Artículo de investigación

Aerospace monitoring in solving problems of modern precision agriculture

Аэрокосмический мониторинг в решении задач современного точного земледелия
Monitoreo aeroespacial en la resolución de problemas en la agricultura de precisión contemporánea
Monitoramento aeroespacial na resolução de problemas na agricultura de precisão contemporânea

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Written by:
Lyudmila B. Metechko[214]
https://www.scopus.com/ authid/detail.uri?authorId=57201183447
Andrey E. Sorokin[215]
https://www.scopus.com/authid/detail.uri?authorId=56478254000
Sergey V. Novikov[216]
https://orcid.org/0000-0001-6921-1760
https://www.scopus.com/authid/detail.uri?authorId=57192318711

Abstract

The article is devoted to the problems of modern agricultural management development. The authors pay special attention to the use of aerospace monitoring systems in solving the problems of precision agriculture.

A logistic analysis was carried out to identify the most effective means of aerospace monitoring for the precision agriculture development.

The innovative trends in the development of the Earth's modern space sensing are investigated, and recommendations on the use of mini-, micro - and nanosatellites in modern agricultural management are formulated.

Keywords: aerospace monitoring, agricultural management, environmental monitoring, nanosatellites, precision agriculture, remote sensing.

Аннотация

Статья посвящена проблемам развития современного агроменеджмента. Основное внимание авторы уделяют применению систем аэрокосмического мониторинга в решении задач точного земледелия.

Проведен логистический анализ по выявлению наиболее эффективных средств аэрокосмического мониторинга для целей развития точного земледелия.

Исследованы инновационные тенденции развития современного космического зондирования Земли и сформулированы рекомендации по применению мини -, микро - и наноспутников в современном агроменеджменте.

Ключевые слова: агроменеджмент, аэрокосмический мониторинг, дистанционное зондирование, наноспутники, точное земледелие, экологический мониторинг.

Resumo

Este artigo é dedicado aos problemas do desenvolvimento da gestão agrícola moderna. Os autores prestaram especial atenção ao uso de sistemas de vigilância aeroespacial para resolver vários problemas de agricultura de precisão.

[214] Docent, Institute of Engineering Economics and Humanities, Moscow Aviation Institute (National Research University), 125080 Volokolamskoe highway 4, Moscow, Russia, ncsrm@mail.ru
https://elibrary.ru/author_profile.asp?id=382849
[215] Head of Department, Moscow Aviation Institute (National Research University), 125080 Volokolamskoe highway 4, Moscow, Russia, https://elibrary.ru/author_profile.asp?id=497631
[216] PhD in Economics, Associate Professor, Institute of Engineering Economics and Humanities, Moscow Aviation Institute (National Research University), 125080 Volokolamskoe highway 4, Moscow, Russia, ncsrm@mail.ru
https://elibrary.ru/author_items.asp?authorid=807011

Para este propósito, uma análise logística foi realizada para identificar os meios mais eficazes de vigilância aeroespacial para o desenvolvimento da agricultura de precisão. Além disso, tendências inovadoras no desenvolvimento do sensoriamento remoto da Terra foram investigadas e recomendações foram feitas sobre o uso de mini, micro e nanossatélites no gerenciamento agrícola moderno.

Palavras-chave: agricultura de precisão, gestão agrícola, monitorização aeroespacial, monitorização ambiental, nanossatélites, teledetecção.

Resumen

El presente artículo está dedicado a los problemas del desarrollo de la gestión agrícola moderna. Los autores han prestado especial atención a la utilización de sistemas de vigilancia aeroespacial para resolver diversos problemas de la agricultura de precisión.

Con dicho fin se llevó a cabo un análisis logístico para identificar los medios más eficaces de vigilancia aeroespacial para el desarrollo de la agricultura de precisión. Asimismo, se han investigado las tendencias innovadoras en el desarrollo de la teleobservación espacial de la Tierra y se han formulado recomendaciones sobre la utilización de mini, micro y nanosatélites en la gestión agrícola moderna.

Palabras clave: agricultura de precisión, gestión agrícola, monitoreo ambiental, nanosatélites, teleobservación, vigilancia aeroespacial.

Introduction

The area of arable agricultural areas in our country (according to the data of the annual statistical reference book of Russia) is 2200 sq. km, which is about 10% of arable land worldwide. And if we consider that about 60% of the territories are located in the field of risky farming, then the high importance of improving the modern domestic farming efficiency becomes obvious.

The currently actively developing branch of agriculture relies on the necessary information support as any modern branch, since the results of the labor invested depend on a number of climatic, geographical, landscape, biological factors, etc. Any modern production requires complex high-tech management.

Methodology

Precision agriculture is a new term in the definition of high-tech agricultural work using global positioning technology (GPS), geographical and information systems (GIS) (Balabanov, Zhelezova, Berezovsky, Belenkov & Egorov, 2013).

From the above, it is clear that the modern agro-industrial complex is no longer able to exist without aerospace monitoring (Chernyavsky, 2004).

Only accurate (coordinate) farming can provide a significant improvement in the condition of the fields and the results of all types of agricultural work, while owning innovative means of high-tech agricultural management, in several main areas:

- agronomic: taking into account the real needs of the crop in fertilizers;
- technical: ensuring perfect time management at the farm level (including improved planning of agricultural operations);
- environmental: the negative impact of agricultural production on the environment is reduced (a more accurate assessment of the culture needs for nitrogen fertilizers leads to the limitation of chemical pollution of the soil);
- economic: productivity growth and / or cost reduction increases the efficiency of agribusiness (including, reducing the cost of obtaining the final product).

Electronic recording and storing the history of fieldwork and crops can help both in subsequent decision making and in the preparation of special reporting on the production cycle, which is increasingly required by the legislation of developed countries.

In our information age, a major role is played by information security start any processes for optimal decision-making and management efficiency.

The process of managing even one large farm with a fleet of various agricultural equipment has always been considered to be a difficult activity. Farmers often simply have no opportunity physically to track all the changes that occur in their farmland, having at their disposal immense fields: rationally placing equipment, ensuring efficient logistics, carry out urgent and necessary agrotechnical measures.

Namely agriculture as one of the main areas of environmental management is the most promising area of application aerospace monitoring for efficient and accurate agricultural management production.

The most important tool for coordination and effective management is environmental monitoring. In this sense, the information monitoring system and obtaining accurate data on the state of the territories allows for an accurate prediction of results in advance and becomes fundamental to the successful development of modern agricultural management.

This is because timely management decisions are primarily accurate information about the time of the crop, watering or fertilizing. In agriculture, this information is critical and often determines the result of all the activities of the agricultural system.

The main purpose of such monitoring in agriculture is the timely determination of the need for any measures in each field, including sowing and replanting, and fertilizing.

One of the most important aspects for modern precision farming is ensuring effective time management, where the main role is played by the frequency. All fields should be examined at least twice a week, and it is better to be able to observe the constant dynamics of natural changes taking place and be sure to have an accurate information after each case of extreme weather events - heavy rain, hail, and squally wind.

One of the constant tasks of the agronomist is the operational monitoring of the situation with the vegetation phases of sowing crops. The vegetation goes through several critical growth periods. The first such period is the sowing. For example, shoots can be thinned in case of lack of moisture. Survey of crops is necessary for an objective assessment of the agrocenosis state (Figure 1) (Makarenko & Sorokin, 2017).

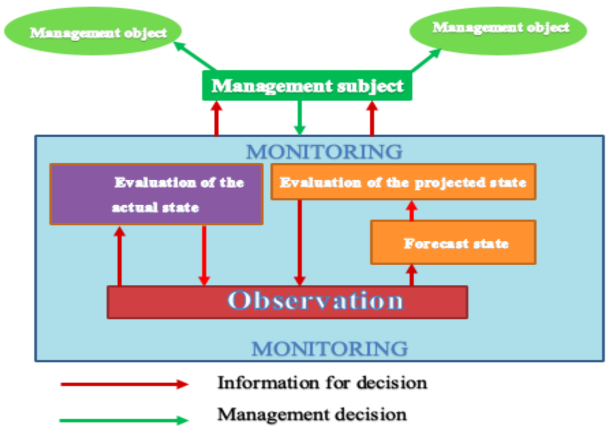

Figure 1. Conditional monitoring scheme

Such comprehensive information can provide aerospace monitoring. Just aerospace monitoring can fundamentally change the performance of a modern agricultural industry. The research conducted on the ground is not always able to fully analyze and assess the condition of agricultural land, to intervene in the process and to exercise the necessary control over the implementation of sowing, harvesting, feeding, watering, etc (Metechko, Datsyuk & Vostrikova, 2017).

Aerospace (remote) methods of environmental monitoring include a surveillance system using aircraft remote sensing tools (aircraft, helicopter, unmanned aerial vehicles (UAV), aerostat facilities) and space remote sensing facilities (flagship satellites and satellite systems, small satellites (mini-, pico- and nanosatellites), as well as a remote sensing data processing system (Metechko & Sorokin, 2018).

We list an approximate list of the necessary information that aerospace monitoring can provide to modern agricultural management:

- farmland inventory, creating electronic maps of fields and cadastre;
- monitoring equipment;
- data for the efficient logistics calculation;
- conditions of crops and fields under pairs;
- maintenance and control of agrotechnical measures;
- qualitative assessment of the crops condition at different stages of the growing season;
- germination of grain crops assessment;
- assessment of the current state of grain crops;
- grain ripening assessment;
- monitoring crop harvest rates;
- facts identification of the negative natural, man-made and anthropogenic effects on agricultural vegetation (droughts, drenching, frosts, pests, etc.);
- fields identification that have deviations from the development norms, their assessment and systematization (including the incidence of agricultural crops diseases).

As it is clear from the above, aerospace monitoring includes various means of remote sensing of territories and, over time, both he and the means of sensing are being improved along with the growing achievements of technology and technology.

It can be assessed how the tasks and technologies of probing devices have changed today, and what advantages and disadvantages modern aerospace monitoring tools have, by conducting a simple analysis based on the main parameters determining the effectiveness of obtaining information.

We will create for all types of aerospace monitoring a conditional scale of parameters for evaluating the effectiveness of obtaining information on the state of agrocenosis to carry out a logistic analysis.

The analysis is based on 5 main parameters:

- cost;
- the rate of coverage of the territory;
- frequency of data acquisition;
- dependence on weather conditions;
- dependence on the time of day (illumination).

Each value of the parameter is assigned a conditional quantitative value of the weight coefficients that determine the degree of its implementation from zero to maximum.

Taking the conditional scale of the five-step, we have the values of the weight coefficient equal to: 0, 1, 2, 3, 4.

The effectiveness of the parameter implementation in the five-step scale will be expressed as: zero, low, medium, high, ultrahigh.

The quantitative values of the weight coefficients are formed in such a way that the quantitative values of the weight coefficient decrease with increasing efficiency of the positive values of the parameter.

For example, the parameter "cost", which determines the cost of monitoring tools with an increase in the value of the cost, reduces its value of efficiency, and the weight coefficient increases its value accordingly with the growth of the cost.

Considering the parameter " rate of coverage of the territory " we note the opposite situation. With an increase in speed from zero to maximum, the efficiency of the specified parameter increases. The weight coefficient reduces the value to zero.

Thus, with increasing the efficiency of the parameter, the value of the weight coefficient is reduced. The smaller the total sum of the weight coefficients for the whole set of the studied parameters is obtained, the more effective the application of the studied type of technical means of monitoring implementation.

It will not be difficult to carry out a logistic analysis using Table 1.

This table contains a set of five indicators with a five-step scale of efficiency values and corresponding values of weight coefficients. (Table 1).

Table 1. Table of weights for the parameters that determine the use effectiveness of aerospace monitoring tools

№	Parameter	Zero	Low	Average	High	Ultra-high
1	Value	0	1	2	3	4
2	Rate of coverage	4	3	2	1	0
3	Frequency of receiving information	4	3	2	1	0
4	Dependence on weather conditions	0	1	2	3	4
5	Dependence on time of day	0	1	2	3	4

We will consider all aerospace monitoring tools with efficiency parameters for analyzing and determining the most effective means of remote sensing in aerospace monitoring in a single summary table and fix obvious weighting factors (Table 2).

Table 2. Aerospace remote sensing in the agro-environmental monitoring

№	Aerospace monitoring tools	Parameter Q	Points	$\sum_{i=1}^{5} Q_i$
	Aviation facilities			
1	Aircraft facilities (small aircraft)	Value	2	**13**
		Rate of coverage	2	
		Frequency of receiving information	3	
		Dependence on weather conditions	3	
		Dependence on time of day	3	
2	Rotary-wing aircraft (helicopters)	Value	3	**15**
		Rate of coverage	3	
		Frequency of receiving information	3	
		Dependence on weather conditions	3	
		Dependence on time of day	3	
3	Unmanned aerial vehicles	Value	1	**12**
		Rate of coverage	2	
		Frequency of receiving information	3	
		Dependence on weather conditions	3	
		Dependence on time of day	3	
	Space tools			
4	Flagship and satellite systems	Value	4	**4**
		Rate of coverage	0	
		Frequency of receiving information	0	
		Dependence on weather conditions	0	
		Dependence on time of day	0	
5	Mini, micro, pico and nano-satellites	Value	2	**2**
		Rate of coverage	0	
		Frequency of receiving information	0	
		Dependence on weather conditions	0	
		Dependence on time of day	0	

To assess the effectiveness of the use of various means of remote sensing in aerospace monitoring, we define for each the total indicators of weighting factors (1):

$$P_k = \sum_{i=1}^{5} Q_{ki} \qquad (1)$$

Where:

P - the type of remote sensing in aerospace monitoring;
k - the number of remote sensing means in the table;
Q - parameter evaluating the effectiveness of aerospace monitoring tools;
i - the index number of their table 1

The effectiveness of the application in agro-environmental monitoring will be demonstrated by those remote sensing tools, which will gain minimum final total weight. Thus, it is easy to determine the maximum efficiency of using various remote sensing tools in aerospace monitoring by the formula (2), since the most effective tool will be remote sensing, which has gained a minimum of weight points:

$$P_{effect} = P_{k\,min} \quad (2)$$

We can determine the number of efficiencies in descending order by the formula (3) rounding to integers:

$$N = P_n = \frac{P_k}{P_{k\,min}} \quad (3)$$

It is possible to determine the order of effectiveness of the use of remote sensing tools in agro-environmental monitoring based on the logistic evaluation (Table 3).

Table 3. the order of effectiveness of the use of remote sensing tools in agro-environmental monitoring based on the logistic evaluation

№	Aerospace monitoring tools	$\frac{P_k}{P_{k\,min}}$
1	Mini, micro, pico and nano-satellites	1
2	Flagship satellite and satellite systems manned by RKK	2
3	Aircraft facilities (small aircraft)	6
4	Unmanned aerial vehicles (UAV)	6
5	Rotary-wing aircraft (helicopters)	8
6	Aerostats	8

It can be seen from the obtained results that the space remote sensing tools demonstrate a leading advantage in the efficiency of obtaining information in agro-environmental monitoring.

Results and discussion

Space technology has become an integral part of the daily life of modern society today. Increasingly, publications began to appear that space monitoring could fundamentally change the performance of a modern agricultural sector (Metechko, Sorokin & Novikov, 2016).

Space monitoring of the Earth remote sensing (ERS) is a method of studying the earth's surface, based on non-contact recording of electromagnetic radiation of the earth's surface in different spectral ranges.

The ultimate goal of remote sensing data processing is the recognition of objects or situations within the field of view, and the determination of their position in space. Space photography is one of the leading places among the various methods of remote sensing.

Space monitoring systems include (Metechko, Sorokin, Tikhonov & Novikov, 2017):

- satellite systems in orbit (flight control and shooting control center);
- reception of information by ground receiving points, repeater satellites.
- storage and distribution of materials (centers of primary processing, archives of images). In detail, the pictures are conventionally divided into the following classes:
- low resolution images (kilometers);
- medium resolution images (hundreds of meters);
- high resolution images, in turn, are divided into:
- very high-resolution images (10-20 meters);
- high resolution images (less than 1 meter).

The possibilities of space imagery and space monitoring with the growing power of modern technology have become almost limitless.

Here is a sample list of information that aerospace monitoring can provide (Novikov, 2018):

- farmland inventory, creating electronic maps of fields and cadastre;
- monitoring equipment;
- analysis of the efficient logistics organization;
- conditions of crops and fields under pairs;
- maintenance and control of agrotechnical measures;
- the crops condition assessment at different stages of the growing season;
- germination assessment of grain crops;
- the current state assessment of grain crops;
- grain ripening assessment;
- monitoring crop harvest rates;
- facts identification of negative natural, man-made and anthropogenic effects on agricultural vegetation (droughts, drenching, frosts, pests, etc.);
- fields identification that have deviations from the developmental norms, their assessment and systematization (including the incidence identification of agricultural crops diseases).

Various methods of pattern recognition, methods of computational and mathematical biology (including mathematical modeling) are used to process the data of environmental monitoring, as well as a wide range of information technology.

Sensing methods can be passive, that is to use the natural reflected or secondary thermal radiation of objects on the Earth's surface, due to solar activity, and active - using stimulated emission of objects, initiated by an artificial source of directional action (Novikov & Veas Iniesta, 2018).

ERS data obtained from spacecraft (SC), previously characterized by a high degree of dependence on atmospheric transparency, therefore, modern spacecraft use multi-channel equipment of the passive and active types, recording electromagnetic radiation in various 9 ranges (Novikov, 2018).

ERS equipment of the first SC launched in the 1960-1970 was the route type, i.e. the projection of the measurement area on the Earth’s surface was a line. Later, the ERS equipment of a panoramic type appeared - scanners, a projection of the measurement area, on the Earth's surface which is a strip.

The advantages of combining optical and radar equipment lies in the fact that it allows to observe the Earth's surface at any time regardless of the atmosphere state.

The quality of data obtained as a result of remote sensing depends on their spatial, spectral, radiometric and temporal resolution (Petrukovich & Nikiforov, 2016):

- Spatial resolution. It is characterized by the size of a pixel (on the surface of the Earth) recorded in a raster image - it can vary from 1 to 1000 m.
- Spectral resolution. Landsat data includes seven bands, including the infrared spectrum, ranging from 0.07 to 2.1 microns. The Hyperion sensor of the Earth Observing-1 is capable of recording 220 spectral bands from 0.4 to 2.5 microns, with a spectral resolution of 0.1 to 0.11 microns;
- Radiometric resolution. The number of signal levels that the sensor can register. Usually it varies from 8 to 14 bits, which gives from 256 to 16,384 levels. This characteristic also depends on the noise level in the instrument;
- Temporary resolution. The satellite’s flight frequency over the surface area of interest. It is important in the study of a series of images, for example in the study of the dynamics of forests. Initially, an analysis of the series was carried out for the needs of military intelligence, in particular, to track changes in the infrastructure and movements of the enemy.

A transformation that removes geometric distortions is needed to create accurate maps based on remote sensing data. The image of the Earth’s surface by the apparatus, directed exactly downward, contains an undistorted image only in the center of the image. With a shift to the edges, the distances between points in the image and the corresponding distances on Earth are increasingly different. Correction of such distortions is made in the process of photogrammetry.

But modern trends towards miniaturization have also been reflected in space monitoring.

The new trends have emerged over the last decades with the increasing miniaturization of electronic instrumentation and in space-based earth monitoring programs reflected in the miniaturization of both the satellites themselves and remote sensing instruments themselves (Yakushev, 2016).

The emergence of new opportunities, the reduction of material, energy and capital intensity in the development and creation of satellites for various national economic goals has allowed them to be developed in small laboratories of universities, in small research enterprises and centers (Sorokin, Bulychev, Novikov & Gorbachev, 2019).

This has reduced the cost of projects when creating small, super small and nanosatellites from a million to several million rubles.

A whole galaxy of mini-satellites (up to 500 kg.), micro-satellites (up to 100 kg), nanosatellites (up to 10 kg.) and even picosatellites (up to 1 kg) have appeared along with the traditional "flagship" projects of multifunctional satellites weighing about a ton (Figure 2).

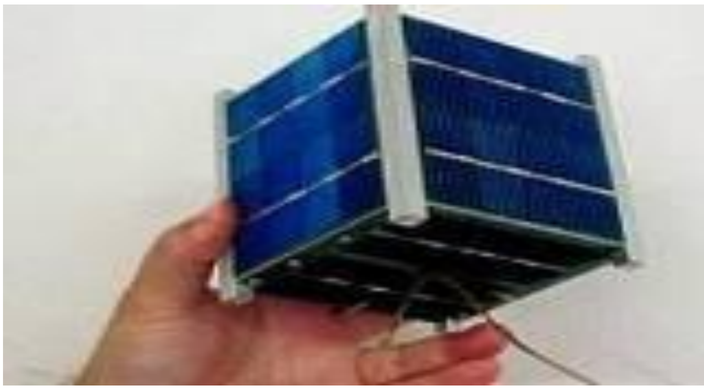

Figure 2. An example of a nanosatellite

The new indicators of the space technology effectiveness have appeared, expressed in the relative cost of the satellite, which is expressed in the ratio of the information amount received in bytes to the project cost, in which miniature devices are certainly in the lead. Of course, they cannot compete in universality with large satellites, but they are quite suitable for specific tasks (Sutyrina, 2013).

Reducing the cost and availability of nanosatellites made it possible to use less expensive means of delivery for their launches or to use “associated” launches of Soyuz-type launch vehicles.

The annual monitoring cycle on the basis of such a short-term satellite and upon the term expiration is replaced by a new one carrying out a similar mission or a more refined one in accordance with the needs of the research program (Tokolova, 2016). Upon completion of their own batteries’ life, such satellites that do not have additional solar cell designs burn “like moths” in the upper layers of the atmosphere without damage when they fall, like traditional satellites and spent space stations (Figure 3).

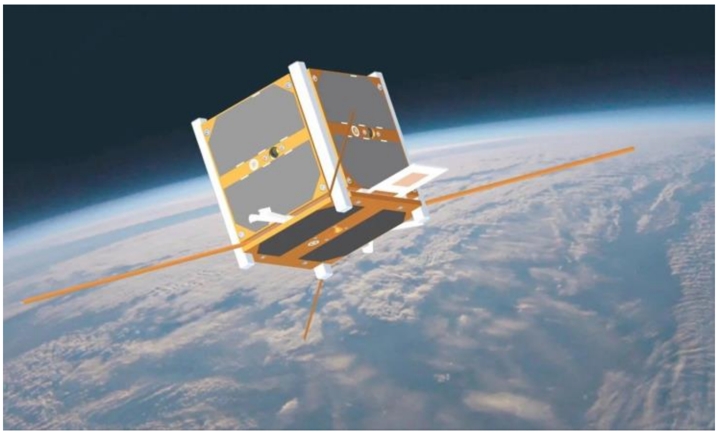

Figure 3. Nanosatellite without solar batteries in orbit

Conclusions

Thus, a new direction in space monitoring has opened up the possibilities for agro-industrial associations and farms to monitor their lands with the help of nanosatellites and picosatellites in an affordable price range.

The undoubted conclusion is that humanity has no other alternative, such as creating high-tech agriculture using global positioning technologies (GPS), geographical and information systems (GIS), improving the environmental performance and efficiency of agricultural work in a growing population, and food.

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