IMPROVING AN EFFICIENCY OF AGRICULTURAL TERRITORIES ON THE BASIS OF SPACE-BASED AND GEOINFORMATION TECHNOLOGIES

Taisia Scherbinina\textsuperscript{a}, Rafail Mustafin\textsuperscript{b,1}, Mikhail Panasyuk\textsuperscript{c}

\textsuperscript{abc} Kazan federal university, Kremlevskaya, 6/20, Kazan 420111, Russia.

Received on 14-08-2016 \hspace{1cm} Accepted on 20-09-2016

Abstract

This article is devoted to the development and use of space-based and geoinformation technologies allowing for agricultural enterprises, state and municipal authorities to carry out an objective assessment of agricultural areas, to analyze and give a forecast of development of agro-business in specific areas and territories. The aim of the study is to determine the territorial features of agricultural plots. The object of research is the territory of the agricultural enterprises in the Republic of Tatarstan with a total area of about 10 thousand hectares, including an area of 7500 hectares of arable lands with their unique physical and geographical characteristics. In this work we have used traditional geographical techniques: mapping, based on methodological foundations of thematic and complex mapping, and on the achievements in the field of geo-information technologies, comparative descriptive method, spatial analysis method, and statistical method. As a result of the study, a method was developed on evaluating the efficiency of crop production on the territory of individual agricultural areas of enterprises with space-based and geoinformation technologies what will allow timely management decisions to make; and also it is suggested to introduce a specially developed hardware and software for monitoring and implementation of measures aimed at improving the efficiency of use of agricultural land.

Corresponding author name. Tel.:+ 7-927-409-14-00

E-mail address: Rafail.Mustafin@tattelecom.ru

Keywords: space-based technology, geographic information system, agriculture, farmland map, geospatial data, geological interpretation, space-based images, ore-controlling structure

Introduction: Agriculture of the Republic of Tatarstan is one of the leading among Russian regions. Republic of Tatarstan, with a little over 2\% of agricultural land in Russia, produces 8\% of the gross grain harvest, is the largest
Agriculture takes fourth place in the gross regional product (7.9%) yielding to manufacturing industry, service sector and construction. State and private agricultural enterprises operate in the agricultural industry. More than half of agricultural production comes from enterprises of small business forms - farming enterprises (4.6%), private subsidiary farms (48.7%) [1]. Such vertically integrated agricultural holding companies with full cycle of production and processing of agricultural products stand out among large enterprises as JSC "VAMIN Tatarstan", JSC Holding company "Ak Bars", JSC "Krasny Vostok Agro", CJSC HC "Golden Ear", JSC "Agrosila Group". Due to significant financial investments of companies, half arable lands in the Republic, and breeding cattle stock are involved in the scope of their activities. The Republic of Tatarstan has created Europe's largest high-tech mega-farms equipped with modern automated equipment for production of meat, milk, and eggs [2].

In modern conditions, one of the major problems of agricultural development is to assess the competitiveness of the administrative-territorial units. This is especially important in connection with the deepening of the globalization process and beginning the transition of society to a post-industrial development stage [3]. Evaluation of the investment potential of different regions of Russia is an important tool for determining the quality and effectiveness of the management areas [4].

In the conditions of post-industrial development of regions, there has significantly increased the role of their positioning and competitiveness in the competition for investments, innovations, and high technologies [5, 6].

Given the importance of agriculture in the economy of the Republic of Tatarstan, a relevant issue is introduction of modern geoinformation technologies in this field of activity.

Geographic information systems (GIS) are used to solve the problems of socio-economic analysis of regional and urban systems, as well as there is a prospect of GIS application for realization of the basic functions of a regional government, including in agriculture [7].

Municipal districts of the Republic of Tatarstan differ significantly by most socio-economic indicators. The imbalance in the development of regions indicate the need to increase their investment attractiveness. Of particular importance is the investment policy at the regional and municipal levels of management that must take into account the prospects of development of the administrative-territorial units with regard to their specific features, be a basis for the development of target-oriented programs, support for the most promising projects. At the territorial level, the administrations of the
constituent territories of the Russian Federation and municipalities are involved in the development and implementation of investment policy [8, 9].

One of the most promising and important mechanisms for increasing efficiency in agriculture is the use of space-based technologies, including the use of Earth remote sensing (ERS). Crops well appear on satellite images, are hidden by nothing, single storey, well decoded both in texture and spectral characteristics.

An inventory of farmland is necessary to conduct for target-oriented investments in the agricultural sector. However, without the use of Earth remote sensing technologies, almost insurmountable difficulties arise in the solution of this task if the traditional system to obtain data on the state of agricultural lands is applied.

Carrying out the accounting, inventory and classification of agricultural lands require availability of special large-scale agricultural plans and maps. Therefore, the high-priority tasks to be solved with the help of Earth remote sensing data in the agrarian sector of the Republic of Tatarstan, is an inventory of agricultural land and creation of special thematic maps. Farmlands and also abandoned, foul, overgrown (including forested) lands are well decoded by the image texture. The large array of archival images can also be of great help. With the help of satellite images, it is easy to identify lands that have become unusable and require significant financial investments to return in turnover.

Currently, the most promising in terms of "price-quality" ratio for the inventory of agricultural land and creation of special cards are the data from the ALOS (Japan) satellite. Sensor PRISM with which the satellite was provided, is intended primarily for mapping. Each of the three lenses of the sensor (for forward, vertically downward and rearward viewing) provides a spatial resolution of 2.5 m. PRISM is characterized not only with high resolution, but also quite wide band of shooting up to 35 km. The most indicative characteristic distinguishing this shooting system among the other similar is the highest positioning accuracy of pictures with using only orbital data, without making any whatsoever land surveys. Using RPC (rational polynomial coefficients) supplied together with the images obtaining a spatial framework with a positioning accuracy better than 10 meters what fully meet the requirements of the agricultural mapping in scale to 1:25 000. The optical system of PRISM is based on the three mirrors, has no chromatic aberration across the field of view, and gives a clear image what is important for decoding and determining the boundaries of various kinds of farmlands and other land. It should be noted that the value of digital images ALOS SC is significantly lower than with
other satellites with the same resolution (for example, SPOT-5 (France) or Cartosat-1 (India)), and the cost of data processing at construction of orthotranslated images to create map products is a small part of the total project cost.

Earth remote sensing techniques play the special role in such a relatively new field of agriculture as a "precision farming", the essence of which is that equal conditions are created for growth and development without violating environmental safety standards for all plants of a certain agricultural land to gain the maximum volume of quality and cheap products from the field. "Precision agriculture" is being implemented through the gradual development of a qualitatively new agricultural technologies on the basis of highly efficient and environmentally friendly technical and agrochemical means. Of paramount importance for the "precision farming" is constant monitoring of the state of vegetation. An important component of the "precision farming" technology is the early detection and localization of sections of the suppressed condition of vegetation within a field what can be caused by different factors: parasitic attack, the dominance of weeds, etc. Earth remote sensing data for rapid response to the situation are indispensable, but they must meet the following conditions:

- Possibility of rapid acquisition and processing;
- High and ultra-high resolution for increasing the accuracy of determination of biophysical parameters of vegetation;
- Availability of multispectral mode to be used when interpreting differences in spectral brightness;
- Sufficiently small intervals of spectra obtaining [10].

2. Materials and Methods

In this study, we have implemented the space-based and geoinformation technologies in the agricultural company "Tan" located in the Cheremshansky district of the Republic of Tatarstan.

The works on creation of vector layers for thematic mapping and information filling of the database on agricultural lands and agrochemical activities of the enterprise.

The purpose of the work was creation and filling the database on agricultural lands and subsequent creation of vector layers for thematic mapping of the territory.

Main goals:

- Study of documentary support for accounting agricultural facilities and agrochemical activities;
- Formation and filling of information guides;
• Creation and filling tables on the attribute-based information on field plots;

• Creation and filling tables on the agrochemical and phytosanitary measures;

• Vectorization of boundaries of field plots on the basis of satellite images;

• Formation of thematic maps for field plots;

• Collection and processing materials, and filling the mapping database;

• Systematization and selection of information required for inclusion into the database; The sources for formation of the database were:
  • The accounting records;
  • Working plans on agricultural works;
  • Programs to improve fertility of the fields;
  • Documentation on the farming and land management system;
  • Results of agrochemical study of soils in regional farms;
  • Land regulation plan;
  • Soil map of the region;
  • Satellite images.

We have developed the special software: geographic information system "Accounting for agricultural lands and agricultural activities" designed to automate the agricultural enterprises management in the crop farming sector. The software is one of the constituent elements of the complex technology of agricultural production based on the use of space-based and geoinformation technologies.

The system allows the automated collection of operational data, monitoring the current status of field plots, operational control for resources, automated processing of agrotechnological data, automated planning and accounting agricultural activities. The basis of the system operation is vector thematic layers with attribute-based information on field plots. The main functions of the system are:

• Maintaining a normative documentation database;

• Accounting the agricultural lands with reference to maps;

• Maintaining agrochemical monitoring of agricultural land;
Planning and accounting actual works.

Maintaining a normative documentation database is carried out by means of the built-in subsystem "List of information guides". All normative information is provided in the form of a tree of directories separated by the following main categories:

- Basic information guides;
- Information guides in composition of soils;
- Normative and reference information about the crops grown;
- Information on fertilizers, crop protection means and chemical reclamation;
- Information guide of the agricultural enterprise;
- Personnel records;
- Normative and reference information on agro-technical measures.

Accounting the agricultural lands and agrochemical monitoring are carried out on the basis of geospatial data binding. Screen navigation tools allows upon selection of a field on the map to view its properties, and vice versa, when viewing the parameters of an agricultural land to assess its placement on the ground. The main functions of the subsystem are as follows:

- Obtaining geometrical parameters of fields and work areas (area, perimeter);
- Calculation of the distances between fields and other objects in the map;
- Maintaining data on agricultural lands based on reference to the crop year;
- Review and analysis of thematic maps for the agrochemical monitoring of fields, cultivated crops, fertilizers applied, crop yields, and so forth.

Planning and accounting actual works allows for unified planning and consideration of mechanized operations, as well as accounting actual works grouped by functional purpose: fertilization, application of plant protection products. The account of the works is carried out on the basis of filling data upon completion of the works.

The system also allows the collection of operational data, visual monitoring of the current state of the work conducted in the agricultural units, operational control of resources, automated data processing, automated planning and accounting agricultural activities.
3. Results

In this study, we have carried out the work on interpretation of satellite images. As a result of this work:

- The boundaries of the farm were determined;
- The exact areas of spatial objects were determined;
- The boundaries and the areas of arable land were determined;
- Grasslands were identified (location, area);
- Water bodies were identified;
- Eroded and degraded lands, and the growth of gullies were revealed;
- Flooding areas were identified;
- Windbreakers were identified.

![Diagram of farmland boundaries](image)

**Fig. 2. Delimitation of farmland boundaries of the enterprise.**

Individual plots of farmland were formed on the basis of the satellite image (Fig. 1). The system automatically counts the area of each plot. Thus, according to updated information, the total area of arable lands was 7 493.46 ha.
Figure 2 shows how the system performs the automatic distribution of agricultural crops by species. Different colors on the map display the following types of crops: peas, buckwheat, corn, alfalfa, oats, wheat, rye, canola, sugar beet, barley.

Figure 3 shows the characteristic of the farm lands by the degree of contamination. Red color identify areas with a high degree of contamination, pink - areas with moderate contamination degree, green and yellow - areas with low levels of contamination.
Figure 4 shows the agrochemical characteristics of arable lands of the enterprise by the degree of phosphorus availability. The red color marks areas on the map with a very low content of phosphorus in the soil, yellow - medium content of phosphorus, green - increased content, and blue - high content of phosphorus. In addition, the system accounts a composition and content of the various microelements in the soil, including potassium, humus, soil acidity level and other characteristics. On the basis of comprehensive information, an agronomist has the ability to make timely decisions on diversification of croplands, and crop rotation planning.

4. Conclusions

The system provides workstations for agronomists and heads of companies, are intended to enter the attribute-based and geometric information in a map, monitoring and management decision making. Initial data for the input data are: Earth remote sensing data, paper based maps, and different reporting documentation. An agronomist enters for each agricultural object the following features data: general data (field data sheet, crop rotation), the agrochemical composition of the soil, phytosanitary conditions (total weed infestation, diseases, pests), the use of protective means. In addition to capabilities of editing attribute and geometric information of objects, there is also the ability to store more information on objects, such as photos, documents. On the basis of such information, an agronomist and a manager have the ability to:
Tatiana V. Bagayeva* et al. / International Journal of Pharmacy & Technology

- farmland state simulation on crop rotation for the next years;
- calculation of an amount of necessary sown plants seeds;
- calculation of a necessary amount of fertilizers in accordance with the algorithm provided by crop rotation and other attribute-based information.

Discussion

Russia, with its vast areas of agricultural lands, is one of the largest fertilizer producers in the world. At the same time, the overall land quality and productivity are significantly inferior to such indicators of advanced agro-industrial countries. Application of innovative technologies at the state level has an important role in reforming and improving the efficiency of agroindustrial complex. Transfer of agricultural production in the private property is able to increase the efficiency of agroindustrial complex, but state control and supervision will become a very urgent task. For example, intensification of agricultural production through the use of chemicals requires strict environmental controls. It is not enough that the farmers themselves evaluated the volume of introduced chemicals and fertilizers being guided only by economic interests. The task of public services is the analysis of the admissibility of using certain means in a given volume on a particular field in terms of impact on the environment. Restrictions can arise from both the environmental concerns and the conservation of the surrounding of protected areas, and because of the danger to contaminate ground and surface water sources supplying water to cities or populated localities. It is possible to identify places with such restrictions using spatial analysis tools mentioned above, and their execution must be monitored by means of space-based and geoinformation technologies. In addition, in order to improve efficiency of the whole agricultural sector the public authorities should create at the expense of the federal budget a dedicated web resource which provide centralized ordering and procurement of satellite images, their preview and use in the local geographic information systems. It is necessary to create an authorized access system to that web resource. Access to the web resource can be seen as an element of subsidy for the most promising agricultural enterprises. This will allow the use of important tools of Earth remote sensing in production activities of small and large farmers without their significant expenses.

Acknowledgements

The work is performed according to the Russian Government Program of Competitive Growth of Kazan Federal University.
References

1. The official website of the Ministry of Economy of the Republic of Tatarstan on the Internet http://mert.tatarstan.ru
2. The official website of the Ministry of Agriculture and Food of the Republic of Tatarstan on the Internet http://agro.tatarstan.ru