Digital technologies for the survey of the state of agricultural land

Y Y Zapara, E I Zatolokina, N M Zatolokina, A A Melentyev* and D O Prikhodko
Belgorod State Agrarian University, 1, Vavilova st., Maysky village, Belgorod district, Belgorod region, Russia

*E-mail: melentev_07@mail.ru

Abstract. Agricultural land is a strategic resource that ensures the food security of the population. They act as the main means of production in agriculture, have a special legal regime, and are subject to special protection aimed at preserving their area, preventing the development of negative soil processes, and increasing soil fertility. The irrational and inappropriate use of agricultural land leads to its degradation, which consists in the loss of fertility, overgrowth, contamination, and the appearance of other negative consequences that negatively affect the possibility of obtaining agricultural products. The functioning of all branches of agriculture and the economy as a whole depends on the rational use of land resources, so the most important task of the state land administration is the organization of land monitoring. The Ministry of Agriculture of the Russian Federation has developed a departmental project "Digital Agriculture" with an implementation period of 2019-2024, the main goal of which is to introduce digital technologies and platform solutions that provide a technological breakthrough in the agro-industrial complex and achieve a 2-fold increase in labor productivity at “digital” agricultural enterprises by 2024. Within the framework of this project, it is planned to form a common system of accounting for agricultural land. It can be used to track which part of the land is used, and which is empty.

1. Introduction
Currently, the main information resource of digital land management is the Unified Federal Information System on Agricultural Land. This system provides the Ministry of Agriculture of the Russian Federation, subordinate organizations, and agricultural producers with operational, up-to-date, and reliable information on agricultural land, including information on the location, condition, and actual use of each land plot by region of Russia, agricultural culture and the state of agricultural vegetation in real-time [1].

One of the sources that ensures the rapid acquisition of objective information about agricultural land is the data of remote sensing of the Earth, which is carried out by satellites with high and ultra-high spatial resolution survey equipment, which contributes to obtaining spatial information with high detail of the terrain display. However, this information is not always sufficient to form a modern, effective land management system; therefore, to ensure full-fledged monitoring of land that meets modern requirements for collecting, analyzing, storing, and using information, it is necessary, along with traditional methods, to apply new surveillance systems, including those based on the use of unmanned
aerial vehicles. Research shows that aerial photography using UAVs is a high-quality and cost-effective way to obtain operational data in the form of high-resolution digital images at optimal costs.

An important source for the rapid acquisition of information about agricultural land is the data of remote sensing of the Earth (RSE). Remote sensing is the process of obtaining information without direct contact with the object under study. With the help of special devices, electromagnetic waves reflected and radiated by the earth's surface are recorded. By measuring the radiation of the agricultural field (mainly in the optical or radar ranges), it is possible to determine the properties of soils and crops. Remote methods and tools based on the acquisition and processing of digital images have important advantages: ease of archiving with the preservation of the maximum amount of data for further analysis; the ability to record, inventory, and classify agricultural land with the construction of specialized plans and maps; detection of emergencies in the fields, assessment of the potential for productivity and the risk of crop losses; monitoring of the reclamation state of agricultural fields. Remote sensing is directly related to working with various types of software, using algorithms for data analysis and processing [2, 3].

Remote methods include satellite imagery, aerial photography from manned vehicles, aerial photography, and video shooting from unmanned aerial vehicles.

In recent years, satellite images have been widely used in agriculture to obtain RSE data. However, such a source has disadvantages: high cost; limited opportunities to obtain them in a given time and with the necessary frequency; errors caused by weather conditions, clouds, and haze.

Aerial photography using airplanes or helicopters requires high economic costs for maintenance and refueling, which leads to an increase in the cost of the final product. The use of standard aircraft systems is also unprofitable when shooting small areas. In this case, the economic and time costs for the organization of work per unit of the captured area significantly exceed similar indicators when shooting large areas.

In this regard, a promising alternative is the use of UAVs, the main advantages of which are profitability, the ability to shoot from low altitudes and near objects, high resolution with simple shooting equipment, and the efficiency of obtaining images. This ensures an optimal balance between data quality and cost. UAV images are processed in automated photogrammetric systems. The initial data for them are the images obtained in the course of aerial photography, the coordinates of the centers of photography, and the coordinates of reference points. Processing results - orthophotomaps, point clouds, three-dimensional and digital terrain models [4].

2. Material and methods
The original images in the extension of the raw material, which were obtained as a result of the aerial survey with the UAV, were processed in photogrammetrical software complexes. The assembly principle is to search for the same areas of terrain on different frames.

When determining the boundaries of land plots, a field survey of the plots was conducted, planning and cartographic materials, the project of on-farm land management of the "Tsentralnaya" work-study unit, the plan of the boundaries of the "Tsentralnaya" work-study unit, cadastral information on adjacent land plots were used. The total area of the plots is calculated-11060590 sq. m. The coordinate system MSK-31. The area of the land plot was calculated using the Arc view software, using the boundaries of the land plot and the coordinates of the rotation angles, and processed in the GIS Map 2011 software product version 11 (figure 1).
The route of the unmanned vehicle was laid in such a way that the overlap of the images was 60% vertically and 80% horizontally. In other words, the same plot of land is fixed on several images at once and then glued together into a single file based on the same characteristics. This is necessary to eliminate the parallax effect. About 8000 images were obtained (figure 1).

![How does the plane fly?](image)

**Figure 1.** The territory of the V. Ya. Gorin Belgorod State Agrarian University.

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![Construction of the UAS flight task with the indication of the take-off and landing location.](image)

**Figure 2.** Construction of the UAS flight task with the indication of the take-off and landing location.
3. Results and discussion.

A vector layer of production fields has been compiled. "Vectorization" refers to the process of converting a bitmap view of information into a vector format that is perceived by computer-aided design programs. At the same time, the vector format conveys graphic information more accurately and is more compact than the raster format, and any editing of raster files is extremely difficult and requires a lot of computer resources and operator time.

The terrain is a crucial factor in the development of erosion processes. Taking into account the terrain in land management and agricultural production is of great importance. To fully and comprehensively take into account the terrain, a heightmap, and a slope steepness map were compiled (figure 5, 6).
The direct production and economic significance of the relief are diverse. It largely depends on the terrain:

- productivity of agricultural machinery, tools, and transport;
- it determines the nature of measures to combat soil erosion;
- it is of crucial importance in the design and development of irrigation and drainage reclamation systems;
- affects the timing of agricultural work.

Therefore, in territorial soil surveys, the terrain should be studied and taken into account with sufficient completeness and detail, according to the established scale of the soil survey.

The use of aerial photography from UAVs in agriculture allows us to solve the following tasks: clarification of the contours of fields and acreage; identification of local areas of depressed vegetation in an agricultural field; identification of areas of fields subject to water erosion; identification of agrotechnical errors; clarification of maps of the microrelief of agricultural land; technical support of the process of implementing technological solutions in precision agriculture; monitoring of the state of drainage reclamation systems [8].
Clarification of the boundaries of agricultural land contributes to a more accurate calculation of the costs of performing agricultural operations and the costs of chemical protection products and fertilizers. Early detection of depressive foci from aerial photographs allows you to adjust agricultural technologies to preserve the crop or to perform targeted processing of crops.

Aerial photography in the early spring period is aimed at determining the erosion areas of the field and adjusting agricultural technology to prevent the degradation of the soil layer (figure 7).

Figure 7. Erosion areas of the field.

Timely control of the implementation of agricultural operations with the help of aerial photography is aimed at avoiding losses of potential yield. Figure 8 shows a fragment of an aerial photo of grain sowing. Crop losses from uneven application of agrochemicals can reach 25%.

The timely information received and the operational decision made on its basis will help to avoid crop losses and use the full potential of the field and the cultivated crop.

Figure 8. Example of agrotechnological errors.
Based on aerial photography data, it is possible to build a high-precision digital terrain model and model the movement of water flows on the field surface (figure 9). This information helps to estimate the volume of possible removal of nutrients from the surface under various weather conditions and to calculate the amount of work on profiling the field.

![Figure 9. Modeling the movement of water flows.](image)

The analysis of scientific and technical information shows that agricultural land acts as the main means of production in agriculture, has a special legal regime, and is subject to special protection aimed at preserving its area, preventing the development of negative soil processes, and increasing soil fertility. In the whole country, as of January 1, 2021, the area of unused land was 11.38% of the total area of agricultural land.

However, the task of introducing them into agricultural circulation is complicated by the lack of up-to-date and reliable information about unused plots, their location and borders, and their quality condition. To ensure full-fledged land monitoring that meets modern requirements for collecting, analyzing, storing, and using information, it is necessary, along with traditional methods, to apply new surveillance systems based, among other things, on the use of unmanned aerial vehicles.

4. Conclusions
It is revealed that the use of aerial photography from UAVs allows solving a wide range of tasks: inventory of farmland, clarification of the contours of fields and acreage; identification of local areas of depressed vegetation; identification of areas of fields subject to water erosion; identification of agrotechnical errors; clarification of maps of the microrelief of agricultural land; technical support of the process of implementing technological solutions in precision farming technology; monitoring of the state of drainage reclamation systems [6, 7].

The introduction of an information system for managing agricultural production allowed specialists and managers of agricultural enterprises:

- receive complete and reliable information about the structure of land and crop rotations (their area, intended use, quality condition);
- get information about the location of any farm object and the distances between them with an error of no more than 2.0 m, for example, determine the length of the rut;
- optimal distance between fields and delivery points of agricultural products on a digital map;
- determine the amount and area of work performed with piecework payment, using satellite navigation receivers and a digital map;
• control fuel consumption during fieldwork;
• promptly account for the use of pesticides and fertilizers;
• exercise constant control over the amount of seed consumption during sowing;
• change the functional purpose and use of arable land, taking into account the degree of erosion hazard;
• adjust crop rotation patterns based on terrain and slope data on any plot of arable land;
• optimize the directions of mechanized tillage;
• maintain e-books of the history of crop rotation fields in a digital map;
• adjust the agronomic operations of fields and individual plots of arable land due to the availability of data from agrochemical and soil surveys integrated into the digital map.

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