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The use of unmanned aerial vehicles in digital agriculture

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Abstract. The task of forming a system of remote monitoring of soil conditions based on unmanned aerial vehicles was solved by this work. The authors conducted an experimental study that showed the principal possibility of such monitoring. It was shown that the most informative channel is the red one when using a high resolution digital camera. As a result of statistical processing, the experimental regression dependences allowing to estimate the amount of humus in the soil with the error not exceeding the value of 16 percent were received. Experimental plots were laid for conducting experiments for which the soil quality was determined by laboratory methods according to Tyurin. Similar experiments with the use of hyperspectral equipment were defined as further research.

1 Introduction

Digital agriculture is a way of agricultural production that actively uses the latest information technology to significantly increase the volume and quality of agricultural products [1-3]. At the same time, production costs are significantly reduced and yields are increased.
Digital or smart agricultural production uses artificial intelligence, Big Data, the Internet of Things (IoT), remote monitoring methods based on satellite Earth sensing, as well as the use of unmanned aerial vehicles (UAV) of various types as the main technologies [4-6].

The application of remote sensing methods makes it possible to obtain real-time information on the state of crops, soils and other important components of agricultural production, which makes it possible to forecast the main production parameters and to plan the necessary agrotechnological measures promptly [1, 4].

It should be noted that the most important component determining soil fertility is the organic carbon contained in its composition, which is 87 percent represented by soil humus. Therefore, it is necessary to constantly monitor the amount of humus in the soil and maintain its fertility. This requires reliable and operational spatial information about the soil of agricultural agrocenoses [1, 5].

In their work [1, 4] the authors reviewed satellite sensing technologies for soil fertility assessment and showed the principal possibility of remote monitoring of soil fertility

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conditions on large agricultural areas of the grape agrocenoses of the southern regions of Russia. At the same time, the analysis of the application of the mentioned method of soil condition monitoring showed that it is not always possible to apply it because of the sufficiently high cost of images, especially those using hyperspectral equipment. Also, it is not always possible to obtain images of the required plots of agricultural areas at the required date and time.

Therefore, it is reasonable to use remote sensing with the application of UAVs as a supplement to space sensing [7, 8].

The objective of the study is to assess the possibility of remote monitoring of soil conditions and soil fertility based on images obtained by UAVs.

2 Materials and methods

Remote sensing systems based on UAVs are widely used in all areas of agricultural production. These complexes are used to control large areas and are used to obtain detailed information about the state of the earth's surface and the agricultural production objects located on it [9].

The complexes include means of processing the incoming image data. The processing means are specialized for the solution of a certain task, for example, detection of objects, remote control of the specified territories, topographic survey, as well as monitoring of soil conditions of agricultural territories.

In soil conditions monitoring, sensors in the visible and infrared wavelength range are usually used, characterized by low resolution and which, as a rule, have a small impact on the radio information channel when transmitting the received images to the control point of the complex.

In the case of a large information flow, an onboard flash drive can be used, and the processing of the received images performed after the flight is completed at the ground control point. However, this circumstance reduces the efficiency of the performance of monitoring tasks.

In recent years, there has been a tendency to increase the amount of information from the onboard remote sensing equipment located on air-surveillance complexes.

These complexes include:

- optical electronic sensors of high-resolution frames, panoramic and scanner type of visible and infrared spectrum ranges;
- digital television sensors of visible and infrared spectrum ranges;
- Hyperspectral optical-electronic sensors with the number of channels up to 1000.

The improvement in the characteristics of surveillance equipment (spatial and spectral resolution) leads to a significant increase in the amount of information obtained and, as a consequence, the use of specially developed data compression algorithms, allowing to significantly reduce the amount of transmitted information and thereby ensure the transfer of this information through the information channel with limited bandwidth [10].

For experimenting on soil condition monitoring there was the use of Irkut-10 complex, weighing 8.5 kg, with a flight time of up to 2.5 hours. It consists of two UAVs (one UAV was used), ground-based control and maintenance facilities, and is equipped with a communication line with two digital secured controls and data transmission channels. It is launched from a mobile catapult and landed by parachute. The appearance of the aircraft is shown in Fig. 1.

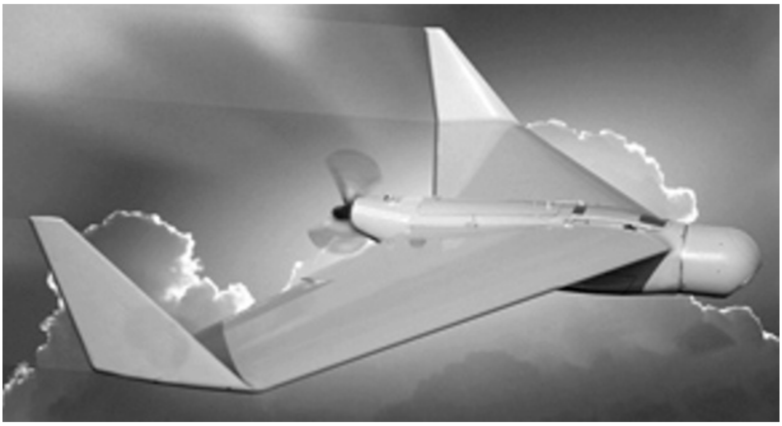

Fig. 1. Irkut-10 UAV.

The objects of the study at the initial stage of the work were the soils of vineyards located in the South of Russia. The main parameters of the studied soils and areas of their location are shown in Table 1.

Table 1. Characteristics of the areas and soils.

Sample No.	Farm, plot	Types of soil
1	"Zolotaya Balka"	Southern low-humus high-carbonate chernozem
2	Grapevine Nursery Stock Kober	Southern low-humus chernozem
3	AC "Magarach"	Southern low-humus chernozem
4	Agrofirma "Chernomorets"	Ordinary micellar-carbonate foothill chernozems

The samples on the experimental plots were taken from a depth of 10 to 15 centimeters. Laboratory analysis of humus content in the soil was made according to Russian standard 26213-91 Soils. Methods for determination of organic matter.

Soil samples for the laboratory studies were pretreated through drying and grinding. The technology of surveying with a digital camera is described in the authors' work [1].

The UAV was equipped with a camera similar to the one used in laboratory studies of soil samples. Its focal length was 75 mm, resolution was 4272x2848 pixels and the spectral range of the digital matrix was 400 to 780 nm. The surveying was performed during the flight of the UAV at an altitude of about 50 to 100 meters from the ground surface.

3 Results and discussion

The data obtained as a result of the experiments should be analyzed on the data obtained in laboratory conditions, as well as those obtained by remote sensing from the Irkut-10 UAV.

The data of the laboratory studies are presented in Table 2. The analysis of these data shows that the greatest value of brightness is in the red range (R), and the smallest is in the blue range (B), the brightness value of the green (G) channel is in between. In the table, the humus content is indicated as G.

Data of Table 2 were processed by statistical methods, and the regression equation (1) describing the level of humus content in the soil depending on the brightness of the red channel of the camera was obtained:

$$G = -0.136R+11.651 \quad (1)$$

At the same time $r^2 = 0.87$, which shows a sufficiently high level of correlation with the standard error value being m=2.6.

Table 2. Spectral characteristics of soils.

Sample No.	*R*	*G*	*B*	G , %
1	75.6	65.1	51.2	1.2
4	76.1	67.3	53.6	1.55
3	64.3	52.9	42.1	2.5
2	62.9	56.8	45.7	3.5

Samples of images obtained by the onboard camera of the studied areas are shown in Figure 2.

a *b*

Fig. 2. Images of the analyzed areas obtained from the UAV a - sample 1, b - samples 2-4).

The images obtained by the UAV camera were subjected to preprocessing similar to the laboratory images. Statistical processing of the results was also performed, and a regression relationship similar to regression (1) was obtained from the laboratory results:

$$G = -0.014R + 8.95 \quad (2)$$

Statistical indicators of the regression dependence (2) are as follows: $r^2 = 0.83$, which shows a good level of correlation, and standard error $m = 4.2$, which allows us to assert a good approximation of the results obtained by regression.

It should be noted that the error of the value of humus content in the soil according to the images obtained from the UAV does not exceed 16 percent, allows us to assert the possibility of remote monitoring of the soil quality.

We emphasize that the series of articles by the authors contains the initial study results, but shows the possibility of remote monitoring of soil fertility both by remote sensing from satellites and UAVs. In the future, experiments are expected using the hyperspectral and multispectral equipment placed onboard satellites and UAVs.

4 Conclusion

As a result of the work performed, it can be concluded about the fundamental basis and sufficiently high efficiency of the methods for estimating the spectral reflective soil surface to analyze its fertility based on remote sensing from the UAV.

The method of processing and interpretation of images obtained from UAVs has been developed, which allows us to determine with a sufficient degree of accuracy the content of humus in the soil, the most important element determining the fertility of the soil.

Further studies will focus on assessing the possibility of using hyperspectral sensors of satellites and UAVs to improve the accuracy of soil fertility assessment by remote sensing methods.

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