Digitization of agricultural land using an unmanned aerial vehicle

N V Abramov, S A Semizorov, S V Sherstobitov, M V Gunger and D A Petukhov

1Northern Trans-Ural State Agricultural University, 7, Respubliki str., Tyumen Region, Tyumen, Russia
2Novokubansk branch of Russian Research Institute of Information and Technical and Economic Research on Engineering Support of Agro-industrial Complex, 15, Krasnaya str., Krasnodarsky region, Novokubansk, 352243, Russia

E-mail: sv5888857@yandex.ru

Abstract. Using an unmanned aerial vehicle Geoscan 201 Agro, 20,286 hectares of agricultural land were surveyed in Tyumen and Sverdlovsk regions, where 206 fields were with an area of 5,552 hectares. Creating electronic maps when piloting an UAV is a more accurate, operational method in comparison with the use of the circular tour method and the use of a space satellite. It allows getting the geographical coordinates of the boundaries of the field, calculating its area, forming orthophotomaps and an electronic image of the fields.

1. Introduction

High-tech technologies based on the use of satellite navigation systems require efficiency in obtaining information on the state of agroecosystems. The need for new approaches is also caused by the concentration of land among large producers, which size even in Western Siberia reaches 40-100 thousand hectares of arable land. Traditional methods of monitoring soil fertility, phytosanitary condition of crops are becoming ineffective for the timely execution of technological operations.

The huge potential in the advancement of digital technology lies in the use of unmanned aerial vehicles (UAVs). Today there are ample opportunities for the use of UAVs for digitizing fields, monitoring the use of agricultural land and even quickly solving problems in local agroecosystems.

UAVs can operate in manual, automatic and semi-automatic modes. Manual mode is carried out using a remote control within the limits of optical observability or according to the specific information received from the front-view camera. An autonomous flight of an aircraft is carried out along a predetermined trajectory, at a given height, at a given speed and with stabilization of orientation angles using on-board software devices. The semi-automatic control means an automatic flight without human intervention using autopilot according to the specified parameters, but the operator can adjust the route interactively [1].

The collection of information on the state of agroecogenesis and agricultural land using UAVs is more accessible for agricultural producers compared to remote sensing of land (RSL) by space satellites and manned airborne vehicles. UAVs make it possible to shoot from low altitudes, near objects, in the emergency zone without risk to the life and health of pilots. UAVs allow quickly obtaining high-resolution images and are economically more profitable [2].
Unmanned aerial vehicles of the USA, Japan, China, Italy and other countries have great success in the agricultural sector. Aircraft-type vehicles of foreign countries can be in flight for up to 55 minutes at an altitude of up to 2000 meters with a payload of up to 1 kg with a dead weight of 2.4 kg [3].

Unmanned aerial vehicles designed by domestic scientists deserve the attention of the business community in the agricultural sector. Therefore, we set a goal at the first stage, to develop an order (form a methodology) for the practical use of an unmanned aerial vehicle in monitoring agricultural land. This work allows really assessing the use of agricultural land, quickly compiling and adjusting crop rotation within the adaptive-landscape farming systems, developing resource-saving technologies for cultivating crops, controlling the phytosanitary state of crops, forming unrelated support for 1 hectare of arable land, and regulating rental relations between a landowner and produce.

2. Materials and methods

The development of the piloting process of an unmanned aerial vehicle for monitoring agricultural land and the state of agrocoenosis was carried out under production conditions on the fields of OJSC “Priozernoye” of Tyumen Region and APC “Kalininsky” of Sverdlovsk Region. Unmanned aerial vehicle Geoscan 201 Agro was used. The flight duration is up to 3 hours with a maximum flight altitude of 4,000 meters and a maximum route length of 210 kilometers with a minimum safe flight altitude of 100 meters. The operating temperature is from -20 to +40°C with a maximum permissible wind speed of 12 m/s. The shooting area for 1 flight at a scale of 3-10 cm/pixel is 7-22 km² at a speed of 64-130 km/h and a maximum take-off weight of 8.5 kilograms.

The total area of the surveyed agricultural land amounted to 20,028.6 hectares, where 206 fields are 5,552 hectares.

The compiled electronic maps of the fields (their contour, area, image quality) were compared with previously digitized maps by the circular tour method, according to our proposed method, with maps of the same fields obtained after decoding satellite images.

When digitizing the fields, the QGIS program (Quantum GIS) was used, the Aqisoft Metashape Professional program was used to decrypt photos, and the Sputnik Agro program was used to construct the color gamut and interpretation in NDVI.

3. Results

Digital technologies also have a certain sequence of their implementation in the agricultural sector. Their basis is geographic information systems. Gathering information about the terrestrial and space factors in the production of agrocoenosis, establishing their role for the growth and development of crops provide the basis for the development of technological operations using satellite navigation systems [4, 5, 6].

Unmanned aerial vehicles at the first stage of high-precision technology play an important role as a mechanism for digitizing fields. Earlier, a method for creating electronic field maps by the circular tour method was developed [7]. It was tested in the farms of Tyumen, Sverdlovsk, Kurgan regions on an area of more than 224,000 hectares. This approach allows really assessing the situation of land use; the method is accurate in determining the configuration of fields, their area, takes into account natural and artificial objects inside agricultural land. But the method of driving around fields is laborious and has a number of limitations when performing work (seasonality, weather conditions, cultivation of crops in the fields, etc.).

The formation of maps of agricultural land with geographical reference to the coordinates when using the unmanned aerial vehicle "Geoscan 201 Agro” has a wider time range of work. 206 fields were examined in the farms of Sverdlovsk and Tyumen regions; the difference in the area was determined by the circular tour method and using UAVs was 0.1-0.3 hectares (figure 1).
Figure 1. Digitization of fields using the circular tour method and unmanned aerial vehicle.

Depending on the size of the land plot, fluctuations in the area determined by these methods were in the range of 0.3-1.2%. For example, the area of field No. 72, which was determined during the flight of the unmanned aerial vehicle Geoscan 201 Agro, was 22.9 hectares, and when using the circular tour method it was 23.0 hectares, the area of field No. 73 was 25.2 and 25.5 hectares, respectively. However, when digitizing agricultural land using Geoscan 201 Agro, it took 8.6 minutes to fly around 100 hectares, and when driving around, depending on the field configuration, the state of the field boundaries, weather conditions, the presence of artificial and natural indoor objects, it took up to 24-33 minutes, that is 3-4 times more.

Comparison of these results gives reason to prefer unmanned aerial vehicles when digitizing fields. High-resolution satellite systems are used to build digital models of agricultural land. When decrypting satellite images, direct signs are color (tone), image structure and texture. Studying and analyzing them allows establishing spatial relationships between territorial complexes [8].

The formation of electronic field maps using satellite imagery helps to reduce the time it takes to complete them, labor costs, to receive operational information, biometric indicators of crops, since artificial Earth satellites take the same territory several times during the day.

At the same time, the construction of field boundaries using space satellites can distort their location with a violation of geographical coordinates (figure 2, 3). The reason for this may be a temporary source of borrowing satellite images from archival databases of various satellite systems (GOOGLE, YANDEX, BING, etc.), their technical capabilities and mode of operation.

In space images the main object for us is the earth's surface with its agrolandscape specifics. A space image of the central projection, when the terrain design is carried out by straight (perpendicular) lines, ideally displays the geometric properties (shape, size) of agricultural land. In the process of image formation of the object, due to the tilt of the optical axis at the time of the image, the field boundaries are distorted, i.e. coordinate points on the orthophotomap turn out to be offset relative to the central scene of the space image. The quality of a space image is also influenced by the altitude of space satellites, uneven agrolandscape, and weather conditions.
Thus, a space image of field No. 72 has a blurred image of an in-floor natural object (forest peg), which makes it difficult to determine its exact boundaries and area (figure 4a). The reason for this was a decrease in the resolution of the image, which is associated with the flight altitude of the artificial Earth satellite, as well as the uneven distribution of the horizontal projection of the object. The use of Geoscan 201 Agro to produce an orthophotomap allowed obtaining a clearer image of an in-floor forest splinter (figure 4b).

The accuracy of determining the boundaries of fields when using spacecraft is influenced by weather conditions. Remote sensing of the Earth by satellite systems has limitations due to cloud cover in the surface layers. This natural phenomenon in Western Siberia often happens: the duration of sunshine (when the sun is not covered by clouds, fogs) is only 18.5-37.4% [9]. In such cases, raster images obtained using artificial Earth satellites cannot be used for digitizing fields, since they do not have solid boundaries (figure 5).
The solution of similar applied problems using the unmanned aerial vehicle Geoscan 201 Agro in such situations is quite acceptable. According to the technical characteristics of UAV with a maximum flight altitude of 4000 meters, it can take pictures at the minimum safe altitude (under the clouds) - 100 meters above agricultural land at the required time (figure 6).

During the summer period, we examined 20,028 hectares of agricultural land in the farms of Tyumen and Sverdlovsk regions using an unmanned aerial vehicle Geoscan 201 Agro, an orthophotomaps of 206 fields with an area of 5552 hectares was formed. figure 7 shows the orthophotomap of the fields of APC “Kalininsky” of Sverdlovsk Region with an area of 3,500 hectares. High quality of orthophotomaps of the fields was achieved with a shooting height of 700 meters and a spatial resolution of 12 cm/pixel.
When forming orthophotomaps of farm fields, their boundaries were determined with a geographical reference to the coordinates, the areas of each field in the crop rotation were calculated taking into account in-field natural and artificial objects.

APC “Kalininsky” is located in the foothill region (the Urals) of Sverdlovsk region, where soil erosion can increase by 2 times with an increase in the surface slope from 3 to 5°. When developing adaptive landscape farming systems, it is advisable to take into account the uneven terrain in a multidimensional coordinate system. A digital model of a number of fields has been formed (figure 8).

The digital field model is informative and is the basis for the rational use of agricultural land. The nature of the relief, the peculiarity of the location of the natural hydrographic network are displayed, the
model helps to develop a resource-saving farming system in these fields, which will ensure the reproduction of soil fertility and the growth of productivity of agroecosystems.

4. Conclusion
Thus, the creation of electronic maps using unmanned aerial vehicles is an accurate, operational method that allows obtaining the geographical coordinates of the field boundaries and calculates its area.

The use of artificial Earth satellites for digitizing fields allows obtaining high-resolution images, but this method is less accurate, depending on many external conditions. Noteworthy is the combined method (field circular tour method) using hardware-software systems based on satellite images. It is also accurate, but more labor intensive.

References
[1] Fedorenko V F, Mishchurov N P, Buklagin D S, Goltyapin V Ya and Golubev I G 2019 Digital agriculture: state and development prospects (M.: FSINI Rosinformagroteh) p 316
[2] Balabanov V I, Fedorenko V F and Goltyapin V Ya 2016 Technology, engineering and equipment for coordinate (precision) agriculture (M.: FSINI Rosinformagroteh) p 240
[3] Best Agricultural Drones of 2018 - Reviews and Specs [Electronic resource] Retrieved from https//www.dronethusiast.com / agricultural-drones
[4] Abramov N V 2013 Productivity of agroecosystems and soil fertility in Western Siberia (Tyumen) p 254
[5] Abramov N V, Semizorov S A and Sherstobitov S V 2015 Agriculture using space systems Agriculture 6 13-8
[6] Abramov N V and Semizorov S A 2018 Innovative Technologies of Cultivation of Crops in the Era of the Digital Economy International scientific and practical conference “Agro-SMART-Smart solutions for agriculture” 151 1-5 DOI: 10.299/agrosmart-18.2018.1
[7] Abramov N V, Semizorov S A and Sherstobitov S V 2019 Creation of electronic field maps (Tyumen) p 84
[8] Sukhikh V I 2005 Aerospace methods in forestry and landscape construction (Yoshkar-Ola) p 390
[9] Fedoseev A P and Pasov V M 1986 Agronomist Handbook of Agricultural Meteorology (L.: Gidrometizdat) p 526