

PAPER • OPEN ACCESS

Geoinformation system for monitoring and assessment of agricultural lands condition

To cite this article: M V Panasyuk *et al* 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **579** 012147

View the [article online](#) for updates and enhancements.



The Electrochemical Society
Advancing solid state & electrochemical science & technology

240th ECS Meeting ORLANDO, FL

Orange County Convention Center Oct 10-14, 2021



Abstract submission due: April 9

SUBMIT NOW

Geoinformation system for monitoring and assessment of agricultural lands condition

M V Panasyuk¹, F N Safiollin², V A Sultanov³, A M Sabirzyanov²

¹ Department of Geography and Cartography, Kazan Federal University, Kazan, Russia

² Department of Land Administration and Inventories, Kazan Federal University, Kazan, Russia

³ Department of Technical Physics and Energy, Kazan Federal University, Kazan, Russia

E-mail: VASultanov@kpfu.ru

Abstract. The article is devoted to the analysis of prospects of application of geoinformation systems (GIS), methods and technologies of remote sensing of the Earth for monitoring and assessment of the state of agricultural lands. The article assesses the possibilities of specialized GIS in improving the efficiency of current crop monitoring, implementation of principles and technologies of organic agriculture. The peculiarities of the structure of perspective GIS for assessing the state and monitoring of agricultural lands are considered. The article describes the main tasks and functions of GIS data, notes the importance of an electronic map as the basis for the integration of cartographic, textual, digital and visual information. The work analyzes the geoinformation system of the region's agro-industrial complex being developed in the Republic of Tatarstan. The main directions of its development have been noted, among which special attention has been paid to the use of unmanned aerial vehicles (UAVs) and UAV-technologies, which create opportunities for the operative collection and processing of large volumes of information in the GIS environment for the purpose of solving the tasks of monitoring and assessment of land conditions, which facilitates the transition to the systems of organic and precision agriculture on the basis of a more reasonable formation of directions of application of biological means of plant protection, development of recommendations on the composition of lands, structure of sowing..

1. Introduction

Geographic information systems are complex and functionally diverse software systems that allow, due to built-in software tools, to provide not only the environment for the development and maintenance of databases of spatial data (DSD) and the creation of cartographic images, but also to solve complex problems of spatial and temporal analysis [4, 7]. GIS has great prospects for solving the main tasks of geosystems research, including tasks of analysis and monitoring of their condition [5]. GIS application in the conditions of growing demand for Earth information increases the economic and social efficiency of the projects of territory development and development.

The experience of many countries shows that GIS is increasingly becoming a unifying factor, integrating diverse geographical knowledge, techniques, materials in textual, cartographic and visual forms, including Earth remote sensing information.



Content from this work may be used under the terms of the [Creative Commons Attribution 3.0 licence](https://creativecommons.org/licenses/by/3.0/). Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

The main feature of GIS as a tool for solving analytical and monitoring tasks is the feature of information stored in its databases, which is characterized by a complex combination of cartographic, textual and numerical data, the spatial binding of which determines the special ways of implementation, both general (input, output, search, etc.) and analytical and monitoring functions of GIS, including the functions of spatial analysis, the choice of the optimal variant of management solutions, etc. The main feature of GIS is the fact that it is a tool for solving analytical and monitoring tasks.

Summarizing the existing concepts of GIS as a tool for analysis and monitoring of territories, it should be noted that in this regard they are a repository of knowledge systems (databases and knowledge bases) of geosystems reflecting the processes of interaction between nature and society [1]. GIS is designed to study geosystems, optimize and manage human interaction with the natural environment, and provide geographic information to a wide range of stakeholders [2].

Taking into account not content but technical characteristics, GIS is a system of technological and organizational means by means of which data related to the earth's surface are collected, transferred, stored and processed. It is the medium for creating, operating, transforming, storing and presenting geographic information [1, 3].

GIS as a means of solving analytical and monitoring problems have a number of distinctive features [6]:

- Ensuring the possibility to collect information for a wide range of levels of spatial hierarchy - from the global to localities, locations, settlements, enterprises. Each level defines parameters of spatial GIS databases.
- Multistage iterative process of GIS creation, focused on solving a certain type of analytical and monitoring tasks, including planning, design, implementation and operation of GIS.
- The block principle of GIS structural organization, assuming that its individual components can be created and exist relatively independently.
- The necessity to display not only spatial but also dynamic characteristics of objects, including retrospective restoration of their dynamics.

This allows to draw conclusions about the main promising areas of GIS application in the field of geosystems analysis and monitoring. These include:

- Collection and storage of information on current and previous states of geosystems in cartographic, numerical, text and visual forms. Availability of a developed system of spatial data bases, which reflects the main characteristics and processes of development of geosystems.
- Solution of a wide range of analytical problems based on the possibilities of algorithmization of the process of solution and development of specialized software. Such tasks include, first of all, the tasks of analysis and monitoring of the state of geosystems, forecasting and examination of its development.
- Problems of zoning and geographic classification/grouping by given indicators.
- Analysis of variants of strategic decisions on development of territories and choice of optimum on criteria of efficiency.
- Assessment of possible consequences of anthropogenic impacts on the natural environment.

Thus, GIS provides opportunities for comprehensive analysis and monitoring of the formation and development of territories at different levels of the spatial hierarchy, facilitating the integration of traditional methods of geographic research – descriptive, comparative, statistical, cartographic, etc. with modern algorithmic and mathematical methods of analysis and monitoring.

2. Materials and methods

Modern agricultural production requires an inventory of natural, agricultural, organizational, technological, economic and labor resources, especially when working with land, crop production.

A specific feature of agricultural production is heterogeneity of ecological and biotic conditions, significant differences in the size and morphometric characteristics of fields, their soil cover, fertility and instability of production indicators [14].

In the production of agricultural products, the producer often has to face problems of informational and analytical nature, such as:

- the need to have extensive information about the state of fields and plants;
- necessity to react quickly to unfavorable phenomena in different areas of the farm;
- necessity to perform field work, especially in crop production, in a short time;
- poor availability of technical and labour resources for the enterprise.

All this leads to organizational difficulties and hasty adoption of ineffective decisions, which in turn can lead to negative results (low yields, reduced land fertility, environmental impact, etc.) [13].

The importance of rapid collection and processing of spatial data on the state of agricultural lands, especially in the framework of the transition to precision farming technologies, determines the need to develop and implement specialized GIS projects for the analysis and monitoring of agricultural land. Such GIS should meet rather strict requirements to the efficiency of work in terms of completeness of coverage of the analyzed territory and timely provision of digital and cartographic data, as well as the results of analytical and monitoring tasks.

A GIS for monitoring and assessment of agricultural land should be able to address two main tasks in a timely, real-time manner:

- creation of digital terrain maps integrated with the extensible DSD;
- visualization of digital maps with the possibility of interactive work with them by the user.

It should be able to perform a number of general and specific functions, including:

- processing of remote sensing data obtained using space and UAV technologies [11, 12];
- implementation of modern methods of photogrammetry and cartography, spatial data analysis;
- maintenance of specialized databases of spatial data for analysis and monitoring tasks;
- operative construction and visualization of matrix and vector maps of agricultural lands.

Along with them, one of the main functions of GIS for monitoring and assessment of agricultural land should be included among the main ones:

- storing, controlling and providing consumers with digital information on land condition in coordinates of a given plot;
- creation of digital orthophotoplans;
- linking video footage to digital orthophotoplans;
- creation and display of spatial terrain models;
- analysis and monitoring of agricultural lands on the basis of GIS maps and the results of analytical and monitoring tasks.

Structurally, such GIS is a combination of a hierarchically organized cartographic or topographic base with a complex DSD system that contains systematized and linked to appropriate points in the cartographic images heterogeneous digital data on the state of agricultural land.

The basis for the integration of cartographic, text, digital and visual information of this type of GIS is an electronic map. Vector or raster electronic map, created using GIS software and technical means, is formed in a given map projection, coordinate and height system, conventional signs that transmit the required content. It is intended for displaying attributive (including statistical) data, analysis and modeling, as well as for solving information and calculation tasks.

The GIS electronic data card system has a hierarchical structure. On the lower level, information about individual map objects is stored. Objects can be combined into map groups, layers and sheets. The combination of map sheets of the same scale and view is a separate subsystem of electronic maps. The GIS electronic map system allows storing and processing map images in formats:

- vector maps;

- raster map;
- matrix data.

Different types of data should be processed together or separately. Digital data can be converted to different formats, converted from one view to another, output to different devices, edited, transformed, etc.

3. Proposed System

Complex, information-intensive tasks of assessing the state of agricultural lands in the Republic of Tatarstan, which include the tasks of agricultural production, analysis and monitoring of agro-ecosystems, organizational and technological tasks and tasks of improving agricultural performance based on new technologies have required the development of adequate geoinformation support.

The GIS of the agro-industrial complex of the Republic of Tatarstan (RT), which is a part of the Digital Model of the Republic of Tatarstan, is being introduced in Tatarstan, and provides for the digitalization of all main production sectors (crop, livestock, vegetable), engineering and technical support, economy and management of each agricultural enterprise with the possibility of monitoring the activities of departmental and management bodies. The basic component of this system is field passports [9], which contain information on their natural and economic condition, stored in databases.

In 2017, the boundaries of Tatarstan fields were defined with the help of gadgets (mobile phones). In July 2018, only 57 % of Tatarstan's fields were filled in with passports, and as of September 2019, 95 % of agricultural land, including natural forage land, was passport-land. Basically, there remained those plots where owners have not been identified and where land is not in demand. It is planned to further increase the area of crops in the country to 2.8 million hectares.

1. The data of passportization of fields of agrarian sector will provide:
2. Reduction of control costs on the use of cultivated areas.
3. Identification of crop lesions from natural disasters and epidemics, effective damage assessment.
4. Increasing the efficiency of new agro-industrial complex facilities location and attracting investors by providing full information about the agro-industrial complex infrastructure, land quality and economic characteristics.
5. Increasing the reliability and reducing the cost of economic assessment of agricultural land.
6. Effective assessment of vegetation and biomass condition, forecasting and preliminary yield assessment using space images together with ground-based observations.
7. Risk reduction and information support in crop insurance and damage assessment.

During field passportization it is possible to remotely control the operation of agricultural machinery during its operation. This gives management and specialists of farms a number of additional opportunities, including:

1. Accurately determine the area of cultivated fields, taking into account the types of work performed and the tools used (harrowing, seeding, fertilizing, etc.).
2. To know the speed of different types of works.
3. Improve the quality of field treatment.
4. Fix technique downtime.
5. Cut off illegal driver's trips [10].

Connection of space monitoring services provides the possibility of current control over the state of sowing of cereals, oilseeds, technical, vegetable and other crops, assessment of germination capacity, infestation, degree of ripeness of crops, as well as detection of violations during agro-technical works and identification of adverse environmental phenomena, such as wind, water erosion, drought, etc.

Based on space images processing on spectral analysis and NDVI coefficient for such plant parameters as biomass and leaf index, monitoring of crop condition from sowing to harvesting is carried out, which in its turn enables to estimate yield in advance and determine optimal harvesting terms for these crops [8].

The space land monitoring service was tested in two pilot regions of Tatarstan – Sabinsk and Pestrechinsk.

Among the promising directions of improving the GIS of the agro-industrial complex should be mentioned the expansion of application of technologies for collection, storage and processing of spatial data, obtained through the use of unmanned aerial vehicles (UAVs) [16]. UAV-technologies are especially necessary for surveying hard-to-reach areas, for conducting surveys of separate territories in the general land mass and for determining the state of fields. It should be done in early spring after snow melting from the fields and periodically control changes in vegetation flow. Then it is possible to identify areas subject to soil degradation, low-productive areas of fields where plants are underdeveloped, such as winter crops after overwintering, monitor plant growth and development, infestation of diseases and pests, contamination of fields in the total area of cereals and industrial crops, and it is also possible to determine the technological properties of fields and natural forage lands (Figure 1).

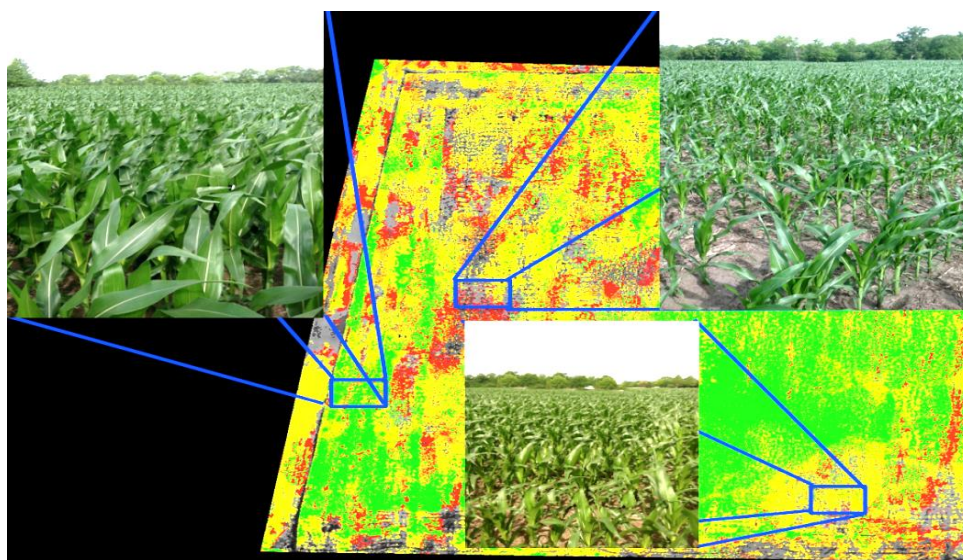


Figure 1. Abstract model of the city-planning formation of the districts near the railway station

The technological properties of agricultural lands monitored by UAV technologies include: energy and stony soils, the contour of working areas, their relief and remoteness from the economic center. All these parameters influence the amount of costs during cultivation. In particular, the energy intensity of soils is directly proportional to fuel consumption and inversely proportional to the performance of machinery and tractor units during the main soil tillage. The higher the stoniness index, the higher the evaluation coefficient and, consequently, the lower the productivity of the field mechanized works. The terrain and the contour of the land plots, which characterizes the complexity of the configuration and the ruggedness of the area borders, in the aggregate determine its favorability for the field mechanized works.

The location (remoteness) of fields (work areas) relative to business centers or field mills also has a significant impact on agricultural land valuation indicators. The volume of intra-farm transportation of seeds, fertilizers, cultivated products makes up more than half of the total volume of transportation of the farm, which significantly affects the amount of total costs and production costs.

An important direction of improving the GIS of the agro-industrial complex of Tajikistan is to support methods and technologies of precision and organic farming, cultivation technologies for crops suitable for environmentally safe products. Creation in the region and individual farms of spatial databases for precision and organic farming based on remote sensing and GIS-technologies allow to expand and control the application of biological factors to increase soil fertility, as well as to

optimize the system of soil tillage, crop care and spot application of modern organic-mineral fertilizers, bio-preparations, growth stimulants, which allows to predict and plan the yield of crops.

The use of UAV technology to create databases on the state of the fields of farms should be based on the creation of a network of UAVs with integrated equipment, with which you can obtain information about individual plots and transfer it to the server GIS Situation Center (SO). Complex UAV attachments, including a high-resolution camera with a spectrometer, air analyzer and robotic sampler equipped with sensors, will allow for the rapid collection and transmission of information on the state of the fields (picture 2).

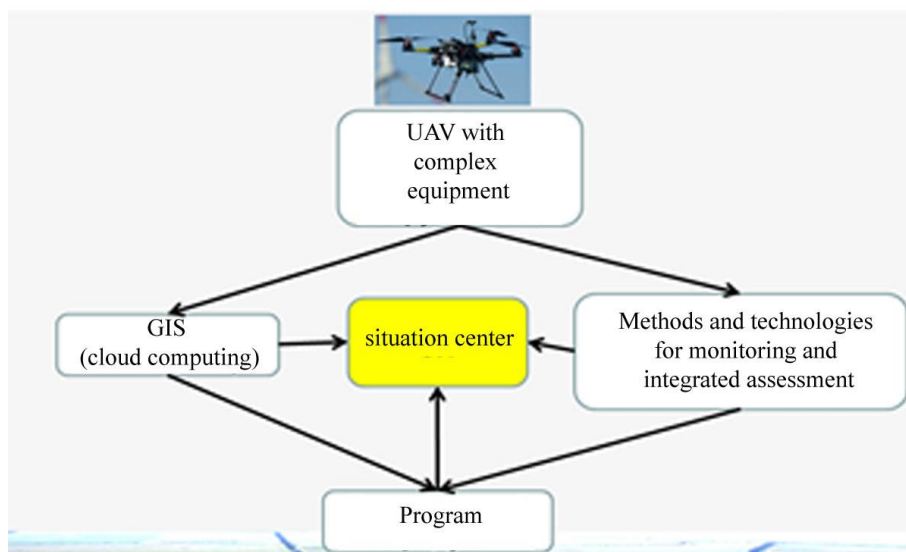


Figure 2. UAV in the system of the situation center of the agricultural sector of the region

4. Results and Discussion

Creation of specialized GIS for monitoring and assessment of agricultural lands in the region allows to increase the efficiency of agricultural land use, assess their condition, create the basis for the introduction of accurate and organic farming technologies through rapid data collection and processing. The GIS also makes it possible to promptly, in real time mode, solve the tasks of creating and visualizing digital maps integrated with the extensible DSD by implementing a number of special functions, including: processing of remote sensing data obtained from the use of space or UAV technologies; maintenance of databases of spatial data for analytical and monitoring tasks; implementation of modern methods of photogrammetry and cartography, spatial data analysis.

Within the framework of the creation of spatial databases of this type of GIS, the use of remote sensing methods and technologies should be expanded. The most promising in this regard is the use of UAV technologies. The development of methods for the integrated assessment of remote sensing data makes it possible to control and assess the use of agricultural land on the basis of various parameters in dynamics over a number of years. It promotes the transition to organic and precision agriculture on the basis of a more reasonable formation of directions of application of biological means of plant protection, development of recommendations on the composition of lands, structure of sown areas, their correct alternation in crop rotations and agricultural techniques of cultivation of crops.

5. Conclusion

Development of specialized software product on analysis and monitoring of agricultural lands, expanding the standard functions of GIS, should provide computer implementation of methods and technologies of information collection and processing on the basis of remote sensing technologies,

allowing to quickly get scientifically grounded recommendations on the use of agrotechnical and agrobiological methods and transition to precision and organic farming.

6. Acknowledgement

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

References

- [1] Vatlina T V, Evdokimov S P, Koshkarev A V, Putrenko V V, Tikunov V V 2012 International conference “InterCarto-INTERGIS-18” Sustainable development of territories: GIS theory and practical experience *Geodesy and cartography* **10**, pp. 60–63.
- [2] Ginis L A, Gordienko L V, Levonyuk S V 2017 Development of a conceptual problem-oriented metamodel of imaginative representation of a complex system based on a geoinformation system *Engineering Journal of Don* **1**(44) pp. 43.
- [3] Zhenibekova A B 2014 On the issue of formalization of cartographic images *Bulletin of Siberian state University of geosystems and technologies* **4**(28) pp. 124–128.
- [4] Lomedchikov N N 2001 Cartography of the XXI century: theory, methods, practice *Reports of the II all-Russian scientific conference on cartography dedicated to the memory of Alexander Lyutoy* (vol. 1).
- [5] Kremers X, Popkova L I, Solnceva O I, Tikunov V S, Torres M 2013 Development of a conceptual problem-oriented metamodel of imaginative representation of a complex system based on a geoinformation system *Geodesy and cartography* **5** pp. 47–54.
- [6] Mukhina A E 2018 Geographic information systems-part of decision support systems *Information technologies in education. materials of the X all-Russian scientific and practical conference* (pp. 263–266).
- [7] Mandryk O M, Arkhypova L M, Pukish A V, Zelmanovych A, Yakovlyuk Kh 2016 Theoretical and methodological foundations of sustainable development of Geosystems *IOP Conference Series: Materials Science and Engineering* **200** 012018.
- [8] Sabirzyanov A M 2015 Application of remote sensing for crop yield forecasting (on the example of Nurlat municipal district of the Republic of Tatarstan) *Land management, land monitoring and cadaster* **4**(124) pp. 36–39.
- [9] Tikhonchuk P V, Zakharova E B, Stolyarov A S 2009 Creation of information system of certification of fields of the agricultural enterprise *Achievements of Science and Technology of AIC* **11** pp. 42–45.
- [10] Chekmarev P A, Sorokin I B, Kataev M Yu 2017 Agroecological condition of arable lands of Tomsk region and prospects of application of methods of remote sensing of the Earth *Agriculture* **5** pp. 8–10.
- [11] Lanya I, Subadiyasa N, Sardiana K, Ratna Adi G 2019 Remote sensing and GIS applications for planning of sustainable food agriculture land and agricultural commodity development in Denpasar city *IOP Conference Series: Earth and Environmental Science* **313**(1).
- [12] Memon M S, Jun Z, Sun C, Jiang C, Hu Q et al. 2019 Assessment of wheat straw cover and yield performance in a rice-wheat cropping system by using Landsat satellite data *Sustainability* **11**(19). DOI: 10.3390/su11195369
- [13] Neswati R, Baja S, Ramlan A, Arif S 2019 Using GIS for integrated assessment of agriculture land suitability and food security in small islands *IOP Conference Series: Earth and Environmental Science* **279**(1).
- [14] Seyedmohammadi J, Sarmadian F, Jafarzadeh A A, McDowell R W 2019 Development of a model using matter element, AHP and GIS techniques to assess the suitability of land for agriculture *Geoderma* **352** pp. 80–85.