ASSESSMENT OF THE IMPACT OF OUTFLOWING GEOTHERMAL WATER ON THE ECOSYSTEM BY VARIOUS RESEARCH METHODS

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Abstract

The relevance of the work is determined by the fact that the problem of geothermal waters flowing from wells in the Chechen Republic has remained unsolved for many years and has managed to make its own adjustments to the ecology of the areas where they are located. The purpose of this article is to study the state of vegetation in the area of influence of the flowing geothermal water from the wells 9-T Kargalinskaya (Shelkovsky district) and 11-T Gunyushki (Grozny district) of the Chechen Republic using field and remote methods,and to conduct a brief comparative analysis of the obtained data, on the basis of which it is possible to make forecasts and make proposals for improving the geoecological situation in the study area. To achieve this goal, the following tasks were solved: 1) assessment of biodiversity in the area affected by the flowing geothermal water from the wells; 2) study of the features of NDVI dynamics and identification of the main trends for areas subject to different levels of anthropogenic impact. The studies were conducted using both field and remote sensing methods over the period 2017-2022. The conducted geobotanical studies indicate the suppression of vegetation in the area of geothermal water discharge from the well. The results of calculating the vegetation index (NDVI, MTVI) using Earth remote sensing data also confirm these changes. The consequences of geothermal water discharge on the daily surface can give in to the environmental situation in the study of the territory, drawing other components of the environment into the cycle, such as underground and surface watercourses, soils, microclimate, etc. The solution of the indicated problem in complex with scientifically grounded approach to rational use of geothermal potential, will allow to stop the process of deterioration of the vegetation cover in the research area.

Keywords: geothermal well, vegetation cover, dynamics, geothermal waters, outflow, transect, NDVI.

I. Introduction

The twentieth century has been characterized by significant anthropogenic transformation of the environment. Consequently, one of the pressing issues of our time has become the dramatic decline in biodiversity—a necessary component of the stability and functioning of natural ecosystems, as well as an integral part of human existence on Earth. And, of course, even seemingly minor changes occurring in the environment should not be ignored. They serve as indicators of the impact of a particular factor, the duration of which can lead to irreversible processes. Maintaining the environmental sustainability of areas annually involved in economic activity and ensuring rational nature management—the sustainable development and health of all living organisms in these areas depend on addressing these issues.

To study the state of vegetation in the geothermal water impact zone, geobotanical studies were conducted in the early autumn of 2020-2022. Using remote sensing data, the NDVI and MTVI were calculated. Geobotanical research involves the comprehensive study of plants and their habitats, which, to a certain extent, shape each other. The growth of both individual plant species and the communities they form is directly dependent on a range of physical and geographical factors (topography, soils, parent materials, etc.). The role of topography, albeit indirectly, influences vegetation in particular. Topography has a profound impact on the specificity of phytocenoses and their distribution. Plants and the phytocenoses they form, in turn, modify their environment: the climate at the macro- and micro-levels, the composition, structure, and moisture content of soils, and the drainage network.

II. Methods

The study revealed heterogeneity in the area's vegetation cover, caused by anthropogenic factors (primarily well outflow) and subsequent cause-and-effect relationships (grazing, trails, recreation, etc.).

The routes were designed taking into account the topography and the impact of the outflowing waters on the landscape. For comparative analysis, two profiles were established in the study area: Profile I directly in the geothermal water impact zone, and Profile II—a control profile (Figs. 1, 2) [1].

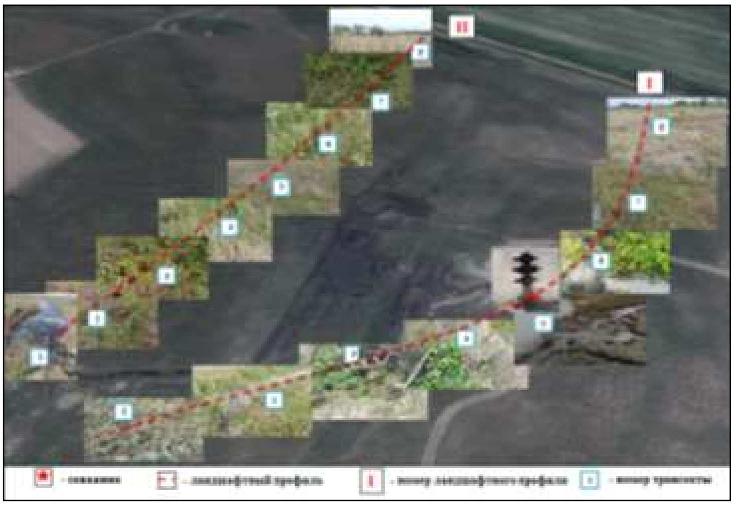


Fig. 1. Field survey map (impact area of well 9-T Kargalinskaya)

Fig. 2. Field survey map (impact area of borehole 11-T Gunyushki)

Geobotanical studies were carried out with the identification of the main phytocenoses, at certain points of which transects (1 m^2) were laid and dominant associations, the number of dominants, and the total projective cover were determined (Table 1) [2].

Table 1. Geobotanical descriptions of transects

Wells	Profile	Parameter	Transect number							
			1	2	3	4	5	6	7	8
11-T Gunyushki	I	Projective cover, %	15	5	30	40	55	30	80	50
		Number of species	1	1	3	3	4	2	1	2
	II	Projective cover, %	50	50	30	30	60	50	60	40
		Number of species	3	3	2	2	5	4	4	3
9-T Kargalinskaya	I	Projective cover, %	30	40	30	30	0	10	30	20
		Number of species	2	2	2	1	0	1	2	2
	II	Projective cover, %	40	40	50	50	30	40	60	70
		Number of species	2	2	3	3	4	5	3	3

III. Results

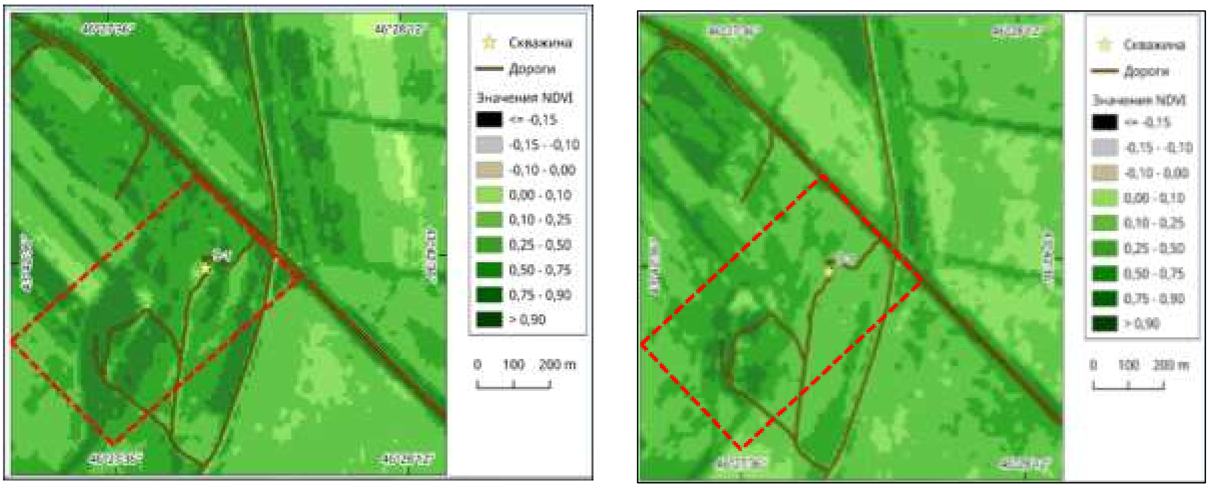
As a result of field studies, the following was revealed: in the area of borehole 9-T Kargalinskaya: on profile I, the flora is represented by 12 plant species belonging to 10 genera and 6 families, on control profile II, the species diversity is slightly higher: here there are 20 plant species belonging to 13 genera and 8 families; in the area of borehole 11-T Gunyushki: profile I: the flora is represented by 17 plant species belonging to 14 genera and 11 families, on control profile II, the species diversity is slightly higher: here there are 26 plant species belonging to 18 genera and 12 families.

Thus, on the control profiles, the species composition and the area of projective cover are higher, with the exception of those transects that are influenced by other factors (proximity to running paths and roads, small lakes) [1, 2].

In parallel, studies were conducted to monitor the state of the vegetation cover in the area of the geothermal water discharge and wells 9-T Kargalinskaya and 11-T Gunyushki using remote sensing data in the 2017-2022 time frame from Sintenel-2A, which provides data on the spectral reflectivity of the earth's surface that have undergone atmospheric correction, which allows for a more accurate analysis of surface properties (Figs. 3, 4).

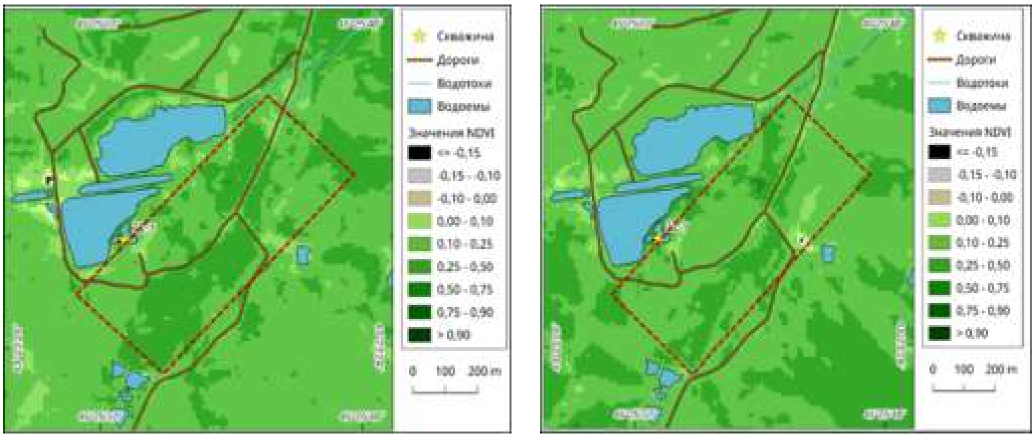
Detection and quantification of green vegetation is the main purpose of vegetation cover research using remote sensing data. This can cover a range of tasks: monitoring agricultural lands, analyzing changes in vegetation cover associated with temperature fluctuations under the influence of natural and man-made factors, monitoring the physiological state of plants due to insufficient or excess moisture, assessing projective cover, etc.

In addition, individual indicators (for example, the normalized difference vegetation index (NDVI) can be used to measure the uneven fertilizer requirements of agricultural crops across the entire field, to create productivity maps, and for differentiated fertilizer application [4]. NDVI is often used as one of the tools in conducting more complex types of analysis, the results of which can include productivity maps of forests and agricultural lands, maps of landscapes and natural zones, soil, arid, phenological, and other maps. It can also be used to obtain numerical data for use in calculations assessing and forecasting crop yields and productivity, biological diversity, the degree of disturbance, and damage from various natural disasters. both natural and man-made, etc., which is confirmed by the results of studies conducted in the field of environmental and nature conservation [5, 7, 8, 10].



a) June 2017 б) June 2022

Fig. 3. Monitoring the NDVI index in the area of well 9-T Kargalinskaya



a) June 2017 б) June 2022

Fig. 4. Monitoring the NDVI index in the area of well 11-T Gunyushki

As is well known, the optical properties of a vegetated area vary over time due to various factors characterizing the state of the vegetation cover: moisture, age, mineral deficiency, various pests, canopy geometry, and leaf distribution within the canopy. These factors influence the reflectivity of the vegetation and, consequently, the vegetation index [4, 5].

To understand the health of a plant, it is necessary to calculate the ratio between the difference in the intensities of reflected light in the infrared and red ranges and their sum [3,9]:

$$NDVI = \frac{NIR - R}{NIR + R}$$

where NIR is the near-infrared reflectance; R is the red reflectance. Typical NDVI values are shown in Table 2. [6].

It should be noted that, based on NDVI values, most of the study area is classified as having sparse or sparse vegetation (NDVI values generally range from 0.3 to 0.6).

NDVI monitoring in the impact area of well 9-T Kargalinskaya revealed the following: higher index values are observed in 2017 images (from negative values to 0.5-0.6). In 2022 images, NDVI values have significantly decreased compared to 2017, with a slight increase in vegetation mass in the area of the small lakes, which is also confirmed by geobotanical studies (an increase in the number of species on transects 5 and 6 on the control profile). This NDVI trend can partly be attributed to fluctuations in meteorological conditions in the study area between 2017 and 2022. In the zone of maximum impact of the effluent, significant transformation of natural plant communities is observed. However, overall, the studies showed that a spatial resolution of 10 m/pixel is insufficient for the purposes of this study; more accurate UAV data (5 cm/pixel) is required.

Table 2. NDVI values for different types of surfaces [3,6]

Object Type	Red reflectance	Near infrared reflectance	NDVI
Dense vegetation	0,10	0,50	0,700
Sparse vegetation	0,10	0,30	0,500
Open soil	0,25	0,30	0,025
Clouds	0,25	0,25	0,000

Figures 5 and 6 present the Multi-Temporal Vegetation Index (MTVI) values, which is a simple difference calculation of NDVI(date1) – NDVI(date2). This index allows one to estimate the range of NDVI variation. It is the difference between NDVI values obtained in June 2017 and 2022. MTVI values below zero or negative indicate areas where the NDVI has increased. As can be seen from the results, NDVI dynamics are spatially heterogeneous: some areas exhibit a significant increase, while areas exposed to the effluent are characterized by a decrease in average NDVI values.

In general, the results of the conducted studies using field and remote sensing methods confirm the suppression of the state of the vegetation cover in the area of the geothermal water discharge depending on the level of anthropogenic impact.

IV. Conclusion

Plant life plays a crucial role in Earth's ecosystems, influencing virtually all components of the geographic envelope. Understanding the current state and dynamics of vegetation change is essential for the timely resolution of environmental problems and the efficient use of natural resources.

A comparative analysis of vegetation cover survey results in the thermal water discharge area using various methods provided information on vegetation change dynamics over the 2017-2022 period.

Geobotanical studies revealed the number of species and the area of projective cover, indicating vegetation suppression along transects located close to the 9-T Kargalinskaya and 11-T Gunyushki geothermal wells. These indicators are higher on the control profile, with the exception of those transects influenced by other factors (proximity to roads, trails, small lakes, etc.).

A high correlation with net primary production allows the NDVI index to be considered a reliable indicator of landscape productivity. The temporal dynamics of the NDVI reveal changes in productivity, a key ecological parameter of landscapes. As an example, the NDVI and MTVI were calculated in the area of the 9-T Kargalinskaya well. Overall, an increase in these indicators was observed over the analyzed period. The ecological situation here can be assessed as favorable. However, in the detailed study area, NDVI values decreased, and correspondingly, vegetation productivity also declined, indicating a negative landscape-ecological situation.

Thus, the studies independently confirm the suppression of vegetation cover directly in the area of the geothermal discharge from the 9-T Kargalinskaya well.

From a cost-effectiveness perspective, studies using remote sensing are generally attractive for vegetation cover studies, but at the micro-level, geobotanical studies are more appropriate for achieving the required level of detail. However, with growing interest in vegetation indices, which offer advantages such as ease of use and reliability, and more recently, thanks to the expansion of the Earth observation satellite data base, they are becoming a key and widespread tool for monitoring and assessing the condition and dynamics of vegetation.

CONFLICT OF INTEREST.

Authors declare that they do not have any conflict of interest.

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