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Assessment of Database of Multispectral Shooting for Environmental and Economical Checking of Disturbed Lands

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Abstract. Coal mining areas such as Kuzbass create a land resources heavy anthropogenic loading. In the region many territory occupied with mining and mine waste, resulting in the land degradation and disturbed land are. Dusting and fissuring lead to land cover degradation in the surrounding areas to mining. As a result, the socio-economic value of these territories is reduced in terms of cadastral value of land, recreational and agricultural using. In modern land management practices, this factor has not yet been underrecognized, and the regional economics has loss of profit. There is no methodological tool to identify such negative impact on the environment, special studies are presented by a few works of soil investigators and biologists. The authors of the article propose to use insights and interpretation of multispectral space surveys of disturbed territories as tools for monitoring and assessing the negative impact of the territories disturbed with mining to the surrounding areas. In the article the ecological-economic results of the space images processing and the extent of the negative impact on vegetation and soil of spaces around disturbed areas not formally classified as disturbed, are presented. The work is performed a case study of Kuzbass.

1. Introduction

The problems of environmental and socio-economic consequences of the development of mining industries are becoming increasingly relevant and are constantly in the spotlight not only at the national, but also at the international level. Currently, the coal industry has a significant negative impact on all elements of the environment. Opencast and underground coal mining is accompanied by disturbance of land and significant changes in the natural landscape and hydrological regime, with the movement and storage of “empty” rocks on the surface, including potentially hazardous ones, with radioactive isotopes. All this leads to the formation of environmental and socio-economic problems that create restrictions for the development of coal mining regions. The annual rate of extraction of combustible minerals is steadily increasing.

Thus, over the entire history of the development of the coal industry in the world, more than 150 billion tons of coal have been mined [1]. Over the past hundred years, more than 2 billion hectares of land has been violated (about 24% of all world land areas) - and this is only according to the most conservative estimates, because it is not possible to more accurately assess their degree of degradation due to problems in determining the boundaries of disturbed lands and related indicators for quantification [2]. Moreover, more than 1.5 billion people live on these lands. One of the most important tasks in the field of environmental protection and rational nature management is to restore the productivity of disturbed lands, in other words, to carry out land restoration work. In accordance with the environmental protection requirements of coal mining regions, each enterprise engaged in the development of mineral deposits is required to bring all of its disturbed lands into a state suitable for their further economic



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use. And in order to approach the issue of reclamation most effectively, one should understand in general the very mechanism of the negative impact of disturbed lands on adjacent natural ecosystems and socio-economic objects.

2. Materials and methods

The initial data for the implementation of research work in the Kemerovo region of the Russian Federation were the archival data of the Landsat satellite imagery and materials for their processing. Space materials were obtained from the Landsat images database of the USGS Earth Resources Observation and Science (EROS) Center [3]. In addition, for solving some problems and conducting analytical studies, Sentinel satellite materials from the Sentinel-hub Playground online GIS platform were used [4]. Basic methods of solving the task of research selection and analysis of materials for remote sensing; complex interpretation of materials from space surveys, including the analysis of synthesized multispectral images with the aim of revealing the transboundary zone of land impacts, disrupted in the results of carbon activities.

In the course of the work, licensed software "ArcGIS" was used.

3. Results and discussion

The long-term history of the development of the mining industry in the Kemerovo Region determined the formation of the richest experience in Russia in the study and restoration of technogenic landscapes and soil cover. According to scientists with many years of experience in studying the consequences of technogenesis, a complete restoration of the ecosystem is impossible due to completely different conditions for its formation at the present time. First of all, it is impossible to create geological conditions for the formation of parent rocks for soils and climatic conditions in which the ecosystem has evolved.

A large contribution to the development of a set of theoretical and applied works on the study of technozems and reclamation of disturbed lands was made by the staff of the soil restoration laboratory of the Institute of Soil Science and Agrochemistry of the SB RAS. They pay the main attention to the study of the processes of restoration of the economic and environmental functions lost by the soil and soil and environmental assessments of technozems (Trofimov, Taranov, Ragim-zade et al., 1977; Kurachev, 2002; Androkhonov, 2004; Ovsyannikova, 2000). On the basis of studies conducted in different years, recommendations and experimental technological schemes were developed that are necessary for the preparation of projects for the biological reclamation of lands disturbed by open coal mining in the steppe, forest-steppe and sub-taiga zones of Siberia [5, 6, 7, 8, 9]. Some authors use indicators on the restoration of disturbed lands in the Kuzbass even as indicators of the sustainable development of the region due to the high damage intensity of the mining industry. Losses of the Kuzbass economy due to the environmental factor can amount to 7–13% of the volume of GRP [10, 11].

Currently, the total area of all disturbed lands of Kuzbass is 102 thousand hectares, of which more than 96 thousand hectares are degraded during the development of coal and other deposits [12, 13, 14], most of which was withdrawn from agricultural circulation [14]. Also, as a result of mining enterprises in the region, more than 300 small rivers disappeared [16, 17, 18].

At present, Kuzbass occupies the second place in Russia in terms of the area of disturbed lands, slightly yielding only to the Yamalo-Nenets AO (103 thousand ha). The reclamation rate remains at a fairly low level, despite significant changes in the state management of land use, regulated by Decree of the Government of the Russian Federation No. 800 of July 10, 2018 "On the implementation of land reclamation and conservation" [19]. The effect of this Decree applies only to land plots that are formally located within the boundaries of a disturbed or contaminated territory. Sites directly bordering these territories, but experiencing significant negative impacts, do not normatively fall under the regulatory effect of legislation in the field of restoration of disturbed lands. The economy of the region has losses from the under-receipt of agricultural products, rent and land tax. Landowners cease their economic activity.

Analysis of these multispectral images showed that in the studied areas of open mining work strongly violated the natural landscape, almost completely destroyed the vegetation and soil. In the areas adjacent to the site, the work is deciphered by man-made landscape in the form of alternating quarries. The technogenic relief is also recorded, which was formed due to a sharply changing hydrological regime as a result of lowering the groundwater level to the existing working horizons. In many coal mining areas of Kuzbass, there are multilevel dumps that create high risks for future periods. For example, weathering and chemical oxidation processes can occur on dumps, as well as migration and removal of impurity elements into transboundary natural environments. As a result of oxidative reactions inside heaps and dumps, spontaneous combustion can occur, which will lead to underground fires. Currently, these processes are recorded in the Novokuznetsk municipal district and the Kiselyovsky urban district of the Kemerovo region, where internal combustion occurs between the villages of the Krasny Kuzbass mine and in waste dumps between the villages of Alekseevka, Ananyino and Apanas. In some places, the earth was heated to 170 °C. Regional authorities had to introduce an emergency mode in the aforementioned municipalities [20].

According to multispectral images, it is most difficult to detect a violation underground in the form of underground mine workings. However, undermined territories can also be deciphered by indirect signs of technological failures, cracks and funnel-shaped relief forms. Despite the fact that there is soil cover above the mine workings, these lands are most often excluded from agricultural and forest use due to violations in the structure of the land cover and the hydrological regime of the territory. In the course of the analysis, it can be said that the problem of disturbed lands of the Kemerovo region is aggravated by the high concentration of coal mining enterprises and their proximity to the residential zone (see Fig. 1).

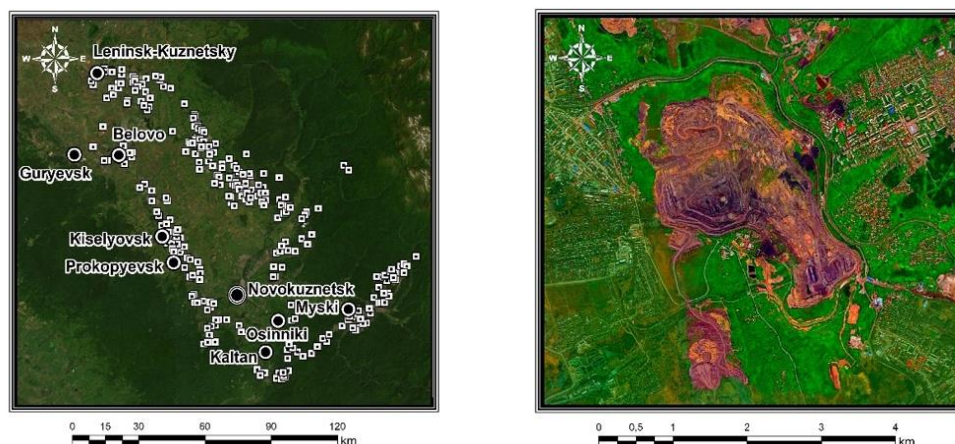


Figure 1. Left picture – cosmos of the location of coal mining enterprises in the territory of the middle and southern Kuzbass; the right picture is the synthesized multispectral image “Landsat-7” of the territory of the city of Kiselyovsk from 2019. In the center of the image, coal mines bordering end to end with residential quarters are captured.

The influence of these two factors is most acute in the Kiselyovsky, Krasnobrodsky and Prokopyevsky urban districts, the Prokopyevsky municipal district, as well as in the Novokuznetsk municipal region. Space images of the territory of the cities of Kiselyovsk and Prokopyevsk demonstrate an inextricable conglomerate of coal mines and the residential sector. Historically, these coal cities were created, but with underground coal mining. There was less disturbed land and the impact on adjacent ecosystems was different.

When analyzing multispectral images with a combination of Color Infrared channels combining wavelengths reflected by the vegetation of the studied territories, the vegetation cover was studied near coal opencasts. More than 90% of all analyzed sites show the coefficients of spectral brightness of vegetation in the border areas with disturbed lands in the images of 2019 lower than in the images

of 2016. This indicates a decrease in the physiological parameters of phytocenoses as a result of the negative impact of both the existing industry and disturbed lands. In the photographs of past years, the spectral brightness of the soil cover also differs, and not everywhere, but locally. So, in transboundary zones, spectral indices are reduced in comparison with the background values of the image area. This indicates that in the soil-land cover there are migration processes of chemical elements from one medium to another. In our case, from man-made sites to the natural environment. This leads not only to soil pollution and degradation; but also inhibition of soil formation processes, a change in the quality of soil conditions; the accumulation of harmful substances in plants; reduction and loss of the biological diversity of the territory. All this is complicated by the proximity to residential settlements, which in turn affects the level and quality of life of the population.

To quantify the vegetation cover, the relative vegetation index (NDVI) was calculated. Only for the most information and time visualization were taken images for 20 years. The results showed that in all the images of the studied territories, the areas of the vegetative index NDVI with high indices were significantly reduced in comparison with the 1999 images (see Fig. 2).

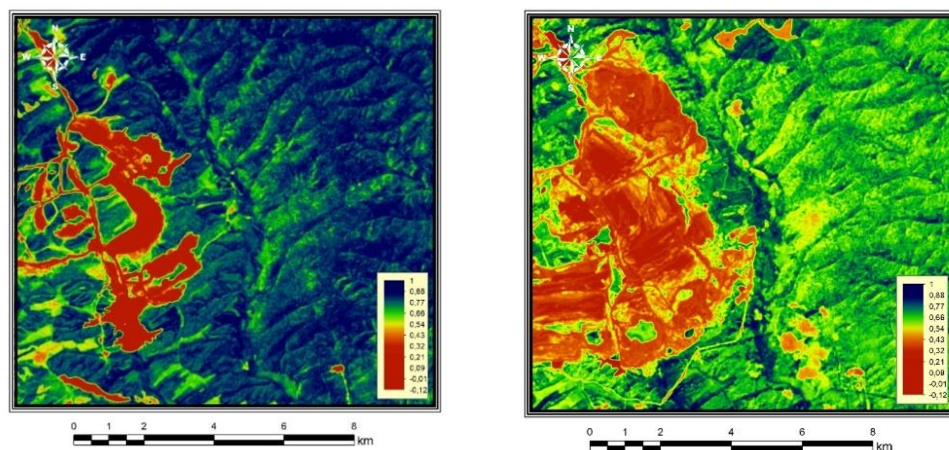


Figure 2. Left figure – the result of processing the Landsat-4 image from 1999 of Taldinsky territory using the NDVI method; the right picture is the result of processing the Landsat-8 OLI image from the year 2019 of Taldinsky territory using the NDVI method. Note from 1 to 0.77 – highly productive plant zones; from 0.77 to 0.43 – low-productive plant zones, as well as zones of oppressed vegetation; from 0.43 and below – areas of dead vegetation, as well as areas without vegetation cover.

This fact indicates a decrease in the amount of photosynthetically active biomass near land plots disturbed by coal mining enterprises. This means that the growing season for plants is shrinking and the volumes of biomass produced on it are also decreasing. The territories of intensive coal mining in Kuzbass coincide with the territories of mass agricultural production, both in collective farms and personal subsidiary farms. However, do not forget about other factors that negatively affect the state of vegetation. But in our case, the spectral indices in transboundary zones are more pronounced relative to other territories. Of course, the influence of other factors cannot be ruled out, but it is important to consider that in a transboundary context, as a rule, they have a negligible effect compared to the impact of negative consequences from disturbed and degraded land plots.

It is known that vegetative activity is directly affected by moisture, which plants take from the soil cover, therefore, in addition to transboundary zones of vegetation inhibition, zones with a disturbed hydrological regime should also be recorded. To confirm this hypothesis and to reveal a close correlation between the soil moisture content and the violation of the hydrological regime, the normalized differential water index (NDMI) decryption method was used. The results showed that in the territories bordering with disturbed lands, the average indicators of NDMI significantly decreased by comparison with similar periods in annual monitoring. Abnormal shifts of NDMI values are fixed in all studied transboundary territories, which testify to the violation of the local hydrological regime. Now, in places where streams previously flowed, natural anomalies of increased values of the water index disappeared, and in many areas the indicators generally went into the negative zone (see Fig. 3).

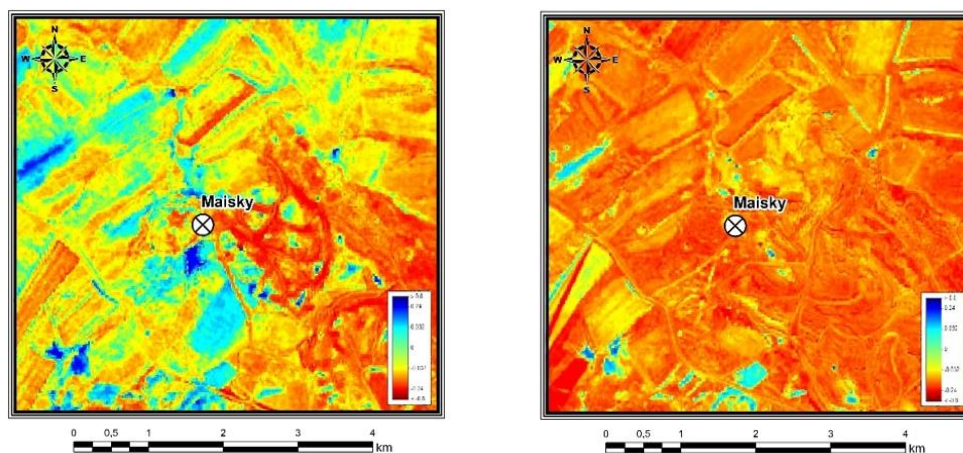


Figure 3. Left figure – the result of processing the “Sentinel-2 L1C” image from 2017 of the territory of disturbed lands at the site of the former May village of the Prokopyevsky municipal district using the NDMI method; the right picture is the result of processing the Sentinel-2 L1C image from 2019 of the territory of disturbed lands at the site of the former Maysky settlement of the Prokopyevsky municipal district using the NDMI method. Note values above 0 – zones with relatively high soil moisture; values below 0 – zones with relatively low soil moisture.

This fact speaks of the fact that the increased cracking of the soil and the disappearance of small rivers and streams, the pursuit of mining, has significantly reduced the receipt of moisture in the soil, and this, in turn, has led to the return of the sum, in multispectral images. Thus, we can confidently speak of a violation of the hydrological regime of the territory, which also affects the vegetation activity of the vegetation cover, including crops.

The disturbed lands in the form of underground mine workings in the studied territories according to multispectral images were discovered by indirect signs of anthropogenic relief and materials that are in the public domain. The results of the study showed that disturbed lands such types also negatively affect transboundary environments. It is often possible to observe technogenic failures and wetlands, which will contribute to a change in the quality and structure of the soil cover, disruption of the hydrological regime and intensification of erosion processes. For example, in the Rudnichny district of the city of Kemerovo, land subsidence in the area of former mines is deciphered, moreover, all this in the border areas with residential quarters. The same situation is in the cities of Prokopyevsk and Kiselyovsk. In the latter, the situation is complicated by underground fires in old mine workings and landslides - and all this happens near residential buildings. The problem of earth surface failures over liquidated mines also exists in the Ordzhonikidze district of Novokuznetsk and the Prokopyevsky municipal district.

4. Conclusion

As a result of the analysis of multispectral data, transboundary zones of negative impact of disturbed and degraded lands as a result of the mining enterprises of Kuzbass were identified. Also, multispectral images were used to monitor the state of disturbed lands in terms of their impact on the ecosystems of adjacent territories. So for 20 years in the transboundary zones a significant decrease in the amount of photosynthetically active biomass has been recorded (in many zones – more than 50%). Almost 90% of the areas of all the studied territories experience significant changes in the hydrological regime. Multispectral analysis showed that disturbed lands contribute to the migration of substances (primarily inorganic dust and coal dust), which leads to a change in the qualitative characteristics of soils and vegetation in transboundary zones.

It should be noted that the results of the study showed the possibility of using methods of combinations of channels of the electromagnetic spectrum to study, evaluate and monitor the negative impact of land disturbed by mining on adjacent territories. These methods allow not only to assess the environmental situation around disturbed lands, but also to carry out the development of measures to eliminate and reduce their negative impact on crop yields, the attractiveness of landscapes, and a decrease in the quality of the environment as a whole. The use of digital methods will help create a system for the operational assessment of the state of transboundary territories, which will allow timely and accurate determination of the degree of negative impact and coordinate the work is open to the public on the verge of collapse, liquidation of the consequences and the conduct of reclamations.

In this study, only a small part of the environmental and economic problems that arise as a result of land disturbance was raised. According to the authors, the use of digital methods in land management will create a system of continuous environmental and economic monitoring and more quickly respond to changes in ecosystems and the quality of the environment as a whole.

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