Smart analysis of agricultural land use with NDVI at Kuraginskoye agricultural experimental production facility

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Abstract. The article presents the results of a geospatial analysis of the NDVI distribution for the 2020 growing season for the territory of the Kuraginskoye Agricultural Experimental Production Facility, which is currently part of the Federal Research Center Krasnoyarsk Science Center of the Siberian Branch of Russian Academy of Sciences. A geospatial database of the Kuraginskoye Facility has been created, which stores an electronic map of fields and a time series of vegetation indices for each field for 2020. The initial data are cloudless satellite images of the PlanetScope constellation with a spatial resolution of 3 m. The average NDVI value was calculated for all fields of the Kuraginskoe farm using all available satellite data. For each field, graphs of the dependence of the distribution of the vegetation cover NDVI index for the vegetation period of 2020 were prepared and analyzed.

1. Introduction
In recent years, new technical and technological opportunities have appeared for the creation of remote monitoring systems for agricultural lands [1]. Remote sensing data today act as a non-alternative source of regular operational information for monitoring the state of agricultural land. A lot of problems related to monitoring of agricultural lands based on the use of satellite data are being solved [2]. Studies show that most of the parameters of agricultural crops, such as plant density, biomass of reproductive organs, leaf index, and others, affect the reflective characteristics of plants in certain parts of the spectrum and, therefore, can be reconstructed by measuring these characteristics. Thus, there is a possibility of improving the yield forecasting models by replacing the calculated parameters of the base model with the parameters determined by measurements from Earth satellites [3].

Among the numerous analyzed parameters that can be used to assess the features of changes in vegetation over vast areas of the earth's surface, there are vegetation indices. Among the most widespread and used indices that use quantitative estimates of vegetation cover is the Normalized Difference Vegetation Index (NDVI), which to some extent reflects the quantitative indicator of photo synthetically active biomass.

At present, NDVI is widely used to analyze the state of vegetation [4], including crops of agricultural crops [5]. The NDVI vegetation index was applied to assess the spatial distribution of yield, based on the use of optical ground-based and satellite spectral data from the PlanetScope Dove satellites from
Planet Labs. A feature of the method is the use of the integral of values of vegetation indices (NDVI, MSAVI, ClGreen) at various stages of crop development [6]. On the production fields of JSC "Osminskoe" of the Slantsevsky district of the Leningrad region, an assessment of the state of vegetation cover (perennial herbage) was carried out using satellite images using the vegetation index NDVI [7]. In the work of A.G. Terekhov, seasonal maxima of the NDVI vegetation index for the period 2000–2009 were used to assess the agro technical level of cultivation of spring crops [8].

This paper presents the results of a geospatial analysis of the NDVI distribution for the 2020 growing season for the territory of the Kuraginskoie Agricultural Experimental Production Facility (EPF), which is currently part of the Federal Research Center Krasnoyarsk Science Center of the Siberian Branch of Russian Academy of Sciences. The initial data are cloudless satellite images of the Planet Scope constellation with a spatial resolution of 3 m.

The purpose of the work is to create a geospatial database of the Kuraginskoie agricultural holding and perform a geospatial analysis of the use of its agricultural lands based on the NDVI distribution for the 2020 growing season.

2. Materials and methods

The territory of Kuraginskoie EPF is located in the south-west part of the Kuraginsky district of the Krasnoyarsk Territory. The total area of the farm is just over 14 thousand hectares. The climate of the Kuraginskoye EPF is sharply continental, with long cold winters and short hot summers. According to the data of the nearby Berezovskaya meteorological station, the average long-term annual air temperature is -1.2°C. The growing season lasts 154 days. The period with an average daily temperature above +10°C is 114 days, the sum of positive temperatures for this period is 1761°C.

On the basis of satellite images of the Kuraginskoye EPF, a digital map of fields was created using the QGIS geographic information system [9]. The next step in the formation of the geospatial database of the Kuraginskoye farm was the filling of the average NDVI value for each field and for all dates of the growing season.

The calculation of the vegetation index NDVI for the territory of the Kuraginskoye production farm was carried out based on satellite information of high spatial and temporal resolution Planet Scope from Planet Labs. This satellite data has a spatial resolution of 3 m, 4 spectral channels: three in the visible and one near infrared.

Cloudless satellite scenes for the 2020 growing season were selected for the study area, and their primary processing was carried out. The calibration was performed channel by channel using the calibration coefficients presented in the corresponding sets of image metadata. All calculations were performed using the QGIS raster calculator.

The NDVI vegetation index is calculated using data on two channels, where the measurements in channel b3 are within the spectrum from 590 to 670 nm, and channel b4 is within the spectrum from 780 to 860 nm [5]. The index values vary depending on the density (closeness) of the canopy and the saturation of plants with chlorophyll [3]. That is, the more chlorophyll is accumulated in the plant and the denser the biomass, the more saturated green colour reflects the vegetation cover, which is fixed using remote sensing data. When there is no vegetation cover on the surface of the earth, the NDVI index values are minimal. The index of the index increases with the beginning of the growing season of plants, and it is noted as the maximum in summer. In addition, the vegetation index has a special periodicity [12].

If the territory consists of several images, then the images were merged into a “single” raster [5]. A digital map of agricultural fields and a set of NDVI images for 2020 provided statistical NDVI values for each field during the entire growing season. In GIS QGIS the tool "Calculate area statistics" was used. The zonal statistics results for the mean were saved in a separate vector layer. The final geospatial analysis was carried out in QGIS Geoinformation system and Microsoft Excel software for more convenient and visual work with data.
3. Results and discussion

A digital map of the fields of the Kuraginskoye EPF has been formed, which includes 84 polygonal objects that correspond to the existing agricultural fields in the area. Each polygon contains attributive information in the form of a field number and its area. The Universal Transverse Mercator projection (UTM) 46 zone (north) was chosen as a unified cartographic projection; this projection is ideal for large-scale mapping of Russia and, in particular, the Krasnoyarsk Territory [9-11].

96 Planet Scope satellite images were downloaded to the study area for the period from 03/11/2020 to 09/28/2020, which were later combined by dates into 31 raster layers.

The geospatial database of the Kuraginskoye EPF was created and filled, which stores the vegetation indices NDVI, VARI, ClGreen for the growing season 2020 for each field. The creation of such a geospatial database of the farm allows you to analyze each existing field individually, that is, it can serve as a tool in the precision farming system.

As an example, consider the distribution of the vegetation index NDVI for two different fields - field no. 22 and field no. 35. At the same time, field no. 22 is used as haymaking, and field no. 35 is used for growing spring wheat.

The dynamics of vegetation for the two selected fields is shown in figure 1. The graph shows that for the period from 27.03.2020 to 20.05.2020, the NDVI vegetation index is increasing from 0.00-0.82 in field no. 22. Further, there is a sharp decline in the NDVI index to 0.42 on 06/13/2020, which most likely indicates the process of mowing grass for haymaking. Further, the growth of the vegetation index NDVI resumes, until the moment of repeated haymaking in the field. In general, according to this graph for field 22, it is possible to determine the main events that took place in the field (when there was haymaking), to evaluate the dynamics of the growing season (according to the change in the NDVI index). It is possible to determine when the maximum indicators were reached, characterizing the greatest accumulation of chlorophyll in vegetative plants. Analysis of the temporal dynamics of changes in NDVI allows determining the trends of the growing season in the current season, and the data accumulated over many years is an effective tool for predicting the yield.

![Figure 1. Dynamics of changes in the NDVI for the 2020 vegetation period in a field used as hayfield.](image-url)
The trends marked on the graph can be visually analyzed on the resulting NDVI distribution maps. Figure 2 shows the NDVI maps for the dates on which the maximum indicators were reached (05/20/2020, 07/18/2020) and the dates on which the mowing of field no. 22 presumably took place (06/28/2020 and 08/04/2020).

Another example is field no. 35, where a spring crop grew. The corresponding distribution of NDVI is presented in figure 3, which shows a gradual increase in the NDVI vegetation index from 0.00 to 0.61, which characterizes the intensification of the development of spring crops.

In the period from 06/28/2020 to 07/29/2020, the maximum indicators are reached, characterizing the greatest accumulation of chlorophyll in vegetative plants. By the end of August, after harvesting, the vegetation index NDVI decreases to 0.21-0.36 units, which is associated with the termination of growth processes and a decrease in the photosynthetic activity of the vegetation cover.

Figure 4 shows the corresponding NDVI distribution maps for field no. 35 for the same dates as for field no. 22. Comparing the raster images in figures 2 and 4, you can see that at the time of mowing of field no. 22 on 28.06.2020 and the corresponding decline in the NDVI vegetation index on field 35, there is a further growth of spring crops and approaching the maximum values of the NDVI index.

Analyzing the entire territory of the Kuraginskoye EPF, it is possible to reveal the heterogeneity of the spatial distribution of the vegetation index NDVI for each array of the field, which demonstrates the unevenness of the growth and development of the vegetation cover. The revealed heterogeneity of the NDVI vegetation index allows to carry out the necessary technological operations (top dressing, cutting, etc.) in an on-line mode in those areas of the field that need them [8].

Figure 2. NDVI maps of field no. 22 for dates with the maximum index values (on the left) and after mowing (on the right).
Figure 3. Dynamics of changes in the NDVI for the 2020 in a field used for growing spring wheat.

Figure 4. NDVI maps of field no. 35 for the same dates as on figure 2.
4. Conclusions

Based on remote sensing data on the territory of the Kuraginskoye agricultural experimental production facility, the NDVI vegetation index was calculated for all 84 fields of this farm. The technology for calculating the vegetation index NDVI has been compiled using the Kuraginskoye farm as an example. For each field of the study area, graphs of the dependence of the distribution of the NDVI index of vegetation cover for the growing season of 2020 were prepared, which allow you to analyze the state of the fields.

If you calculate such data over several years, you can get an average value for each field, in the future this will allow you to plan the implementation of the harvest, predict yields and conduct spot farming. In the future, it is planned to replenish this will allow you to plan the implementation of the harvest, predict yields and conduct spot farming. For each field of the study area, graphs of the dependence of the distribution of the NDVI index of vegetation cover for the growing season of 2020 were prepared, which allow you to analyze the state of the fields.

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