Using the NDVI vegetation index to assess land degradation in industrial agglomeration

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Abstract. A study of high spatial resolution satellite imagery data was carried out to assess land degradation in the vicinity of Novorossiysk. It has been established that the use of indicators that are a combination of various spectral channels of radiation reflected from the object under study makes it possible to successfully identify the degree of vegetation degradation within the quarries and dumps of overburden, urban agglomeration and adjacent territories. Vegetation index data (NDVI) can serve as a source of information on the state of the geological environment, the intensity of vegetation of trees and shrubs, making it possible to make the most correct long-term decisions on the development of measures for artificial restoration of vegetation during the reclamation of disturbed natural complexes.

1. Introduction
One of the leading problems in the mining industry is land degradation as a result of mining [1]. Modern requirements for mining enterprises consider the need to plan reclamation works already at the design stage of new open-pit mining sites. The importance of the cement industry in southern Russia has a great impact on the economic potential and level of development of the region. In the future, the demand for cement is expected to expand even more due to the increase in the pace of development of the construction industry. AO "Novorosement" is one of the oldest cement enterprises in Russia and the largest Russian exporter of these products, forming an industrial agglomeration in the vicinity of Novorossiysk. Topical issues of this territory are the issues of studying the restoration of vegetation on lands disturbed by such activity. A particular danger to the environment is posed by non-reclaimed territories for the extraction of cement raw materials, which serve as a source of dust and areas of mudflow soils.

To study the state of vegetation, the most promising area of research is the analysis of satellite images of high spatial resolution with an assessment of the intensity of vegetation. Vegetation indices are used in various industries [2-4], for the territory of the Krasnodar Territory there is experience in such studies in relation to the state of agricultural crops and to monitor the dynamics of the vegetation cover of estuaries in the Kuban delta [5]. For the purpose of assessing the state of vegetation on disturbed lands, such work was carried out for the first time.

2. Materials and methods
The geographical position, geological and geomorphologic features of the southern slope of the North-West Caucasus determine the nature of the vegetation cover of the study area [6]. The outskirts of Novorossiysk are divided by the river. Tsemes into two sections: western and eastern. In the eastern region - mainly industrial, there are a port, quarries for the extraction of marl, a cement plant, oil
terminals, a railway station and some other industrial enterprises. The main population of the city lives in the western part, which is mainly residential (Figure 1).

![Figure 1. Location of the research object.](image)

The Black Sea coast in the study area has a dry subtropical climate, which is characterized by hot dry summers and warm humid winters. The average temperature of the coldest month, January, is +3°C. The average temperature in July ranges from +23 to +25°C, often reaching +35°C. The average annual temperature exceeds +10°C. The average annual amount of atmospheric precipitation averages at least 700 mm. Precipitation falls mainly in the form of rains; no stable snow cover is formed. Among the main meteorological features of the territory, it is worth noting strong winds of the north-east and south directions, on average about 20 days a year, the wind speed here exceeds 15 m/s.

The slopes made up of marl rocks are considered to be dry, communities dominated by the tree are developed on them. Relict mountain steppes, steppe meadows with elements of upland-xerophytic vegetation have spread over the watersheds. The most typical are junipers: forbs, jasmine, hornbeam, etc. Oak and oak-hornbeam forests grow on the near-watershed parts, giving way to beech and chestnut forests on the eastern slopes. The undergrowth is varied from dogwood, privet, feathery klekachka. The peaks of mountains and ridges above 400 meters are treeless and covered with mountain-steppe and mountain-meadow vegetation [7].

In general, this territory is characterized by weakly structured soils, characterized by a low level of humus. Within the undisturbed landscapes of the study area, the following types of soils were identified: mountain-forest light gray, mountain-forest sod-carbonate, brown mountain-forest, gray mountain-forest.

Methodically, the work was carried out by calculating the NDVI (Normalized Difference Vegetation Index), which is an indicator calculated by how a plant reflects and absorbs different light waves. This normalized vegetation difference index, which was first described by B.J. Rouse [8].

Analysis of the literature shows that the values of the vegetation index, defined as the ratio of brightness in two ranges of the image (red and infrared), correlate with the amount of vegetation biomass. Vegetation has the highest spectral selectivity compared to other objects on the earth's surface. It follows from the peculiarities of the spectral properties of vegetation that its interpretation gives the best results when using survey materials in several spectral zones of the visible and near infrared spectral regions, i.e. multi-zone shooting [9].

The NDVI is calculated using the formula:
\[ \text{NDVI} = \frac{B_{\text{NIR}} - B_{\text{RED}}}{B_{\text{NIR}} + B_{\text{RED}}} \]  

Where the NDVI value shows the normalized brightness difference in the red (\(B_{\text{RED}}\)) and near infrared (\(B_{\text{NIR}}\)) space image zones.

Since green leaves of plants tend to absorb red and reflect infrared radiation, the denser the vegetation, the greater the value of the vegetation index. The NDVI discrete scale from -1 to 1 is used to interpret the calculated values.

In fact, this spectral index reflects a complex of physical and geographical conditions: absolute height, exposure and steepness of slopes, thermal and humidity conditions, attitude to the prevailing wind directions.

In the work, non-contact surveys from the LAND VIEWER measuring platform were used as the initial data. To accurately compare and take into account seasonal climatic indicators, data from the summer seasons of 2009 and 2019 were taken. Figure 2 below shows the indicators of the NDVI index obtained on 08.07.2009 and 12.07.2019.

![Satellite images of the Tsemesskaya Bay area using the NDVI index.](image)

**Figure 2.** Satellite images of the Tsemesskaya Bay area using the NDVI index. Legend: changing the values of the NDVI index.

### 3. Results

NDVI calculations using formula (1) showed the following values:

**FOR 2009:**

\[ \frac{B_{31.40} - B_{72.29}}{B_{31.40} + B_{72.29}} = -0.4 \]  

**FOR 2019:**

\[ \frac{B_{33.90} - B_{87.47}}{B_{33.90} + B_{87.47}} = -0.4 \]
In figure 2, the areas with the most pronounced deviation of the index are painted in red, their NDVI is equal to the calculated value of -0.4, which is a reflection of sparse vegetation.

Analysis of the images shows that with similar values of the index, the areas of vegetation inhibition in 2009 and in 2019 are different. Over the past 10 years, the total technogenic load on the territory has increased significantly due to the expansion of the territory of the village, Myskhako, pos. Kabardinka, involvement in the development of new sections of the coast. However, it should be noted that in the western part of the study area, the values of the NDVI index are increasing. Local decreases are noted here only for intermontane valleys, areas with vineyards, the change of juniper woodlands to herbaceous communities, for intracity areas. The industrial agglomeration area of AO Novoroscement has remained practically unchanged.

Consequently, the high reflection of red and the deviation of the NDVI index towards lower values correspond to areas with mechanical impact on the vegetation cover within built-up or developed areas. While the rest of the territory corresponds to the state of natural or restored vegetation in a given season of the year.

4. The discussion of the results

Novorossiysk is a city with a difficult ecological situation and a high technogenic load. In accordance with the provision of SP 42.13330.2012 [10], it must have at least 10 m² of public green spaces per 1 inhabitant, i.e. not less than 315 hectares of green spaces. In general, depending on the location, the natural overgrowth of a given territory has low values. The obtained cartographic materials confirm the results of the activities carried out in the city to preserve green spaces. Over the past period, green squares of indoor areas were created, planted with fruit trees and shrubs, green lawns and flower beds were laid out, which, in general, straightened the situation with gardening. Nevertheless, there is a continuing decline in urban green areas of squares and boulevards created in the floodplain forest of the river. Tsesmes, there is a reduction in recreational areas and natural monuments of local importance.

The work done has shown that the transformation of natural landscapes, a decrease in biomass during mining have negative environmental consequences, but this impact is of a point nature in comparison with the built-up area. The use of the NDVI indicator in this case allows you to identify problem areas of oppressed vegetation, incl. clearly identify urban areas, quarries, heaps and natural overgrowth.

The complexity of landscaping lies in the fact that the slope type of terrain is characterized by relatively weak natural forest cover. This requires taking into account the peculiarities of the climate in order to restore the vegetation cover, incl. when choosing tree species without special care - watering, as well as full-tier planting of plants: tree, shrub, ground cover perennials or lawn.

Thus, measures for artificial restoration of vegetation during the reclamation of disturbed natural complexes can be based on data on the NDVI indicator as a source of information about the state of the geological environment, the intensity of vegetation of trees and shrubs, making it possible to make the most correct decisions in the long term.

5. Conclusion

The territory of the Novorossiysk industrial agglomeration has a certain potential for use after reclamation. A similar experience exists in various regions of the world [11-13], when the result of reclamation was an ecologically balanced area in the composition of green spaces of general use.

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