Use of Unmanned Aerial Vehicles for Sensing Microrelief During Agrocenoses Monitoring

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Abstract. The use of UAVs for obtaining data on field microrelief within agricultural lands was demonstrated. The work relies on the NDVI integral values during the vegetation period obtained using satellite and ground-based spectrometry. It was established that a change in microrelief has a significant impact on the value of the NDVI integral and yield. The proposed approach can be used in precision farming for planning future agricultural work.

Keywords: UAV, agriculture, vegetation index, barley, precision farming, spectrometry.

1 Introduction

Yield mapping is an element of the precision agriculture system, making it possible to determine the heterogeneity of one of the most important indicators — crop yield [1]. A map of crop yield is the basis for the differentiated application of fertilizers in precision agriculture [2]. It can be used to identify areas with low yield for a focused study of the causes of its decrease in this area of the field and taking appropriate measures to solve this problem [3].

The creation of digital field maps is possible using satellite data of high spatial and temporal resolution. Currently, continuous monitoring of crops with high spatial resolution (3 meters) and daily measurements are provided by the world's largest satellite constellation PlanetScope of the Planet company [4]. The system provides data making it possible to evaluate the condition of crops during the entire growing season.

Today, in the monitoring of areas occupied by crops, unmanned aerial vehicles (UAVs) are widely used [5]. The use of unmanned aerial vehicles in agriculture is one of the most promising areas of application of this technology. UAVs can be effectively used for planning and controlling the stages of agricultural production, as well as for chemical processing of crops and other plants [6]. In addition, the ultra-high resolution of images obtained with the help of UAVs makes it possible to investigate the microrelief and the soil structure of fields [7–8]. This, in turn, makes it possible to take into account a large number of new, previously inaccessible parameters, including the detection of areas with high and low humidity, which directly affects the state of crops [9].

Purpose of the study: exploring the possibility of using UAVs for assessing the microrelief of areas belonging to agricultural lands, and comparing the results with the data on the spatial distribution of yield in the studied area. The results obtained should be relevant for precision farming.

2 Research object and methods.

Studies were conducted on the lands of the Minderlinskoye Instructional Farm LLC, located in Sukhobuzimsky District, Krasnoyarsk Territory, before and during the growing season. The first shootings with the help of UAVs were carried out during the period of snow cover melting. The experimental field consisted of 5 strips, the average length of which was about 650 meters. The width of the stripes was 20 meters, they were located from west to east. Fertilizers were applied in the northern part of each strip; fertilizers were not introduced in the southern parts. Each of the 5 lanes was sown with crops. The work presents the analysis and results of data processing for strip number 5 sown with “Acha” barley.

Barley was sown on May 19th, 2018. All strips were divided into 4 test areas in accordance with four types of soil treatment: “a” — plowing (pickup plow PN-5-35, 20–22 cm); “b” — subsurface treatment (subsurface cultivator KPSHK-3.8, 20-22 cm); “c” — surface treatment (disk header BDShCh-5.6, 8-10 cm); “d” — direct sowing at zero tillage (Agrator 4.8). For the purity of the experiment, all test areas were separated from each other by protective strips 5 meters wide.

To perform high-altitude shooting, a DJI Phantom4 PRO + v2.0 series UAV was used. The resulting data were photographic images with a centimeter resolution and horizontal and vertical tie-in of coordinates.

Also, the following data set was used:

- PlanetScope satellite data with a preliminary atmospheric correction. Correction factors for each channel are present in the metadata of each scene (these images have a spatial resolution of 3 meters);

- The data of field spectrometry that was performed 5 times during the growing season 2018. The distance between measurements was about 50 meters.

When carrying out field spectrometry, the Spectral Evolution PSR-1100F spectroradiometer was used. The data obtained were the spectral brightness coefficients of the object in the range from 320 to 1100 nm.

The satellite and ground-based spectrophotometric data were used to calculate the following spectral indices: NDVI (Normalized Difference Vegetation Index) [10], VARI (Visible Atmospherically Resistant Index) [11], MSAVI2 (Modified Soil Adjusted Vegetation Index) [12], and ClGreen (Green chlorophyll index) [13].

According to the data obtained with the help of UAVs, the terrain orthophotomap, 3D terrain model and vertical profile were constructed for strip No 5.

3 Results and discussion.

During the study of the experimental field with the help of UAVs before the flight, a flight task was compiled. To obtain an adequate orthophotomap, overlapping of images was observed: 60% in the longitudinal and 30% in the transverse direction [14]. The shooting was performed in calm weather, from a height of 50 meters, the camera lens was aimed at the nadir. In the software supplied with the UAVs (DJI GO), the shooting parameters were set to an interval of 5 s and a flight speed of 15 m/s. Then, without the participation of the operator, the flight and survey were carried out, which, on average, took about 30 minutes.

As a result of the shooting, a set of overlapping photo images was obtained, in the amount of 294 pcs. The resulting data set was processed in the Pix4D mapper software. Such processing makes it possible to obtain a full-fledged orthophoto mosaic from a set of individual images and a 3D terrain model that contains information about the horizontal and vertical position of each pixel.

Figure 1 shows the processing results of the data obtained. The image of the investigated strip No 5 shows the zone with the remains of snow cover — Fig.1 (1). In other parts of the strip, there are no remains of snow cover, only areas of high humidity are noticeable, as they have darker tones. On the constructed vertical profile for strip No 5, it can be seen that, in the zone with the remains of snow cover, a 1-meter decrease in the relief is observed — Fig. 1 (3). The comparison of the spectrometry data and the results of the survey using UAVs showed that the relief lowering zone is distinguished on the cartogram by elevated NDVI values.

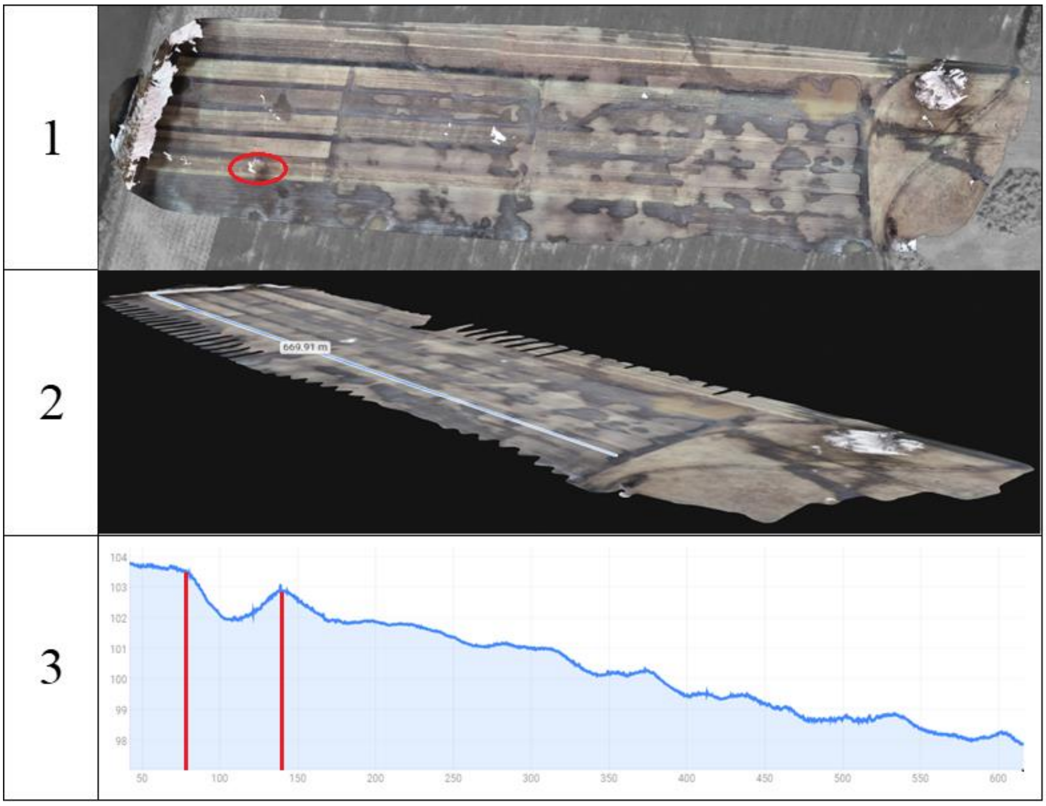


Figure 1. Processed survey results. 1 - orthophoto mosaic, 2 - 3D model, 3 - vertical profile for strip No 5. The red circle and lines mark the area with a 1 m decrease in height.

The actual yield of barley varies depending on the availability of fertilizer background and the type of treatment. The highest yield of barley was recorded in the variant with mouldboard plowing (25.9 centner/ha (fertilized background) and 23.7 centner/ha (non-fertilized background), the lowest — in the variant with surface treatment (19.7 centner/ha (fertilized background) and 15.8 centner/ha (non-fertilized background). For all types of treatment, the application of mineral fertilizers led to an increase in the yield of barley grain.

The evaluation of the actual yield on the field is an important indicator of the efficiency of agricultural production. Determination of the spatial distribution (cartograms) of yield is more informative, making it possible to reveal the heterogeneity of the yield level within one field. Vegetation indices, including NDVI, MSAVI2, ClGreen, are a quantitative characteristic of the state of crops. A number of papers confirmed a stable correlation between NDVI and yield [1-2, 15-16].

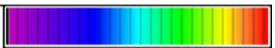
The use of PlanetScope satellite information helps to identify areas with persistently low or high values of phytomass at separate phases of plant growth and development. Creation of high spatial resolution maps of the spatial distribution of index values during the growing season is an integral part of precision agriculture.

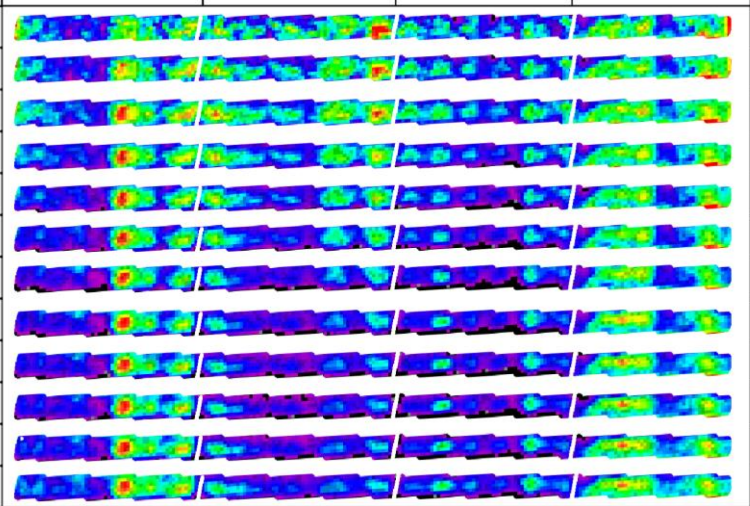
The basic characteristic used in the work is the growth dynamics of the plant agrobiocenosis during the vegetative period. The main parameter used in further work is NDVI. During the growing season, the NDVI value undergoes significant changes from 0.1 to 0.8. The typical NDVI curve during the growing season looks as follows: growth at the beginning of the period, the maximum values in the middle, and decrease at the end of the growing season. Such form of representation of this value makes it possible to calculate the integral of the vegetation index curve.

For practical purposes, it is possible to use not the complete integral from the beginning to the end of the growing season, but its initial part. The earlier the yield forecast is made, the more significant it is for practical purposes. It means that it is necessary to find the optimal date to calculate the integral of the vegetation period, which also ensures the sufficient accuracy of the forecast.

The analysis of the relationship between the yield and the integral value at different vegetation periods showed that starting from mid-July, the value r increased considerably (more than 0.7) for the NDVI, MSAVI2, and ClGreen indices.The maximum values were achieved by early August. The correlation coefficients calculated from July 2nd to September 5th are reliable at a significance level of 0.05. Thus, it was shown that the use of integral indicators allows one to perform a forecast of barley yield at the stage of flowering — milky ripeness.

Figure 2 shows the cartograms of the NDVI integral values of barley crops during the growing season from June 4th to September 5th, 2018, obtained on the basis of the PlanetScope data.





Date		d	c	b	a		
Start	End					min.	max.
04.06.2018	13.06.2018					1,55	2,15
04.06.2018	18.06.2018					3,47	4,85
04.06.2018	23.06.2018					4,9	7
04.06.2018	26.06.2018					6,95	9,55
04.06.2018	02.07.2018					8,35	11,1
04.06.2018	16.07.2018					10,9	14,4
04.06.2018	31.07.2018					16,85	21,7
04.06.2018	08.08.2018					22,55	28,45
04.06.2018	17.08.2018					25,1	31,45
04.06.2018	21.08.2018					27,4	33,7
04.06.2018	26.08.2018					27,9	34,5
04.06.2018	05.09.2018					28,4	35,8

Figure 2. The cartograms of the NDVI integral values of barley crops during the growing season (from June 4th to September 5th, 2018) obtained on the basis of the PlanetScope data. White lines indicate the division into the types of soil treatment (a, b, c, d). The cartograms were colored using a single color scale for all of the research dates. The minimum and maximum values of the color scales are presented in the table — opposite the corresponding cartogram.

Information presentation in the form of the accumulated values of NDVI integrals shows that, compared with the spatial variation of direct NDVI values, a stable structure appears over time in certain types of treatment (d and a). At the same time, there is a clear dependence of the change in the spatial structure of NDVI integrals during b and c type treatments. In type **c** treatment, the pronounced integral value from June 4th to 13th decreases by August 8th, then disappears, and the whole area becomes almost uniform. The same happens in type b treatment, but the difference between the beginning and the end is less than in type **c** treatment.

It is reported that in the map, in the area with type d treatment, there is a red zone — an area with an increased value of the NDVI integral. The expert comparison of the constructed cartogram and the results of the UAV survey showed that the zone with an elevated NDVI value corresponds to a 1-meter relief decrease, which was detected on the orthophoto mosaic.

It can be assumed that the vertical profile decrease leads to an increase in moisture content in the soil. The consequence of this are the increased values of the NDVI integral and, thus, the increase in yield in this area.

It should also be noted that there is a similar connection at site A. In Figure 1 (1), zones of high humidity are visible — dark spots, which were visually observed as areas of soil saturated with melt-water. On the cartogram of NDVI integrals, this section also has elevated NDVI values and, consequently, yields. In this case, the relative decrease of the microrelief is insignificant, but, nevertheless, leads to the accumulation of moisture.

From the above information, it is possible to conclude that a survey with the help of UAVs during the late period of snow melting can provide very significant data for assessing the subsequent dynamics of the vegetation process in cultivated lands.

Thus, the comparison of the cartogram of the NDVI integral values and the UAV survey results shows that using this type of data makes it possible to take into account all the features of the field relief and to detect the distinguished areas requiring a special approach in carrying out relevant activities.

In the future, the resulting cartogram and the data on the microrelief obtained by UAVs are planned to be used for differential fertilization and monitoring of crop growth. Differential fertilization and planting of crops taking into account the microrelief of a field will make it possible to increase the efficiency of the applied fertilizers and level the crop yield within one field. This approach will improve the economic performance of agricultural production.

4 Conclusion.

The use of UAVs when shooting the microrelief of agrocenoses makes it possible to detect areas associated with different levels of moisture in the soil.

It was established that the NDVI integral calculated during the vegetation period can be considered as a parameter related to yield. The analysis of the relationship between the yield and the integral value at different vegetation periods showed that starting from mid-July, the correlation coefficient value increased considerably (more than 0.7, at a significance level of 0.05) for the NDVI, MSAVI2, and ClGreen indices. The maximum values were achieved by early August.

As a result of the research carried out, the orthophoto mosaic and 3D model of the terrain were constructed according to the data obtained from UAVs. The spatial variation of the NDVI values of the barley field from June 2nd to September 20th, 2018 was built using satellite and ground data. The spatial variation of the NDVI integral values of the barley field during the growing season (from June 4th to September 5th 2018) was obtained on the basis of satellite data.

A method was developed for estimating the spatial distribution of the yield of spring barley, based on the use of optical ground and satellite spectral data (PlanetScope data with a spatial resolution of 3 meters).

The connection was established between the change in the NDVI integral values, depending on the change in the field microrelief, and the spatial distribution of areas with high humidity at the beginning of the vegetation period.

The resulting yield maps and field microrelief data will be used in planning future agricultural activities.

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