УДК 519.252

A.V. Koshkarov

THE CHOICE OF UNMANNED AERIAL VEHICLES FOR DIGITAL AGRICULTURE

Astrakhan State University, Astrakhan, Russia

Agriculture as an element of ensuring food security of countries plays an important role in the world and regional economy. The use of digital technologies in agriculture can be one of the sources of growth in the industry. Data in agriculture can be collected using various mechanisms, including the use of unmanned aerial vehicles. This article discusses the selection of unmanned aerial vehicles for agriculture and gives recommendations to farmers on the choice of drones for data collection and monitoring. For example, it is possible to collect useful information on the state of agricultural fields (the size of fields, the level of germination, the state of vegetation) with the help of drones. The basis of this study is an overview of the relevant literature on the use of unmanned aerial vehicles in agriculture in different countries and the author's own experience in implementing the project with the use of an agricultural drone in the experimental fields of the Astrakhan State University. In addition, a survey of farmers of the Astrakhan region was conducted to identify the most demanded areas of agriculture for monitoring in order to increase the effectiveness of decision-making.

Keywords: digital agriculture, data science, agricultural drone, unmanned aerial vehicle, precision farming.

Introduction

Agriculture as an element of ensuring food security of countries plays an important role in the world and regional economy. Increasing the pace of agricultural development and the effectiveness of agribusiness is becoming a priority. The use of digital technologies in agriculture can be one of the sources of growth in the industry. Typically, this approach includes methods of precision farming, data collection and analysis. Data in agriculture can be collected using various mechanisms, including using unmanned aerial vehicles.

Unmanned aerial vehicles (drones) have recently become popular in many industries. In agriculture, for example, it is possible to collect useful information on the state of agricultural fields (the size of fields, the level of germination, the state of vegetation) with the help of drones. By analyzing data from agricultural fields, a farmer can see the whole situation, manage it more efficiently and respond quickly to emerging problems. Such an approach can help a farmer save money and other resources used in agriculture.

Materials and Methods

The basis of this study is an overview of the relevant literature on the use of unmanned aerial vehicles in agriculture in different countries and the author's

own experience in implementing the project with the use of an agricultural drone in the experimental fields of the Astrakhan State University. In addition, a survey of farmers of the Astrakhan region was conducted to identify the most demanded areas of agriculture for monitoring in order to increase the effectiveness of decision-making. The study used a questionnaire, part of the results of which are demonstrated in this article. The survey was conducted on a voluntary and anonymous basis with the participation of 42 farmers over 18 years of age engaged in crop production.

Literature Review

One of the methods of collecting data from agricultural fields is aerial photography. The focus of recent research has been on using unmanned aerial vehicles in agriculture. The basis of this technology is the use of unmanned aerial vehicles (for example, the drones) with a spectral camera (spectral filters) for obtaining multispectral images or video in the visible and near-infrared ranges from agricultural fields [1].

Applications of using unmanned aerial vehicles in agriculture include vegetation monitoring (e.g. [2, 3]), mapping (e.g. [4, 5]), crop classification (e.g. [6, 7]), water stress management (e.g. [8, 9]), pest management (e.g. [10, 11]), leaf analysis (e.g. [12, 13]), and weed surveillance and management (e.g. [14, 15]). A good review of the application of unmanned aerial vehicles for agriculture was conducted by Zhang and Kovacs [16].

Satellite imagery is also used as a source of data in agriculture (e.g. [17, 18]). Although several studies have indicated that there are barriers and limitations in the use of satellites in agriculture. Berni, Zarco-Tejada, Suárez, and Fereres identified two important restrictions for using space satellite in real-time crop management: the absence of images with optimal spectral and spatial resolution and unfavorable times to revisit for most applications of crop stress detection [2, p. 722]. Another problem can be poor visibility due to cloudy weather.

Results and Discussion

A survey of farmers in the Astrakhan region, organized in 2017, was conducted to identify farmers' understanding of data collection and analysis technologies in agriculture, readiness to implement such technologies and identify the most demanded data. One of the most important goals of the questionnaire was to learn in which field of agriculture and at what level, according to farmers, can it be efficient and appropriate to use data collection and analysis technologies. The answers were distributed as follows (see Figure).

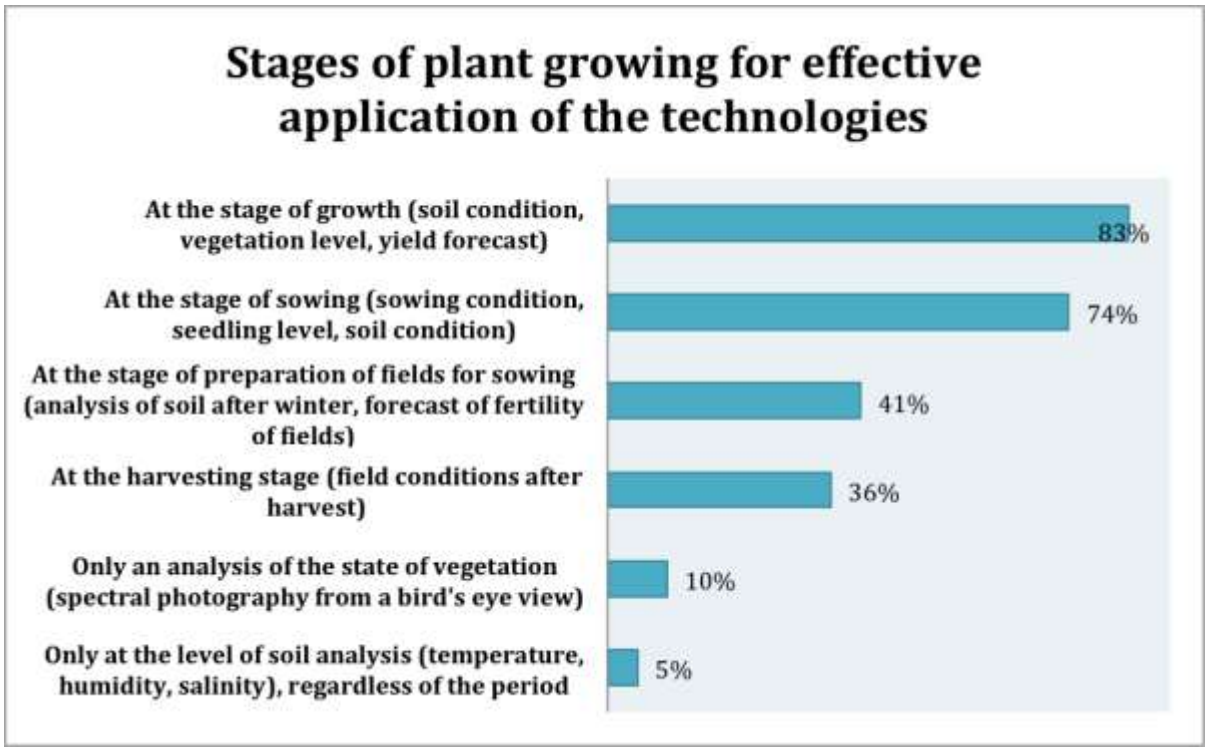

Figure - Stages of plant growing for effective application of the technologies

Among other things, the demanded tasks are assessment of the sowing condition, vegetation level, and yield forecast. Unmanned aerial vehicles can be used to solve these tasks.

In agriculture, drones with a multispectral camera are used, which allows farmers to take field shots in special spectra [6, p. 92]. To identify the state of vegetation, the normalized difference vegetation index (NDVI) is used. It calculates on the basis of the difference in the values of different spectra [19, p. 272]. Visualization of such data allows identifying problem areas in agricultural fields and monitoring the level of germination and growth.

Unmanned aerial vehicles used in agriculture have three main varieties: fixed wing, helicopters, and multicopters [20, p. 871]. Multicopters and helicopters are better suited, for example, for a more thorough examination of individual sections of the agricultural field, since they fly low and slow compared to fixed wing unmanned aerial vehicles. This gives more control over each shot. Fixed wing unmanned aerial vehicles can cover large volumes of fields (and collect more data) due to higher speed and altitude of flight. Additionally, fixed wing drones often carry a large payload and, therefore, can use more sensors to collect data.

It is worth noting that several companies offer special sets of unmanned aerial vehicles for agricultural purposes. An overview of some unmanned aerial vehicles for agriculture is presented in Table.

Table - An overview of UAVs used in agriculture

#	UAV	Special Cameras	Special Software	Manufacturer / References
1	DJI Matrice 100	+	-	DJI / www.dji.com/matrice-200-series
2	BirdsEyeView FireFLY6 Pro; Lancaster 5	+	+	PrecisionHawk / www.precisionhawk.com/agriculture
3	AgBot	+	+	Aerial Technology International / www.aerialtechnology.com/
4	Honeycomb AgDrone	+	+	HoneyComb Corporation / www.honeycombcorp.com/agdrone-system/
5	Trimble UX5 Multispectral UAV	+	+	Trimble Inc. / www.trimble.com/Survey/UX5-Multispectral.aspx
6	eBee SQ; Ag 360	+	+	senseFly, Parrot Group / www.sensefly.com/industry/agriculture/
7	The Sentera PHX; The Sentera OMNI AG; The Indago AG	+	+	Sentera LLC / sentera.com/agriculture-drones/
8	Sentera NDVI Upgrade for DJI Phantom 4 PRO	+	+	DJI; Sentera LLC / sentera.com/dji-ndvi-upgrade/
9	SOLO AGCO Edition UAV	+	+	AGCO Corporation / www.pages05.net/agco/SOLO_UAV/
10	AgEagle RX60, RX47 & RX48	+	-	AgEagle Aerial Systems / ageagle.com/products/

Limitations in the use of unmanned aerial vehicles in agriculture, identified after the analysis, are as follows: the high cost of the device, the short battery life, some restrictions in the legislation (in some countries it is necessary to obtain a license for the use of unmanned aerial vehicles), and the need for additional training for working with devices (and related software).

An alternative to the use of unmanned aerial vehicles in agriculture for analyzing the state of vegetation from the air is data from satellites. Compared to satellites, drones can help farmers collect more accurate and detailed data at the

right time (regardless of cloud conditions) and do it more often. At large sizes of agricultural lands, the use of drones can be more profitable not only in time, but also in financial expenses.

The main stages of using drones in agriculture are as follows:

1. Flight path planning. Many agricultural drones have software for flight planning based on GPS coordinates. After loading coordinates, the drone will automatically fly over the specified territory.
2. Flying and shooting fields. If a specialized agricultural software is included with the drone, the drone will automatically shoot the fields and store the relevant data. Otherwise, the farmer managing the drones should additionally control the cameras for shooting.
3. Image processing. After the work is done, the farmer has tens or hundreds of high-resolution images that need to be processed. Specialized image processing software (including cloud solutions for fast data processing) can be used for this. Different algorithms are used to process images depending on the purpose of the analysis.
4. Analysis of the results and take action. Analysis of the results can reveal the features of crop growth and identify possible problems. Timely solution of problems can help a farmer reduce costs and increase yield.

Monitoring of the state of vegetation can be conducted manually by a person (who walks the fields and records the state of vegetation) or from the air using unmanned aerial vehicles or satellites. The farmer can independently calculate the costs of such monitoring and choose the most optimal option. With large field sizes, the use of images from satellites or drones can be a more advantageous option than an examination by a person who can make a mistake (inaccuracy) due to inattention.

The advantage of drones compared to satellite imagery is that the drone can be used more often (and collect more data) and these images will be more precise and accurate despite cloudy weather. On the other hand, satellite images can be used as retrospective data to build the necessary models.

The literature review, analysis of the drones specifications and the work experience of the author on the use of unmanned aerial vehicles in agriculture have shown some limitations for their use. Besides, unmanned aerial vehicles are relatively expensive devices and if a farmer wants to utilise it into their agricultural business, the following conditions should be considered:

1. The size of agricultural land.
2. Frequency of measurements. In certain situations, it can be rented or a farmer can use the services of third-party companies that offer this type of work.
3. The type of unmanned aerial vehicle (fixed wing, helicopter or multicopter). This choice depends on the size of the fields, the terrain, the

typical climatic conditions in the region (for example, a strong wind), the payload capacity needed, the speed of field survey, and flight range [20, p. 874].

4. Software for processing and analyzing data obtained with an unmanned aerial vehicle. Some drones, for example, can determine the humidity and temperature of the soil with the help of special software (and cameras). It may make it possible to abandon the corresponding soil sensors at a certain level of accuracy. In addition, the latest versions of the drones have software for building the flight path and recording GPS coordinates.
5. Possibility to export data to third-party software.
6. Availability of special cameras. For example, to calculate the normalized difference vegetation index used to analyze the state of vegetation, a multispectral camera is needed [21, p. 614]. The presence of several cameras in the kit can significantly increase the cost of the device.
7. The cost of an unmanned aerial vehicle.
8. The need to obtain permission to use an unmanned aerial vehicle. In some countries, for example, in Russia, the USA and the UK, it is necessary to obtain an appropriate license before using the drones.
9. Presence of instructions on the use of an unmanned aerial vehicle and its software. Training materials and courses can help a farmer more efficiently use devices in agribusiness.
10. If farm management information systems are used in the current business, then it is necessary to make sure that the drone is compatible with the system.

Conclusion

Digital technologies can improve the efficiency of agribusiness management with the proper use of tools and methods. The collection and analysis of data in agriculture is becoming a competitive advantage for farmers. Unmanned aerial vehicles play an important role in this area, and drones can help a farmer to quickly monitor the condition of their farmland, promptly respond to problems and forecast yields. At the moment, drones for agriculture are relatively expensive (especially for small farms) and the correct approach to choosing an unmanned aerial vehicle is very important.

REFERENCES

1. Lelong C. C. D. et al. Assessment of unmanned aerial vehicles imagery for quantitative monitoring of wheat crop in small plots //Sensors. – 2008. – Vol. 8. – № 5. – pp. 3557-3585.
2. Berni J. A. J. et al. Thermal and narrowband multispectral remote sensing for vegetation monitoring from an unmanned aerial vehicle //IEEE Transactions on Geoscience and Remote Sensing. – 2009. – Vol. 47. – № 3. – pp. 722-738.
3. d'Oleire-Oltmanns S. et al. Unmanned aerial vehicle (UAV) for monitoring soil erosion in Morocco //Remote Sensing. – 2012. – Vol. 4. – № 11. – pp. 3390-3416.
4. Everaerts J. et al. The use of unmanned aerial vehicles (UAVs) for remote sensing and mapping //The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. – 2008. – Vol. 37. – pp. 1187-1192.
5. Zainuddin K. et al. Verification test on ability to use low-cost UAV for quantifying tree height //Signal Processing & Its Applications (CSPA), 2016 IEEE 12th International Colloquium. – IEEE, 2016. – pp. 317-321.
6. Park J. K., Park J. Crop classification using imagery of drone //International Conference on Environmental Engineering and Remote Sensing (EERS2015). – 2015. - pp. 91-94.
7. Teke M., Yardımcı Y. Classification of crops using multitemporal hyperion images //Agro-Geoinformatics (Agro-geoinformatics), 2015 Fourth International Conference. – IEEE, 2015. – pp. 282-287.
8. Bellvert J. et al. Mapping crop water stress index in a ‘Pinot-noir’vineyard: comparing ground measurements with thermal remote sensing imagery from an unmanned aerial vehicle //Precision agriculture. – 2014. – Vol. 15. – № 4. – pp. 361-376.
9. Gago J. et al. UAVs challenge to assess water stress for sustainable agriculture //Agricultural water management. – 2015. – Vol. 153. – pp. 9-19.
10. Yue J. et al. The application of unmanned aerial vehicle remote sensing in quickly monitoring crop pests //Intelligent Automation & Soft Computing. – 2012. – Vol. 18. – № 8. – pp. 1043-1052.
11. Faiçal B. S. et al. The use of unmanned aerial vehicles and wireless sensor networks for spraying pesticides //Journal of Systems Architecture. – 2014. – Vol. 60. – № 4. – pp. 393-404.
12. Zarco-Tejada P. J. et al. Estimating leaf carotenoid content in vineyards using high resolution hyperspectral imagery acquired from an unmanned

aerial vehicle (UAV) //Agricultural and forest meteorology. – 2013. – Vol. 171. – pp. 281-294.
13. Córcoles J. I. et al. Estimation of leaf area index in onion (Allium cepa L.) using an unmanned aerial vehicle //Biosystems engineering. – 2013. – Vol. 115. – № 1. – pp. 31-42.
14. Göktoğan A. H. et al. A rotary-wing unmanned air vehicle for aquatic weed surveillance and management //Journal of Intelligent and Robotic Systems. – 2010. – Vol. 57. – p. 467.
15. Torres-Sánchez J. et al. Configuration and specifications of an unmanned aerial vehicle (UAV) for early site specific weed management //PloS one. – 2013. – Vol. 8. – № 3. – pp. 1-15.
16. Zhang C., Kovacs J. M. The application of small unmanned aerial systems for precision agriculture: a review //Precision agriculture. – 2012. – Vol. 13. – № 6. – pp. 693-712.
17. Forster D., Buehler Y., Kellenberger T. Mapping urban and peri-urban agriculture using high spatial resolution satellite data //Journal of Applied Remote Sensing. – 2009. – Vol. 3. – № 1. – pp. 1-12.
18. Schmedtmann J., Campagnolo M. L. Reliable crop identification with satellite imagery in the context of common agriculture policy subsidy control //Remote Sensing. – 2015. – Vol. 7. – № 7. – pp. 9325-9346.
19. Ipate G., Voicu G., Dinu I. Research on The Use of Drones in Precision Agriculture //University Politehnica of Bucharest Bulletin Series. – 2015. – Vol. 77. – № 4. – pp. 1-12.
20. Marinello F. et al. Technical analysis of unmanned aerial vehicles (drones) for agricultural applications //Engineering for Rural Development. – 2016. – Vol. 15. - pp. 870-875.
21. Bhandari A. K., Kumar A., Singh G. K. Feature extraction using Normalized Difference Vegetation Index (NDVI): a case study of Jabalpur city //Procedia Technology. – 2012. – Vol. 6. – pp. 612-621.

А.В. Кошкаров

ВЫБОР БЕСПИЛОТНЫХ ЛЕТАТЕЛЬНЫХ АППАРАТОВ ДЛЯ ЦИФРОВОГО СЕЛЬСКОГО ХОЗЯЙСТВА

Астраханский государственный университет, Астрахань, Россия

Сельское хозяйство как элемент обеспечения продовольственной безопасности стран играет большую роль в мировой и региональной экономике. Использование цифровых технологий в агроиндустрии может стать одним из источников роста отрасли. Данные в сельском хозяйстве могут быть собраны с помощью разных механизмов, в том числе с использованием беспилотных летательных аппаратов. В данной статье рассматриваются вопросы выбора беспилотных летательных аппаратов для сельского хозяйства и даются рекомендации фермерам по выбору дронов для сбора данных. В частности, с помощью дронов можно собирать необходимую информацию о состоянии сельскохозяйственных полей (размер полей, уровень всхожести, уровень растительности). Основу данного исследования составляет обзор релевантной литературы по использованию беспилотных летательных аппаратов в сельском хозяйстве в разных странах и собственный опыт автора по реализации проекта с использованием агродрона на экспериментальных полях Астраханского государственного университета. Дополнительно был проведен опрос фермеров Астраханской области на предмет выявления наиболее востребованных областей сельского хозяйства для мониторинга с целью повышения эффективности принятия решений.

Ключевые слова: цифровое сельское хозяйство, наука о данных, сельскохозяйственный дрон, беспилотный летательный аппарат, точное земледелие.