Assessment of the state of crops in the territory of the Chelyabinsk Research Institute of Agricultural Sciences based on remote sensing data

A.S. Gusev[1], *V.A.* Inysheva[1,*], *P.M.* Lopukhov[2], *Yu.B.* Anisimov[2], and *S.A.* Bronitskaya[1]

[1]Ural State Agrarian University, Yekaterinburg, Russia
[2]Chelyabinsk Research Institute of Agriculture, Chelyabinsk, Russia

Abstract. In the context of climate change and increasing food demand, it is important to optimize agricultural production processes. Remote sensing allows to quickly and accurately assess the condition of crops, which contributes to more efficient management of land resources. The use of satellite data provides wide coverage and allows to obtain up-to-date information in large volumes in a short time, which is an effective tool in planning agronomic activities and forecasting crop yields. This article analyzes the current state of crops using the example of agricultural land in the Chelyabinsk Research Institute of Agricultural Sciences using remote sensing methods, namely, the use of the NDVI (Normalized Difference Vegetation Index) as an increment of the assessment. Despite some limitations related to the influence of external factors and the accuracy of data, the use of NDVI in combination with other monitoring methods opens up new opportunities for increasing agricultural productivity and sustainability in the current environment.

1 Introduction

Agriculture is one of the most important sectors of the economy, which ensures food security and contributes to the sustainable development of territories. In the current conditions of climate change and resource depletion, the need for effective agricultural activities is increasing, and at the same time, the rational use of land resources. Assessment of the condition of crops is a key element of agricultural process management. Remote sensing methods are actively developing, in particular, the use of the NDVI index as one of the most informative indicators of vegetation status. This index allows obtaining operational data on vegetation and diagnostics of plant health, which is extremely important for the rational management of agricultural production [4, 5].

According to the data obtained by performing aerial photography using UAVs, it is possible to create electronic field maps that reflect all the necessary information about the state of land, crops, etc. at the current time. The creation of electronic maps of agricultural lands is necessary to identify unused or misused lands, as well as to identify foci of erosion,

* Corresponding author: inyshevav@mail.ru

water saturation, and waterlogging and other manifestations of land degradation. Topographic maps are used as the basis for creating electronic maps, on which satellite images are processed and superimposed using GIS [3].

The satellite crop monitoring system is a real-time surveillance system that allows to monitor changes in the vegetation index in agricultural fields or for different crops. The vegetation index is obtained by spectral analysis of high-resolution satellite images. In addition, the system makes it possible to assess the dynamics of plant development, both positive and negative [6].

2 Materials and Methods

The analysis of the use of the territory based on Earth remote sensing data was carried out using the example of the Chelyabinsk Research Institute of Agricultural Sciences. The classification of the territory in the SAGA GIS (System for Automated Geoscientific Analyses) software package was used as an assessment method [8]. The remote sensing materials were taken from the EarthExplorer service, which provides free access to Landsat satellite images containing data for classifying the selected territory and detailed information about the earth's surface.

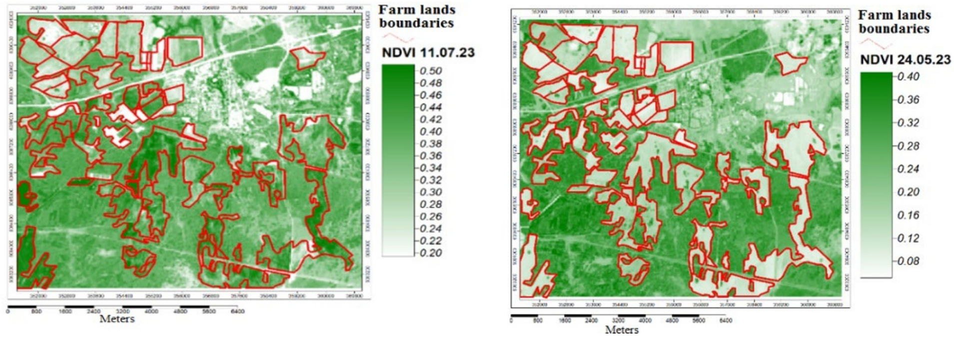
Stages of research:

1. Data collection (satellite images);
2. Calculation of the NDVI index
3. Processing of the received data. GIS products were used to interpret and visualize the data.
4. Field experiment. In parallel, field studies were conducted to verify the data, including plant health assessment and fertilization.

The Chelyabinsk Research Institute of Agriculture is located in the Chelyabinsk region, microdistrict Chebarkulsky, vil. Timiryazevsky. The company is located in the center of the Chelyabinsk region along the M5 Ural highway. The Chelyabinsk — Ufa federal highway runs to the north. The distance to the regional center (Chebarkul) is 37 km. The nearest railway station, Bishkil— is located 7 km north of the village. The Lobanovka River flows through the territory of the farm. East of the village is the source of the Birgilda River. The experimental base of the Chelyabinsk Research Institute of Agricultural Sciences is represented by land with a total area of 1,755 hectares [9].

Remote sensing materials were also used to assess the condition of crops based on the NDVI index [1, 2]. To calculate the NDVI index, 3 Landsat 8-9 OLI / TIRS C2 L2 satellite images were uploaded to the EarthExplorer service, reflecting the state of crops during the growing season of 2023 [10]. 1 snapshot with the date – 05/24/13; 2 snapshot – 07/11/13; 3 snapshot – 12/08/13 (Figure 1).

05/24/23 07/11/23



08/12/23

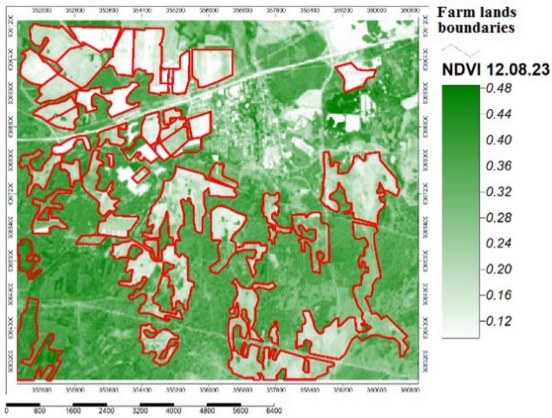


Fig. 1. Snapshot of the territory of the Chelyabinsk Research Institute of Agricultural Sciences in NDVI format.

A GIS product that is publicly available, SAGA GIS (System for Automated Geoscientific Analyses), was used to calculate the index.

To obtain an image with the NDVI index, the Vegetation Index (Slope Based) tool was used, as a result of which images of the territory of the Chelyabinsk Research Institute of Agricultural Sciences were obtained.

3 Results and Discussion

The analysis of the data obtained revealed correlations between the NDVI index and the intensity of biomass growth for various crops cultivated at the enterprise (Table 1).

Table 1. Analysis of the correlation between the NDVI index and the intensity of biomass growth during the growing season of 2023 (Chelyabinsk Research Institute of Agricultural Sciences).

Indicator	Terms of observation		
	03/24/2023	07/11/23	08/12/23
NDVI Index value			
average	0.24	0.36	0.28
minimum	0.08	0.20	0.12
maximum	0.40	0.50	0.48
Value of the NDVI index for crops			
dead fallow	0.08-0.10	0.20-0.22	0.12 – 0.20
crops in the phase of sprouting beginning	0.16-0.18	-	-
crops in the phase of sprouting	0.20 – 0.30	-	-
crops in the phase of tillering and earing	0.20 – 0.30	0.35-0.40	-
crops in the phase of milk ripeness	-	0.35-0.40	0.36-0.40

crops in the phase wax (full) ripeness	-	0.25-0.30	0.23-0.36
perennial herbs	0.30 – 0.40	0.40-0.50	0.38-0.48
fields after harvesting	-	-	0.12-0.20
Correlation between the intensity of biomass growth and the NDVI index value			
grain crops	0.45	0.68	0.52
annual herbs	0.63	0.75	0.68
perennial herbs	0.86	0.81	0.78

In the early spring observation period (May 24, 2023), it is possible to monitor the condition of overwintered plants. The NDVI index, which ranges from 0.2−0.3, indicates that the plants have already entered the tillering phase and are resuming vegetation. Plots of agricultural land with an index value from 0.08-0.16 indicate fields where active vegetation has not yet begun.

The middle of the growing season (July 11, 2023) indicates a significant increase in photosynthetic activity, as evidenced by an increase in the NDVI index values during this period. Crops have already been harvested in fields with a low NDVI index.

At the end of the growing season (August 12, 2023), the density of photosynthetically active biomass decreased. The NDVI index for this period starts from a value of 0.12, which indicates the absence of vegetation in the fields.

For a detailed analysis of the NDVI value, a land plot with cadastral number 74:23:0910001:215 and a total area of 34.67 hectares was selected, of which 7 hectares is an experimental field with the study of various doses of fertilizers, for which an analysis was performed.

Using the Show Cell Values tool, a map of the land plot with the NDVI index was obtained, which in turn was compared with the scheme of experiment on this site. The analysis of the results is presented in Table 2.

Table 2. Analysis of the correlation between the NDVI index and the doses of fertilizers applied during the growing season of 2023. (Chelyabinsk Research Institute of Agricultural Sciences).

Fertilizer doses, kg/ha	NDVI Index value		
	min	max	difference
0	0.23	0.31	0.08
20	0.31	0.38	0.07
40	0.39	0.42	0.03
60	0.41	0.44	0.03
Correlation coefficient	0.76		

Assessment of the condition of crops in the territory of the Chelyabinsk Research Institute of Agricultural Sciences using the NDVI index is an effective tool for monitoring and analyzing vegetation. This methodology allows not only to quickly identify problems in the condition of plants, but also to predict yields, which is important for increasing agricultural productivity. The use of NDVI provides an opportunity to integrate remote sensing data into agronomic practice, which contributes to effective crop management. However, this monitoring tool still has some drawbacks, which we have collected in the main conclusions of this study.

4 Conclusions

Thus, an assessment of crops on the territory of the working sites of the Chelyabinsk Research Institute of Agricultural Sciences was carried out. The assessment of the state of crops at the enterprise according to the NDVI indicator is an effective tool for optimizing agricultural production, but it has its drawbacks. Despite the rather high correlation dependence of the NDVI index on the intensity of biomass growth during the growing season, especially at the beginning of the growing season for annual and perennial grasses (0.63 – 0.86) and on the dose of fertilizers applied (0.76), this indicator should be used with mandatory selective ground control, since the NDVI index can be sensitive to atmospheric conditions, such as clouds, haze, and aerosols, which in turn can distort its values and make it difficult to accurately interpret the data. The interpretation of the values of the photosynthetically active biomass index may vary depending on the type of crop and soil conditions. Also, the use of this index may be limited by the availability and quality of satellite images. Therefore, we recommend using this indicator in conjunction with other studied indicators (agrochemical properties, field history of the enterprise, etc.).

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