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Using Remote Sensing Methods in Precision Agriculture

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***Abstract*— Investigation of natural resources requires development and improvement of remote sensing methods, to be precise, satellite observations, laser scanning and survey using aerial vehicles; their importance increases with comprehensive research and solving problems of rational use of natural resources and environmental protection. Effective soil productivity management requires an integrated approach including using and developing of GPS (Global Positioning), GIS (Geographic Information Systems), YMT (Yield Monitor Technologies), VRT (Variable Rate Technology), and others. This integrated approach using computer and satellite technologies is called precision agriculture. Precision agriculture system is characterized not by a strictly defined set of methods and technical means; but by a general concept based on the use of satellite positioning technologies (GPS), geographic information systems (GIS), precise mapping of fields and others. Remote sensing technologies for observation the Earth from space are an essential tool for studying and constant monitoring of our planet that helps to effectively use and manage its resources.**

Keywords—precision agriculture, remote sensing methods, digital technologies in AIC, satellite observations, soil and land resources, digital technologies, intensification of agricultural production.

I. INTRODUCTION

By precision agriculture is meant the management of crop productivity taking into account the intra-field variability of plant ambient conditions. In other words, it is the optimal management method for each square meter of the field. The purpose of such management is to maximize profits due to optimization of agricultural production, saving economic and natural resources. Currently, along with the term “precision agriculture”, “smart agriculture” is also used. Precision agriculture reduces the cost of fertilizer application, seeds, fuel and lubricants by an average of 30%. In addition to reducing costs and increasing yields, precision agriculture makes it possible to balance the physical and agrochemical properties of soil; the field thus becomes regularly shaped and convenient for agricultural operations.

Using automated systems is due to the large flow of information and the need for its systematic processing.

Currently, the problems of implementation of digital technologies in the AIC of the country are especially pressing. In this regard, the Ministry of Agriculture of the Russian Federation has a special structure for monitoring advanced technologies and the direct implementation of digital technologies in the AIC of the country.

II. LITERATURE REVIEW

Remote sensing methods help in optimal use of agricultural land; these technologies are discussed in detail in many works. The work of Sarmadian S.J. et al. (2019) [1] was dedicated to the hybrid method of describing AHP elements which improved planning and decision making regarding lands which are suitable for growing grain varieties. Knowing physical properties of the soil is necessary for agricultural and environmental activities. Remote sensing methods were used to map soil texture components, spatial distribution of soil fractions using satellite images obtained by Landsat device [2]. Remote sensing data provide more accurate results and can be used for digital surface models of soil fractions on a regional scale. In [3], attention was paid to precision agriculture, processing of yield monitoring data for fields which often go with another information, such as studies of soil test results. Data were obtained from monitoring time series of yields for wheat and barley during three different seasons. Yield forecast was made based on these data. A study aimed at developing regional method for assessing the risk of drought is given in the work of Xiao Liu et al. (2019) [4]. Drought monitoring using remote sensing methods and uncertainty method, and also multimodel method for inverting soil moisture were taken as basis. After analysis and verification, the most suitable drought monitoring model for polynomial temperature and vegetation model was obtained. Estimation of using water for irrigation on the scale of water collection basin in accordance to satellite data on soil moisture was studied in [5]. To this end, SM2RAIN algorithm was used that was originally developed to estimate precipitation. As input to the model, satellite observations of soil moisture obtained with advanced microwave scanning radiometer 2 (AMSR2) were used, as well as different products of precipitation and total evaporation (ET).

The current state of agricultural land based on GIS technology using Earth remote sensing materials as an example of the forest-steppe zone of Western Siberia was studied in the work of M.R. Shayakhmetov et al. Special attention was paid to the issue of spatiotemporal changes in the structure of agricultural land using images obtained by Landsat 8 SC [6].

Using ALOS spacecraft, it became possible to define changes occurred in soil types. Using of images of German RapidEye spacecraft made it possible to solve the problem of finding the mesorelief and the nature of soil. Over the past two years, preference was given to the latest images made by Russia (Canopus-V and Resource-P) and Planet Scope European Space Agency. Currently, a number of municipalities in the Omsk Region started using Sentinel images instead of Landsat-8 ones [7].

In [8], a comparative assessment of the natural potential of Siberian agricultural chernozems for the planning of rational land use, protection of soils and soil cover was given; soil-ecological index (SEI) was estimated which was calculated based on climatic, agrochemical and soil parameters.

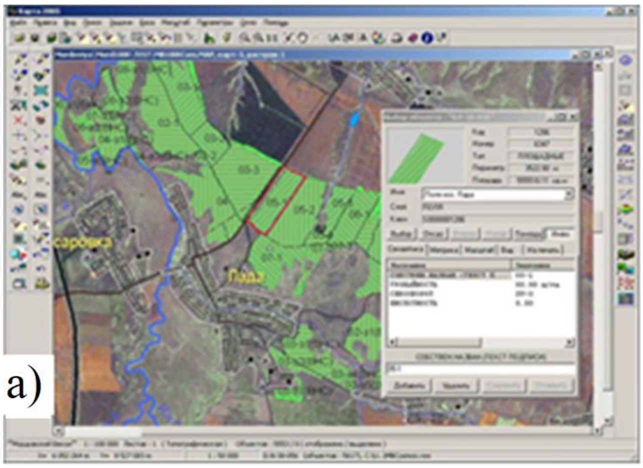
The work [9] showed the analysis of modern methods of remote sensing of the Earth in order to obtain information on the condition of agricultural land. The paper considers the options for equipping existing aerial vehicles with modern multispectral and hyperspectral cameras.

III. METHODS

In the Russian Federation, satellite images for agricultural sector are provided by Roscosmos State Corporation. Images from Kanopus-V, Meteor-M, Resurs-P satellites are used for the development of digital technologies.

As information becomes available, the map acquires new layers: hydrography, road network, etc. Thematic layers are created, for example, the results of agrochemical and agrophysical surveys, weather conditions, topography, crop rotation, yield map, etc. [10]. Thus, such electronic map allows monitoring all agricultural operations.

Geoinformational technologies allow processing remote sensing data and obtaining the agrophysical and agrochemical characteristics of fields shown in Fig. 1 (a) and 3-D surface model shown in Fig. 1 (b) which is used for decision making.



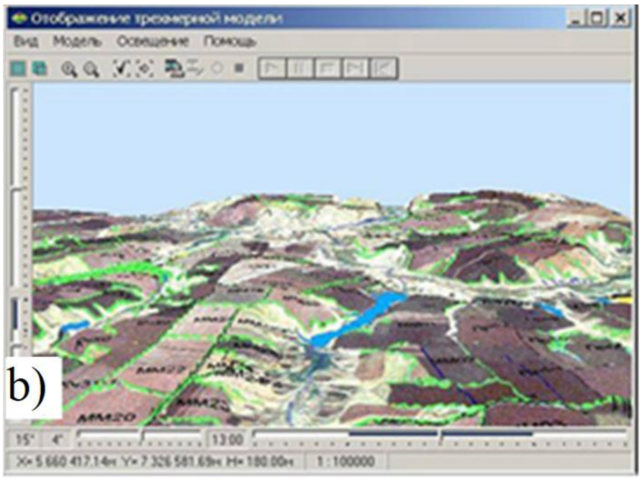


Fig. 1. Examples of processed remote sensing data: a) agrophysical and agrochemical characteristics of fields; b) 3-D surface model

Satellite information used to assess soil fertility is an important element of precision agriculture. On its basis, not only a qualitative assessment of the land is possible, but also developing meliorative methods of management of alkalinity and salinization of soils, flooding and irrigation. Obtained materials are used in assessing soil cover and developing systems for fertilizer application and meliorative methods [11].

Precision farming is a general concept; it includes different technologies: GPS, detailed mapping, parallel guidance and others. They can be applied all at once, or only several of them, at the discretion of management. The main thing is to complete the tasks and achieve the planned result.

Precision agriculture system is based on the use of field maps detailed as much as possible in the sense of plots and parameters. Existing cadastral maps provide little useful information; they mainly specify the boundaries of field on the ground. However information is required on the level of soil moisture, chemical composition, prevailing winds, surface slope, the amount of solar radiation, the presence of natural and artificial objects, and the distance to them. There are different methods for making such maps. Necessary information is obtained from satellites; soil samples are taken on the ground; general analysis is performed for each site, and a map is developed.

Remote sensing data are widely used for the following purposes: monitoring air condition, land inventory, monitoring the construction of buildings and structures, monitoring the condition of natural objects, identifying and studying regional problems [12].

According to remote sensing data, soil structure, vegetative index, and other land parameters are estimated. Thus, remote sensing methods with the help of geoinformational technologies make it possible to survey soil condition, changes and condition of surface, and the relationship between productivity and soil condition.

The essence of the abovementioned different spacecraft is not so much in the resolution which is due to the purposes of using satellite information, but in the required prompt detection of changes in the fertility condition of actual separate soil bodies, such as changes in soil salinity, flooding, etc.

IV. RESULTS

This method can be effectively used in the studying of all types of land reclamation: hydraulic, forest improvement, chemical and agricultural. But for this, high-resolution and ultra-high-resolution satellite images should be used in the presence of not only three visible channels (red, green and blue), but also of long-wavelength energy-saturated infrared channel.

For the analysis of plant material by growth and development periods, the most common NDVI (Normalized Difference Vegetation Index) was used. It is a normalized relative vegetation index, i.e. a simple quantitative measure of the amount of photosynthetically active vegetation (commonly called a vegetation index). NDVI is one of the most common and widely used indices for solving problems using quantitative estimates of vegetation cover; it is calculated from the ratio defined by the following formula:

$$NDVI = \frac{NIR - RED}{NIR + RED} \qquad (1)$$

where *NIR* – reflection in the near infrared region of spectrum;

RED – reflection in the red region of spectrum.

In accordance with the given ratio, it can be stated that the density of vegetation (NDVI) at a certain point of the image is equal to the difference in the intensities of reflected light in red and infrared ranges divided by the sum of their intensities.

NDVI calculation is based on the two most stable (independent of other factors) parts of the spectral reflection curve of vascular plants. Maximum absorption of solar radiation by chlorophyll of higher vascular plants is located in the red region of spectrum (0.6–0.7 μm), and the area of maximum reflection of leaf cell structures is in infrared region (0.7–1.0 μm). That is, high photosynthetic activity (usually associated with dense vegetation) leads to less reflection in the red region of spectrum and more reflection in the infrared one. The ratio of these parameters to each other allows clearly dividing plant objects from other natural objects and analyzing them. Using not a simple relationship, but a normalized difference between the minimum and maximum reflections increases measurement accuracy, reduces the effect of such phenomena as differences in lighting conditions of image, cloudiness, haze, radiation absorption by atmosphere, etc.

V. PRACTICAL SIGNIFICANCE

According to the data obtained, with the help of satellite images and NDVI, the following operations can be performed throughout the whole growing season:

- Monitoring the uniformity of seedlings;
- Monitoring the episodes of diseases or other adverse factors;
- Defining the readiness of crop for harvesting;
- Defining required nitrogen fertilizing of crop.

VI. SUGGESTIONS AND IMPLEMENTATION RESULTS

The main feature of the changes found is based on the analysis of the reflection spectrum of separate surface objects with the obligatory comparison of the short-wave part of spectrum with its long-wave part [10]. There was an increased focus on the dynamics of the infrared part of reflection spectrum which depends on the dynamics of vegetation cover and the moisture content of studied soil cover.

Currently, the main focus of a number of young scientists of the Omsk State Agrarian University is landing on comparing solar radiation spectrum coming on terrestrial objects and reflected by them. Knowing that vegetation cover absorbs the coming solar energy, the task is to establish the influence of the fraction of energy absorbed by the soil on the condition of humus, absorption and movement of moisture, and available nutrients in soil. The solution to this problem allows managing the issues of land reclamation, tillage and fertilizer systems at new levels.

Precision agriculture includes many separate technologies; the need for their implementation is determined at the discretion of the owners and managers of agricultural enterprise. These technologies can be used all at once, if necessary, or just several of them that will have the most significant effect for this enterprise.

VII. RESULTS OF EXPERIMENTAL STUDIES

With the help of digital technologies for monitoring the condition of agricultural land, an electronic soil map was created (Fig. 2 (a)) within the framework of the state policy under the “Unified Federal Information System of Agricultural Lands” program; a digital basis for agricultural lands was created on the territory of Tavrichesky District of the Omsk Region (Fig. 2 (b)).

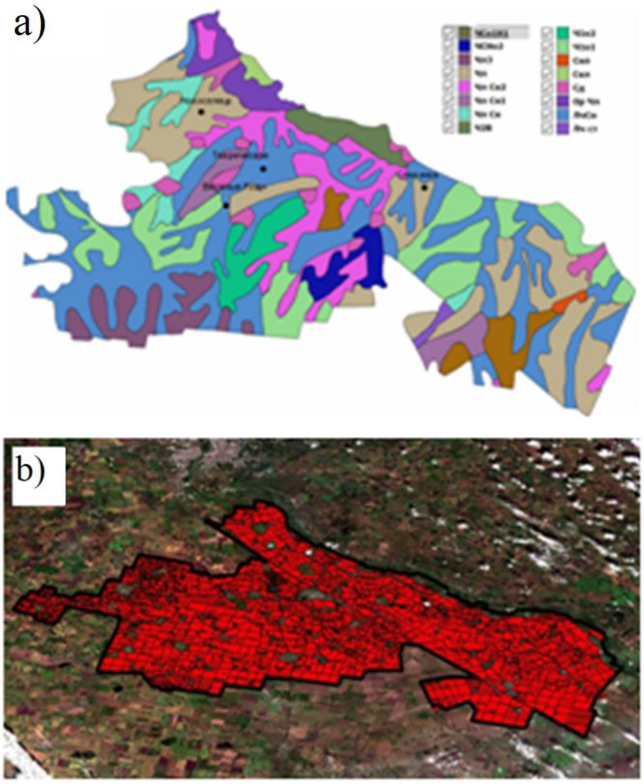


Fig. 2. Tavrichesky District of the Omsk Region: a) electronic soil map; b) digital basis of agricultural lands created using QGis software

In the course of creating a shape-file based on satellite multispectral images made by Sentinel spacecraft, an actual image of using agricultural land at the moment of research was obtained. This digital basis was transferred to the Municipal

Department of Agriculture in order to create a common database for each land plot.

Initially, an attempt was made to monitor agricultural lands at the territory under consideration by the periods of year in order to analyze biomass accumulation both for the whole municipal district and for separate test plots (Fig. 3 (a) summer period; 3 (b) autumn period).

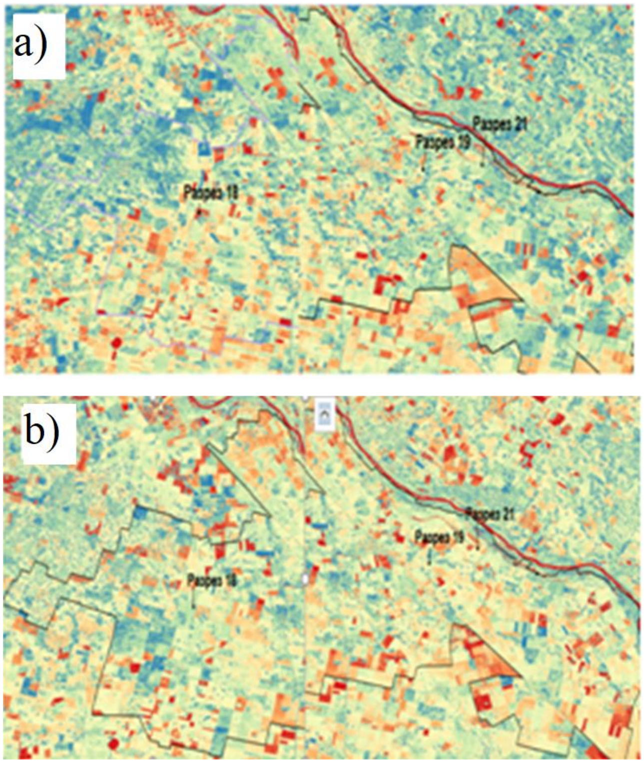


Fig. 3. Survey based on NDVI from Sentinel spacecraft: a) summer period; b) autumn period

Based on the analysis of the biomass at test sites shown in Fig. 4, it should be noted that in selected test sites the uniform development of biomass in the summer period can be noted only for field 1; field 2 and field 3 develop unevenly, since NDVI ranges from 0.4 to 0.6 (conventional units in the range from -1 to 1).

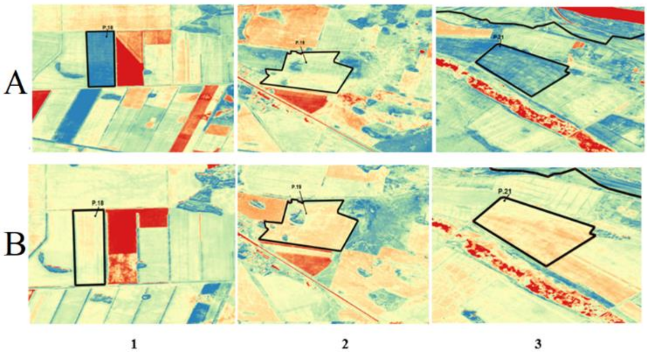


Fig. 4. Biomass analysis of test plots based on NDVI (A – summer period; B – autumn period)

NDVI in all test plots in the autumn is actually measured as 0.1 (conventional units) what indicates that the crop was harvested, but straw after harvesting remained on the surface. If there is no straw on the surface, the coefficient will be about 0 conventional units.

Precision agriculture includes, in fact, all technologies that are based on satellite and computer systems and are used to optimize resource consumption. The most popular of them are: GPS monitoring, irrigation, sensors, SMART technology (clouds), robotic application. The further the technologies develop, the more machines are created that can operate independently, without constant monitoring by the operator. Such systems have already been developed for almost all main stages of crop production: sowing, harvesting, watering, fertilizing.

VIII. DISCUSSION

In the framework of the federal policy of digitalization in agriculture, a digital basis was created for agricultural lands of Tavrichesky District. This map was transferred to the Municipal Department of Agriculture in order to create a common database for each site.

Based on cartographic documents, an electronic soil map of the region was created using modern digital technologies. In the course of conducting partial soil survey, it was found that this soil map is currently relevant.

IX. CONCLUSION

Precision agriculture has the following advantages – it significantly reduces the consumption of seeds and materials, that is, fertilizers, fuel, water and others, and as a result, it reduces production cost. The application of precision agriculture technology leads to increased yields and higher profits; the products are of better quality; the negative impact of production on environment is reduced; agricultural management obtains and accumulates a lot of useful information. Implementation of comprehensive precision agriculture system requires significant investments. Not every farm, even among these with considerable profit, can afford such expenses. Precision agriculture, in fact, is a set of rather complicated computer technologies. This system is new; we have little practical experience of working with it. Moreover, existing technologies are also constantly being improved what further reduces the experience of their application. As a result, it is rather difficult to take a correct view of the effectiveness of its implementation and use. However, mentioned disadvantages are not the essential shortcomings, but just temporary growth problems. They should not become an obstacle for those who understand that the future lies in precision agriculture.

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