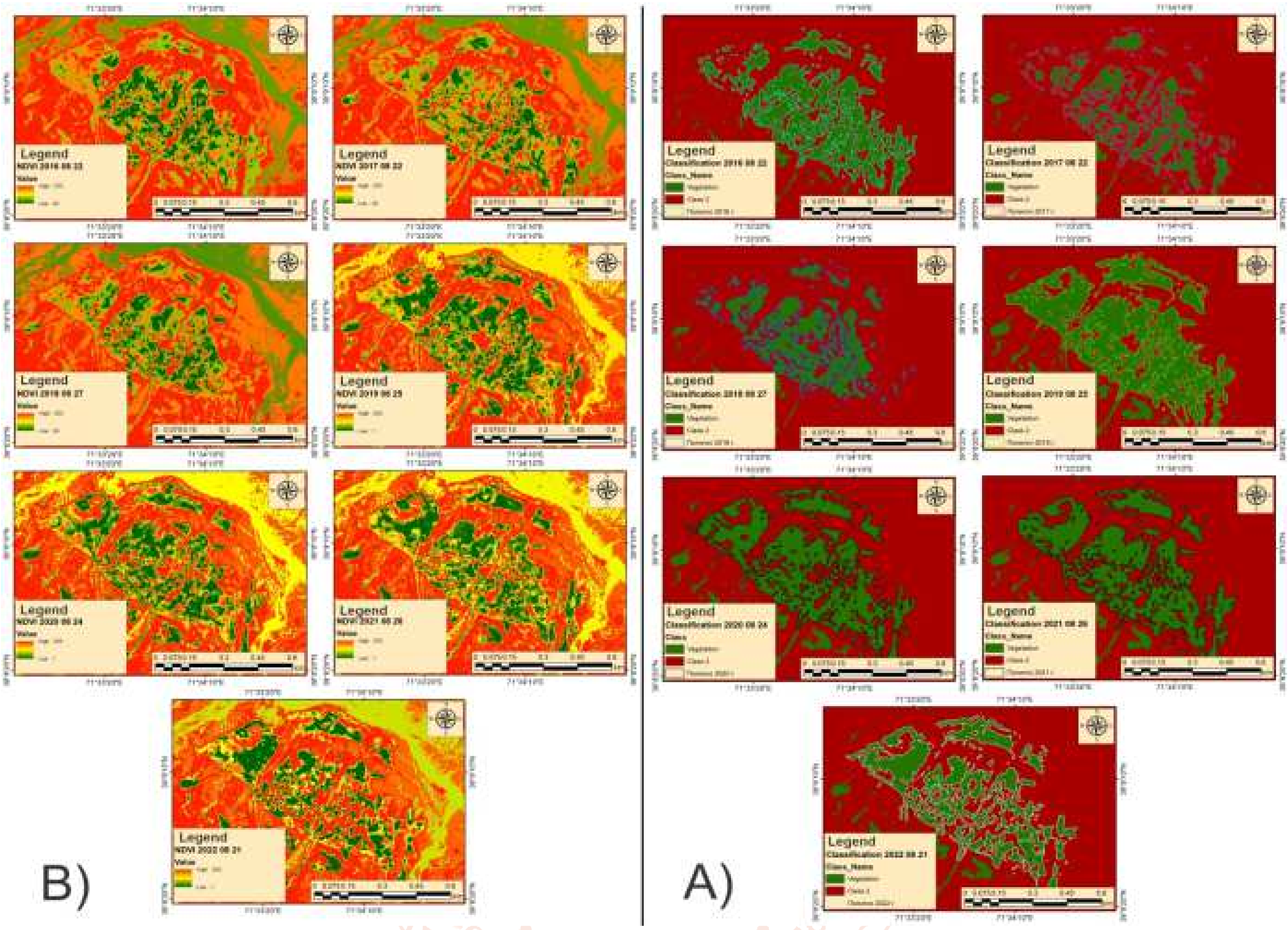


Fig.9. Area of irrigated land from 2016 to 2022 A) NDVI B) Classification

6. Conclusion

The complex of the above methods can be applied to the study of vulnerable agricultural lands in high mountainous areas.

The results of the research made it possible to state the fact of the rapid melting of glacier No. 815.

The degradation of the investigated glacier will naturally affect both the state of the agricultural sector and the quality of life of the people living in this area.

The annual change in the area of irrigated land, due to climate change and the degradation of glaciations, leads to a violation of the cycle of sowing and harvesting dates, agricultural work.

For the stable development of the agricultural sector of mountainous areas, it is proposed to develop measures to adapt to climate change, improve and use water-saving irrigation technologies, as well as search for alternative water sources, taking into account the existing threats of glaciations melting.

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