Geoinformation services in precision agriculture

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Abstract. To maintain the agricultural resources of the Earth, it is necessary to use intelligent farming methods. Precision farming is one of the areas that allow to economically use the resources of the Earth. This article describes the original method of using the geoinformation service in precision agriculture. This strategy includes the following methods of geoinformation service: geoinformation mapping of fields, space monitoring, monitoring using unmanned aerial vehicles, unmanned driving, agricultural machinery that allows the implementation of point application of moisture and fertilizers. A geoinformation service is understood on the one hand to be a professional activity in providing services based on spatial information, and on the other hand, a set of hardware, technical and telecommunication means for providing spatially distributed information. The authors believe that the implementation of precision farming should be based on the creation, editing and use of an intelligent digital field model. The article describes the method of functioning of such a model.

1 Introduction

The number of people living on earth is increasing, which creates an additional burden on agricultural areas. The way out of this situation is precision farming, which allows to increase yields, predict its volume, harvest and preserve crops.

Precision agriculture uses geographic information service methods such as spatial positioning, remote monitoring and smart agricultural machinery based on the principles of the Internet of Things.

The purpose of the article is to develop a methodology for using geoinformation services in precision agriculture. This technique allows to combine disparate methods together and focus them on precision farming tasks.

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Let's consider the individual components separately. A number of well-known authors dealt with issues of global spatial positioning and remote monitoring: Bondur V.G., Levin B.A., Rosenberg I.N., Savinykh V.P. [1, 2, 3].

The scientific teams led by these scientists developed principles and methods for monitoring spatial objects using space methods.

Such scientists as Dorokhov A.S., Erokhin M.N., Vodyannikov V.T. dealt with the creation and use of smart agricultural mechanisms of vehicles [4, 5, 6].

In 2007, at the Russian State Agricultural Academy - Moscow Agriculture Academy named after K.A. Timiryazev a precision farming center was established [7]. The center conducted research on testing precision farming methods in experimental fields. Researches have clearly shown the effectiveness of precision positioning methods.

In the research of this article, the authors took geoinformation methods as a basis and proposed a technique for geoinformation modeling of spatial positioning data for use in precision agriculture.

Thus, the purpose of the article is to develop a methodology for the use of geoinformation services in precision agriculture. To achieve this goal, the analysis of trends in the sustainable development of agribusiness based on precision agriculture is carried out, a comparative analysis of precise positioning methods based on space navigation methods and using unmanned aerial vehicles is carried out. Based on the analysis, a methodology for monitoring fields using geoinformation service methods is presented.

2 Materials and Methods

The research was conducted at the Department of the RSAU-MAA named after K.A. Timiryazev, together with the Semka from the Air company and the Department of Geodesy and Geoinformatics of the Russian University of Transport and the Mytishchi branch of the Moscow State Technical University named after N.E. Bauman. According to the results of the research, monographs [8, 9, 10], textbooks [11, 12, 13], a number of articles in journals [14-18] were written. This scientific literature discussed the effectiveness of digitalization and precision farming in agriculture [19, 20, 21], the possibility of using geoinformation services [8, 14], analysis of space monitoring methods [10, 11, 12] and the possibility of using unmanned aerial vehicles [9, 13, 17, 18].

3 Results and Discussion

Before discussing the results of the study, we would like to clarify the basic concepts used in the article.

Yakushev V.P. rightly connects the precision farming concept with the smart farming concept [19]. He also notes the connection of this concept with monitoring of the earth's cover from space and mathematical modeling methods [20].

Astakhov V.S., Ivanchikov G.O. [21] note that the essence of precision farming lies in the differentiated application of fertilizers.

Osipyan V.G. [22] notes that precision farming methods cover all stages of agricultural production from planning crops, sowing companies, monitoring the cultivation, collection and processing of agricultural products.

The basis of precision farming is an intelligent digital field model [10]. Initially, it can be obtained from existing cadastral maps and plans [8], in the future it will be clarified on the basis of space monitoring [1, 2, 10, 11, 12] or with the help of unmanned aerial vehicles (UAVs) [13, 18, 26, 28].

Let's consider the concept of a geoinformation service. Under geoinformation service, we will understand, on the one hand, the professional activity of providing services based on spatial information, and on the other hand, a set of hardware, technical and telecommunication means for providing spatially distributed information [29].

The basis of precision farming is a digital field model. The initial digital model can be obtained in two ways:

- the field is outlined using a car GPS receiver when a farmer drives around the field on a tractor;
- the field is outlined on the base map obtained from aerial photographs or satellite images.

Using soil maps, farmers can use two strategies to adjust field costs:

- predictive approach: based on the analysis of static indicators (soil, resistivity, field history, etc.) during the growing season;
- control during the harvest cycle by sampling (weighing biomass, measuring chlorophyll content in leaves, weighing fruits, etc.);
- Remote sensing (measuring parameters such as temperature (air/soil), humidity (air/soil/leaves), wind or trunk diameter, possible thanks to wireless sensor networks and the Internet of Things);
- proxy detection (on-board sensors measure the condition of the leaves; for this purpose, the farmer must go around the entire field);
- aerial or satellite remote sensing (multispectral images are obtained and processed to obtain maps of the biophysical parameters of crops, including disease indicators. On-board devices are able to measure the amount of vegetation cover and distinguish between crops and weeds).

Decisions can be based on decision making support models (crop simulation models and recommendation models) based on big data, artificial intelligence (AI) systems based on machine learning and artificial neural networks, but ultimately the decision on business value and environmental impact remains with the head of the agricultural enterprise.

New information and communication technologies make crop management at the field level more operational and easier for managers of agricultural enterprises. The application of crop management solutions requires agricultural equipment that supports technology with variable application rates, for example, different seed densities along with variable nitrogen application and phytosanitary products.

Precision farming uses new technologies on agricultural equipment (tractors, sprayers, combines, etc.):

- positioning system (for example, GPS receivers that use satellite signals to accurately determine the position on the globe);
- geographic information systems, i.e. software that analyzes all available data;
- variator agricultural machinery (seeder, spreader).

Precision farming, as the name implies, means applying the exact and correct amount of resources such as water, fertilizers, pesticides, etc., at the right time for the crop to increase its productivity and maximize yields. Precision agriculture management techniques can significantly reduce the amount of nutrients and other resources used to grow crops, while increasing yields. Thus, agricultural enterprises receive a return on their investments by saving water, pesticides, and fertilizers.

The second, larger-scale advantage of targeting inputs concerns the environmental impact. Precision farming reduces the burden of agriculture on the environment by increasing the efficiency of machines and their use. For example, the use of remote control devices such as GPS reduces fuel consumption in agriculture, while the introduction of nutrients or pesticides with a variable rate can potentially reduce the use of these resources, thereby reducing costs and reducing harmful runoff into reservoirs.

Precision farming is the application of breakthrough digital farming technologies. There are already self-driving tractors that operate on autopilot. Technologies are moving towards unmanned vehicles programmed to fertilize or plow the land using remote sensing data. The autonomy of the technology is due to the urgent need for diagnostics, which is often difficult to perform only with the help of manual equipment controlled by a farmer.

UAVs and satellite technologies are used in precision farming. This happens when UAVs take high-quality images and satellites take a larger picture. Aerial photography from a light aircraft can be combined with satellite data to predict future harvests based on the current level of field biomass. Aggregated images can create contour maps to track where water flows, identify crops with variable rates, and create yield maps of more or less productive areas. Methods of improving ultra-high resolution are increasingly being used in monitoring crop diseases from low-flying aircraft.

Modern advances in geographic information systems (GIS), remote sensing (RS) and global positioning systems (GPS) technologies provide the opportunity to obtain and use high-resolution satellite images and digital spatial data. In the agricultural sector, these spatial data have helped to explore the spatial relationships of social, physical, agroecological and environmental complexities and how they affect agricultural sustainability. GIS technology provides users with a set of spatial information management tools and techniques that allow users to collect, store, integrate, query, display, and analyze spatial data at various scales]. Remote sensing technology receives images and other information about crops and soil from sensors mounted on various platforms, including satellites, airborne remote sensing and ground-based equipment, which are then processed by computers to help make agricultural decisions.

Monitoring of land use is an important task in agriculture, including monitoring food security, forecasting areas and yields, crop estimates, and export planning. Traditional field monitoring and planning systems are based on field observations, which require extremely large and impractical expenditure of resources, time and human labor to measure fields, integrate statistical results and eliminate spatiotemporal errors. Agricultural monitoring systems are looking for sustainable solutions, starting with remote sensing based on satellite data for cheap and timely mapping of fields.

There are sources of satellite images that are provided free of charge and offer a wide spatial range over a large geographical area, covering high time resolution.

Nevertheless, there are also a number of problems. First, although satellite images cover a large geographical area, they often have a relatively low spatial resolution, which can lead to inaccurate crop estimates in the fields. Second, satellite images often suffer from adverse conditions such as cloud shadow or solar radiation. Third, images are often created by polar-orbiting satellites with low sampling rates, which makes it difficult for round-the-clock applications.

Unmanned aerial vehicles (UAV) are an alternative to expensive and time-consuming traditional methods of improving water management in agriculture and increasing yields by collecting, processing and analyzing spatial and temporal crop data with high resolution at the field scale. UAVs equipped with multispectral and thermal imaging cameras facilitate monitoring of crops throughout the entire growing cycle, which allows timely detection of any anomalies and intervention in them. The use of UAVs in small-scale agriculture is designed to ensure food security at the household level and improve water management in agriculture. UAVs facilitate access to agrometeorological information on a field scale and, practically, in real time, important information for irrigation planning and other on-site decision-making. This technology improves small-scale agriculture by facilitating access to information on the biophysical parameters of crops in almost real time to improve preparedness and prompt decision-making. Combined with accurate meteorological data, this technology makes it possible to accurately assess the water demand of plants with high spatial resolution. Timely access to information on the state of crops helps to make operational decisions at the farm level and, thus, increases the standard of living and well-being of rural residents.

Accurate spatial information about agriculture is an essential requirement for planning and decision-making, especially when intending to increase and improve small-scale irrigated agriculture. Most of the freely available space satellite images have been used to create rough land use/coverage maps, but the advent of UAVs has improved mapping accuracy due to their high resolution, albeit with less coverage. The use of UAVs for land-use mapping makes it potentially possible to monitor the fields of small farmers, which are usually too small to be detected using available medium and low resolution satellite images. The land area of small farmers is about two hectares per farmer.

Small-scale farming areas are usually detected as one large agricultural land using low- or medium-resolution satellites, but their mapping accuracy is important because, for example, in southern Africa they occupy about 80% of cultivated land, and their share is about 90% of agricultural products. Therefore, accurate and detailed mapping of agricultural fields is important for policy development and decision-making, especially to ensure the resilience of agricultural sources to climate change. High-resolution satellite images, which can provide the same accuracy as UAVs, are expensive, which limits their use. Unlike a space satellite, UAVs are not limited to cloud cover, since the time resolution (capture time) is determined by the user and can be adapted to local weather conditions. Unmanned aerial vehicles can be deployed multiple times at any time and at any altitude to collect agricultural data. The images obtained with the help of UAVs make it possible to observe individual plants, areas and, eventually, over fields, which is impossible when using space satellite images. These advantages, combined with ultra-high spatial resolution, make UAVs the most suitable for mapping crops planted in narrow rows with optimal accuracy. The main limiting factor of UAV images compared to satellite images is their small coverage per image.

Unmanned aerial vehicles are rapidly becoming key components of agricultural research and industry, being an important source of information on previously unavailable agrometeorological data on a field scale. They open up opportunities for integrating climate-optimized and precision agriculture into small-scale agriculture through improved crop health monitoring and agricultural water management, as they are a source of high-resolution images obtained with user-defined time resolution at low altitudes sufficient for effective monitoring of crops in real time. To date, their use in small farms has been limited by the lack of resources and skills to acquire and operate UAVs; the notion that they are expensive has not considered the benefits that could be obtained through their use in agriculture. In particular, we recommend using UAVs as an opportunity to increase youth participation in agriculture.

The following stages can be distinguished in the methodology of monitoring an agricultural field:

1. Selection of carographic and aerial photography materials and their introduction into information systems.
2. Analysis of the current field state and making adjustments (watering, ridge forming).
3. Using global positioning to treat fields.
4. Harvesting and mapping yields.
5. Conducting an analysis to make a decision on crop rotation.

4 Conclusions

The article develops a methodology for using GIS in precision agriculture. The methodology describes the order of work carried out in precision agriculture based on the methods of geoinformation service. The methods of the geoinformation service include: global positioning, space monitoring, UAV monitoring, smart agricultural machinery, and the Internet of Things.

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