Modern unmanned aerial technologies for the development of agribusiness and precision farming

I V Kovalev1,2,3,4 and N A Testoyedov4,5

1Siberian Federal University, 79, Svobodny pr., Krasnoyarsk, 660041, Russia
2Krasnoyarsk State Agrarian University, 90, Mira pr., Krasnoyarsk, 660049, Russia
3China Aviation Industry General Aircraft Zhejiang Institute Co., Ltd, China
4Reshetnev Siberian State University of Science and Technology, 31, Krasnoyarsky Rabochy Av., Krasnoyarsk, 660037, Russia
5JSC “Academician M F Reshetnev Information satellite systems”, 52 Lenin street, Zheleznogorsk, Krasnoyarsk region, 662972, Russia

E-mail: kovalev.fsu@mail.ru

Abstract. The article discusses modern trends in the use of drones in agribusiness and precision farming. It is shown that agriculture today has an increased demand for data obtained from unmanned aerial systems, mainly for aerial photography, since satellite observations do not fully satisfy users in different regions. Maps showing NDVI are essential for precision farming, since they allow you to analyze the state of vegetation, its density, germination and growth, and predict land productivity. They also help identify problem areas of oppressed vegetation. Traditionally, these data for calculating NDVI farmers received by processing satellite remote sensing information. But after the advent of affordable UAVs, it became possible to reduce the cost of such data, increase the efficiency of their receipt and resolution. We also note a promising trend that is associated with the transition from remote control of drones to robotic systems with automated information processing.

1. Introduction

The use of aircraft in agriculture in Russia was developed at the beginning of the last century, when it was first proved the possibility of a stable flight at low altitude (5-10 m). With the help of airplanes (An-2, An-2M, An-2SX), as well as helicopters (Ka-26, Mi-2), the use of which for gardens and vineyards turned out to be more preferable, aviation chemical work was carried out to process large areas, engaged in agricultural crops, in order to neutralize plantings from harmful insects (locusts, Colorado potato beetles, aphids, harmful turtles, meadow moths, etc.) and plant diseases. Agricultural aircraft was also involved in sowing, for applying mineral fertilizers, and spraying with herbicides (in order to clear the fields of weeds), which made it possible to perform these works on large areas (up to 700 ha per day) and in a shorter time.

In [1-3], the development trends of manned and unmanned aerial systems, the possibilities of their application in the agricultural sector and in the field of freight transportation were considered. The practical use of aircraft in agriculture has shown a number of advantages compared to ground equipment [4-7]. First of all, it is high productivity (processing of large sown areas in a shorter time, low labor costs, economical use of seed and chemical sprayed substances). It should also be noted the possibility...
of carrying out work in hard-to-reach areas (mountainous terrain, wetlands, etc.), the ability to visually monitor the condition of crops and prompt response in the event of a critical situation (massive damage by harmful bacteria, insects, rodents, etc.), eliminating the consequences natural disasters that caused partial death of plants (aging, burnout, etc.) [8-12].

At the same time, the work of airplanes and helicopters in the fields directly depends on meteorological conditions, which is a significant drawback in agriculture, where the fate of the future crop often depends on the speed of solving the problem. In addition, in small areas, using large aircraft is not always cost-effective. However, at present, the completely legal issues of organizing the use of unmanned aerial systems both at the international and Russian levels have not been resolved [8, 13].

2. The use of UAVs in agriculture
The increased demand for data obtained from unmanned aerial systems, mainly for aerial photography, is presented today by agriculture [14-16]. The relevance of the problem of control over agricultural plantings is currently in no doubt. Defects during sowing, such as bald spots, crop loss after drought or flooding, and other factors, require operational control. Sown fields do not always allow this to be done promptly. Most of the assessments made in such cases are made by land using field trips by an expert group. Being on the surface of the earth, it is impossible to assess the full extent of the emergency. Therefore, to accelerate this process, it is necessary to use aerial photography.

The data obtained from the UAV provide the opportunity:

- creating electronic field maps;
- inventory of farmland;
- evaluate the volume of work and monitor their implementation;
- conduct operational monitoring of the state of crops (UAV allows you to quickly and efficiently build maps for seedlings);
- determine the NDVI index (Normalized Difference Vegetation Index - a normalized vegetation index);
- assess the germination of crops;
- predict crop yields;
- check the quality of row cultivation;
- conduct environmental monitoring of agricultural land.

The UAV starts manually, takes off and lands in automatic mode (on autopilot) along the loaded route. A plane flying along a route pre-planned in the GIS performs digital terrain survey. The result of the survey are high-resolution images at the programmed points by GPS coordinates. After the flight, the UAV lands at the same point from where it took off. For each image, a complete set of digital information is obtained - the geographical coordinates of the center point of the image, the height of the exposure, the exposure angle, and a complete set of telemetry data for transfer and use in conventional GIS systems (for example, ArcView or MapInfo). Thus, all photographs are georeferenced and can be stitched into one large orthophotomap field. In one day, one group of operators with one Supercam-350 aircraft performs aerial photography covering an area of 20 * 20 km. Thus, aerial photography from UAVs can replace high-resolution satellite imagery for agriculture, which we can obtain using various satellite-based tools for space monitoring of the earth [17-20].

3. Precision farming technology
At present, precision farming technologies are widely used in agriculture [21-25]. They are based on a new view of agriculture, in which the agricultural field, heterogeneous in relief, and in the agrochemical content of nutrients, requires the application of the most effective agricultural technologies in each sector. Precision farming technologies are aimed at increasing productivity, reducing production costs and preserving the environment.
Scientific and technological progress today makes it possible to widely use modern technologies in agriculture during the planning and implementation of agricultural technologies. Such technologies, of course, are unmanned aerial vehicles.

Precision farming includes a large number of elements that are divided into three main stages:

- collection of information about the household, field, culture;
- analysis of information and decision making;
- implementation of decisions - carrying out an agrotechnological operation.

Before embarking on farming, it is necessary to measure the fields in fact (if they have not been measured) in order to draw up an accurate cost plan for the cultivated area. As a result of field measurements, an electronic field map is compiled.

An electronic map is a land inventory tool that determines the resource potential of farm land. It is also a tool that allows you to accurately calculate the consumption rate of fuels and lubricants, the application rate of fertilizers and plant protection products (plant protection products) depending on the area. When compiling soil quality maps of individual fields, it is possible to introduce the differential application of plant protection agents and fertilizers in various parts of the field, which can significantly save on the application of fertilizers and plant protection products, as well as not to oversaturate the soil. The field map makes it possible to maintain field passports and crop rotation, calculate the required amount of seed material, monitor equipment and determine not only fuel consumption, but also the efficient use of working time, etc.

An electronic map provides the ability to maintain a database for an unlimited period of time and for several indicators.

The advantages of an electronic field map are obvious:

- makes it possible to keep records and control of all agricultural operations, because it is based on accurate data: area of fields, distance of roads, settlements, etc.;
- helps to conduct a complete analysis of the conditions that affect the growth of vegetation in a given field;
- allows to optimize production in order to maximize income, as well as rational use of resources in production;
- maintain passport data on agricultural land, taking into account the link to the year of harvest;
- viewing and analysis of thematic maps of agrochemical monitoring of fields, cultivated crops, fertilizers, productivity, crop economic efficiency, etc.;
- accounting and analysis of the consequences under various adverse weather conditions and other indicators through unmanned aerial vehicles (the area of sowing of crops, frozen sections of crops, the maturation stage, weediness of fields);
- formation of statistical information and reports.

After receiving an electronic map of the field, it is possible to conduct an agrochemical inspection of the fields and enter additional information (maps of the contents of the main elements N, P, K, Ca, Mg, S, Ph, humus) about the field in the existing database.

4. NDVI in agriculture

As is known, the reflection of the vegetation cover in the red and near infrared regions of the electromagnetic spectrum is closely related to its green phytomass. In order to quantify the state of vegetation, the so-called NDVI (Normalized Difference Vegetation Index) is widely used [26-31]. NDVI also characterizes the density of vegetation, allows plant growers to evaluate the germination and growth of plants, the productivity of the land. The index is calculated as the difference between the reflection values in the near infrared and red regions of the spectrum, divided by their sum. As a result,
NDVI values vary in the range from −1 to 1. For green vegetation, the reflection in the red region is always less than in the near infrared due to the absorption of light by chlorophyll; therefore, the NDVI values for vegetation cannot be less than 0. UAVs allow collecting data, necessary to create detailed NDVI maps in a matter of hours.

So, NDVI is one of the many vegetation indices, one of the most popular and often used. It was described by Rouse B.J. in 1973 [32]. The index quantitatively characterizes the volume of photosynthetically active biomass [33].

It is calculated by the formula

\[
NDVI = \frac{(NIR - RED)}{(NIR + RED)},
\]

where NIR is the reflection coefficient in the near infrared (IR) region of the spectrum, and RED is the reflection coefficient in the red region of the spectrum. Normalization allows you to reduce the effects of differences in illumination, cloudiness, haze, etc.

The index for vegetation is always positive, the larger the green phytomass, the higher the index. It is important that the species composition of the vegetation, its closeness, condition, and color of the soil under sparse vegetation influence the index values. On average, for green vegetation, the index ranges from 0.2 to 0.8.

Maps with NDVI index data allow you to analyze the state of vegetation, its density, germination and growth, and predict land productivity. It also helps to identify problem areas of oppressed vegetation - such areas noticeably differ in color when visualizing the data obtained.

NDVI cards are created based on drone seed survey data from conventional and IR sensitive digital cameras. Data is processed by specialized software, for example, Photoscan, and can be visualized, for example, in the GIS "Sputnik Agro" software, which allows not only to visualize the NDVI map, but also to analyze areas, manually selecting them or along contours from KML files, and also export NDVI data to Formfile and CSV formats.

NDVI cards can be generated independently using the data received from the UAV, or purchased as a service - then overflights and subsequent data processing, including recommendations, will be performed by companies providing the corresponding services. In Russia, the market for such services has already been formed as of 2020.

Traditionally, data for NDVI calculations were obtained from satellites. But after the advent of affordable flying UAVs, it became possible to reduce the cost of such data, to increase the efficiency of their receipt and resolution. Obviously, the collection of data from a flying UAV compares favorably with the collection of data by ground-based equipment.

The tractor, with the NDVI ground sensors installed on it, has lower productivity compared to the UAV and is more expensive to maintain. In addition, the cost of one set of sensors is comparable to the cost of one UAV, which can replace up to 10 sets of sensors.

Space images, as is well known [17-19, 31], are distinguished by a lower resolution, which does not satisfy modern requirements in the field of precision farming, especially in the case of small fields, including rice fields. In addition, cloudy is possible on the day of the survey, which will make the results of space surveys unusable, since for the maintenance of precision farming systems, the current values of the NDVI index are the main working information about the state of crops.

Public satellite images have a resolution of 15-30 meters per pixel and can reliably determine only the general state of the field. At the same time, the frequency of satellite observations does not fully satisfy users in different regions, because many plots of land are covered in clouds on the day of shooting. In addition, the time it takes to post material on servers can be 1-2 weeks, which significantly reduces the relevance of this information when processing in a data center (DPC).

At the same time, the UAV Geoscan, equipped with a camera for spectral shooting, is able to provide images with a resolution of 5 centimeters per pixel. Post-processing of materials can be performed both centrally in the data center, and in places, for example, in agrochemical laboratories and even at the workplace of an agronomist. Crop area for servicing one UAV Geoscan - from 30 000 ha, if UAV is the
main source of data, or up to 100,000 ha, if UAV is used to supplement satellite data. At the same time, cloudiness does not impede the UAV survey.

5. Conclusion
The presented analysis allows us to formulate the main trends in the use of drones in agriculture:

- growing demand for B2B services in this segment;
- the demand for the services of IT companies creating software for the collection and processing of large amounts of data in the interests of precision farming is growing;
- regulatory barriers are being reduced, which up to the present have hindered the introduction of drones in agriculture.

Another modern trend, which should also be noted, is the desire of developers to not only offer to buy a drone, but also a set of software necessary for the analytical processing of data obtained during aerial surveys.

Another emerging trend is the transition from remote control of drones to robotic systems. In such systems, drones automatically recharge the batteries, fly out on scheduled routes, fly around and take pictures (video surveillance) in automatic mode, return to the parking spot and transmit information to the automated processing system.

References
[1] Kovalev I V et al 2019 J. Phys.: Conf. Ser. 1399 055095
[2] Kovalev I V et al 2019 J. Phys.: Conf. Ser. 1399 055100
[3] Kovalev I V and Karaseva M V 2020 IOP Conf. Ser.: Earth Environ. Sci. 421 072020
[4] Zubarev Yu N et al 2019 Bulletin of the Perm Federal Research Center 2 47-51
[5] Kovalev I V et al 2011 Economics and management systems 1(1) 36-42
[6] Saramud M V et al 2017 Actual problems of aviation and astronautics 2(13) 64-6
[7] Kovalev I V et al 2011 Vestnik SibGAU 3(24) 105-10
[8] Grishchenko G A 2019 Bulletin of the University named after O.E. Kutafin 12(64) 129-36
[9] Khusnutdinov T D et al 2017 Actual problems of aviation and astronautics 3(13) 139-41
[10] Gavrilova A A et al 2018 Technical and technological problems of service 4(46) 20-2
[11] Loskutova E S 2019 Contentus 511 38-44
[12] Makarov K S 2019 Auditorium 4(24) 48-53
[13] Kovalev I V and Voroshilova A A 2020 J. Phys.: Conf. Ser. 1515 052068
[14] Zelenkov P V et al 2019 IOP Conf. Ser.: Earth Environ. Sci. 315 072019
[15] Kovalev et al 2019 IOP Conf. Ser.: Earth Environ. Sci. 315 052011
[16] Hort D O et al 2016 Farmer. Volga region 7 34-7
[17] Testoedov N A et al 2018 IOP Conf. Ser.: Mater. Sci. Eng. 450 022004
[18] Testoedov Nikolay A et al 2018 IOP Conf. Ser.: Mater. Sci. Eng. 450 022002
[19] Testoedov N A et al 2018 IOP Conf. Ser.: Mater. Sci. Eng. 450 022008
[20] Stepanova V I and Ishikhanova A A 2019 Bulletin of Agricultural Science 1(76) 52-7
[21] Makhotlova M Sh 2016 Symbol of science 1-3 51-3
[22] Akinchin A V et al 2017 Bulletin of the Kursk State Agricultural Academy 9 16-21
[23] Lopachev N A 2015 Agriculture 5 6-9
[24] Pleskachev Yu N et al 2016 News of the Lower Volga Agricultural University: science and higher professional education 2(42) 96-101
[25] Shayachmetov M P and Dubrovin I A 2013 Omsk Scientific Herald 1(118) 197-200
[26] Bratkov V V et al 2016 News of the Dagestan State Pedagogical University. Natural and exact sciences 10(4) 97-111
[27] Savin Yu A et al 2015 Bulletin of the Soil Institute V.V. Dokuchaev 77 51-65
[28] Terechin E A 2015 Earth exploration from space 1 23-31
[29] Hunt E et al 2013 International Journal of Applied Earth Observation and Geoinformation 21 103-112
[30] Crippen R E 1990 Remote Sensing of Environment 34 71-3
[31] Saramud M V et al 2019 E3S Web of Conferences 75 01005
[32] Rouse B J and Birnbaum M H 1973 Imression formation: Datability as a function of face, figure, and personality (WPA, Anaheim, CA)
[33] Rouse B J et al 1973 Monitoring vegetation systems in the Great Plains with ERTS 3rd ERTS Symposium, NASA SP-351 vol I pp 309-17