ATLANTIS PRESS
Advances in Intelligent Systems Research, volume 167
International Scientific and Practical Conference "Digitization of Agriculture - Development Strategy" (ISPC 2019)

The Implementation and Effectiveness of geographic information systems and Location Intelligence technology in digital agriculture

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***Abstract*—A significant change associated with the implementation of information technology occur in the period of digitalization of economic processes in the Russian Federation in all areas of activity. In particular, agriculture is one of the most extensive areas in our country. This article discusses the tools to accelerate the digitization of agriculture - geographic information systems (GIS). An analysis of existing GIS in the context of agriculture, their capabilities, scope of application, functions is proposed. Trends in the development of global geographic information systems with a powerful analysis apparatus based on the collected data and visualization of results have been identified. The article establishes a shortage of specialized products to solve specific problems of the industry that do not require the study of a complex GIS apparatus, and an underestimation of the possibilities for the operational analysis of digital photographs. The prospects for the development of specialized geographic information systems are considered. The development of a GIS based on continuous monitoring of territories using quadrocopters, which will build an up-to-date map with the results of analyzing new data, identifying the areas of intervention required, for example, lack of fertilizer, watering, or fire identification is proposed.**

Keywords — location intelligence, geographic information system, digital image, geodata, agriculture.

I. Introduction

The question of possibilities for optimizing agriculture (increasing and improving harvest) is relevant in connection with the development of opportunities and usability of geographic information systems (GIS) and in the context of global problems of overpopulation and forecasts of a reduction in food resources [1]. GIS is of particular value for the development of precision agriculture [2]. This provides greater flexibility for specialists in developing efficient farming systems and opportunities to optimize and automate planting processes, monitor the necessary data for analysis, predict and identify iteration deficiencies to prevent further repetition of the mistakes.

The new development of geographic information systems is due to the proliferation and improvement of technologies for creating and processing digital images, the availability of high-quality maps, such as Google Maps, data transfer speed via the Internet, the development of Internet technologies and the mobility of personal computers.

The main directions of development in modern GIS are: visualization of geodata, creating maps based on existing ones, storing results in cloud storages and access via the Internet from tablets, computers, and smartphones. The cross-platform format is one of the important features of modern GIS. The development of the technologies described above creates favorable conditions for optimizing agriculture, including the development of precision agriculture. However, there is a shortage of specialized products to solve specific problems of the industry that do not require studying complex GIS and underestimating the possibilities of operational analysis of digital photographs, especially given the development of unmanned aircraft.

II. Material and Methods

The purpose of GIS is the input, storage, processing, and display of geospatial information on user request. Thus, GIS is integrated: with information collection systems; with information storage systems; with information processing systems, with information display systems.

There are various classification methods

GIS (Fig. 1).

According to the problem orientation, the following GIS can be distinguished [3]:

1. Universal geographical (Complex or multi-purpose) to solve common problems. These are integrated GIS uniting systems of digital image processing with GIS functionality for modeling and multivariate data analysis in a single integrated environment. Such systems are used in the areas of regional management and planning.

2. Sectoral (thematic), which solve the problem of optimal mutual location and determining the location, distribution of objects and resources, classification and division into areas of territories, choosing the optimal route, inventory resources, analysis, evaluation, monitoring, management and planning, decision-making support.

3. Specialized, the subject of consideration of which may be the subsoil, environmental management, ecology, transport, communications, socio-economic indicators, political science, urban economy.

4. Information and referral, for reference, tourist, educational purposes.

5. Inventory, cadastral - for accounting and management of land, forest, water, environmental and other types of cadastre, as well as municipal management systems.

6. GIS for making management decisions - to obtain operational data in the decision-making process.

7. GIS for managing processes and systems - help quickly manage resources, plan work of transport, communication, etc.

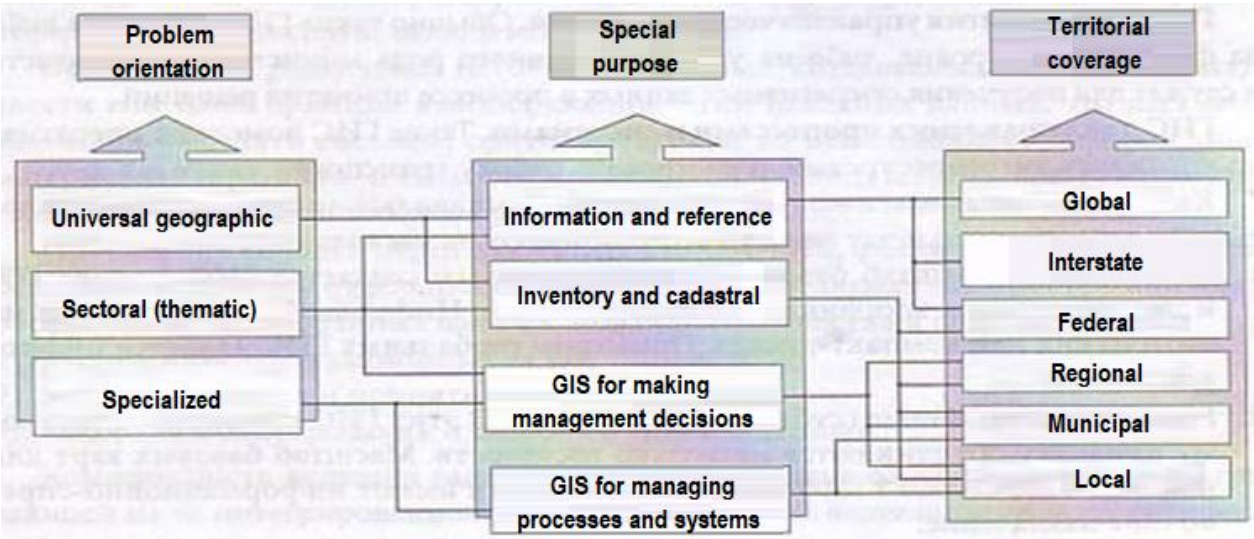

Fig. 1. GIS Classification

The mathematical basis of GIS is usually made up of topographic maps.

The territorial coverage of GIS is divided into several levels:

1. Global, the scale of base maps on the basis of which a GIS is created is 1: 4,000,000 and smaller, the coordinate system is geographical.

2. Interstate (subcontinental). The union of several states on a territorial basis. The scale is from 1: 4,000,000 to 1: 200,000. In general, it has informational and reference character.

3. Federal (national, state). Scale from 1: 4,000,000 to 1: 1,000,000.

4. Regional and subregional. A GIS based on topographic and cartographic data. Scale 1: 100,000 and 1: 200,000.

8. Municipal. Scale 1: 10,000 and 1: 25,000.

9. Local. Scales 1: 10,000 and large.

Functions and GIS are defined in the process of creation. The emphasis on the function determines the configuration of the GIS. Various aspects of using GIS can be reduced to the following groups of GIS functions: collecting, coding and entering information, forming a digital representation of spatial objects and phenomena; editing, updating, effective data preservation, reorganization into various forms, control of the accuracy and quality of data, support of the system at the current level; receiving information - in the primary and generalized form (including generalized, total and average) and in the form of results of analysis, modeling and integration of various kinds of information.

Today there are many software implementations of GIS: CMaps Analytics by Centigon Solutions, Maptitude by Caliper, Map Business Online by MapBussinessOnline.com. Special attention is given to ArcGIS by ESRI, which was established in 1999 and occupies leading places to this day.

III. Results and Discussion

The term Location Intelligence is widely used. This term refers to the process of obtaining meaningful data for solving specific problems from geospatial data and their interconnections. This is the main goal of modern GIS.

CMaps Analytics (from the American company Centigon Solutions) [5] is a system positioning itself as a convenient visualization tool based on popular and accessible electronic maps Google Maps. The main purpose of the product is to create an affordable and simple Location Intelligence. This means using multi-layered visualizations based on chronological or different types of data for better perception and subsequent analysis.

The system is a web service that allows to work with constructed maps on other systems, such as ArcGIS. The main characteristic of the software package is a large number of applications and extensions for various products depending on the needs, and convenient access from any device via the browser interface wherever there is the Internet.

It is proposed to use Quantum GIS - an open source system for more typical tasks. A special plugin (extension) is developed by the company for this. Quantum GIS [6] is an open source graphical information system distributed under the GNU General Public License. This project is the Open Source Geospatial Foundation (OSGeo), which runs on Linux, Unix, Mac OSX, Windows Android, supports a large number of vector and raster formats, databases, and has extensive capabilities for analyzing and presenting geospatial data.

The system supports the ability to add modules (plug-ins) to extend the functionality. The program can be used as a graphical shell with extensive integration capabilities to implement the necessary transformations.

ArcGIS (from the American company ESRI) [6] is one of the most up-to-date geoinformation solutions, which clearly reflects the general trend in the development of GIS systems. ArcGIS is a complex software application. It makes it possible to transform raw data using advanced analysis and highly specialized applications. It helps integrate all types of environmental data and apply sophisticated analytical methods. Results are presented in the form of maps and graphs.

Geoprocessing includes a large number of tools for solving GIS problems, for example, simple buffer construction and polygon overlays to complex regression analysis and image classification.

The processing of geospatial data is based on general principles of transformation. A standard processing tool implements a set of information operations and creates a new set as a result.

Special attention should be paid to specialized methods for the analysis of sown areas that are relevant for use in strict farming:

Soil analysis. Determining the quantity of nutrients in the soil to determine the need for fertilizers.

Productivity. Detailed information is collected during the harvest. This is important data to determine the seeding rate and fertilizer for the soil, and helps to monitor the results and determine the historically productive areas.

Historically productive areas. Image zones retaining trends to higher yields compared to others.

Recommendations. Recommendations for soil amendment are determined based on many factors. Such as nutrients, targets, type of the previous crop, previous harvest.

Tracking testing at selected sites.

The system is designed for a huge number of applications with a huge arsenal of data visualization and analysis of input data. The set of methods for working with a raster image is small and is represented by the Spatial Analyst module (Fig. 2). Basically, operations with two rasters are presented.

According to current trends, the system provides cloud storage and applications for PC, mobile devices, and web client.

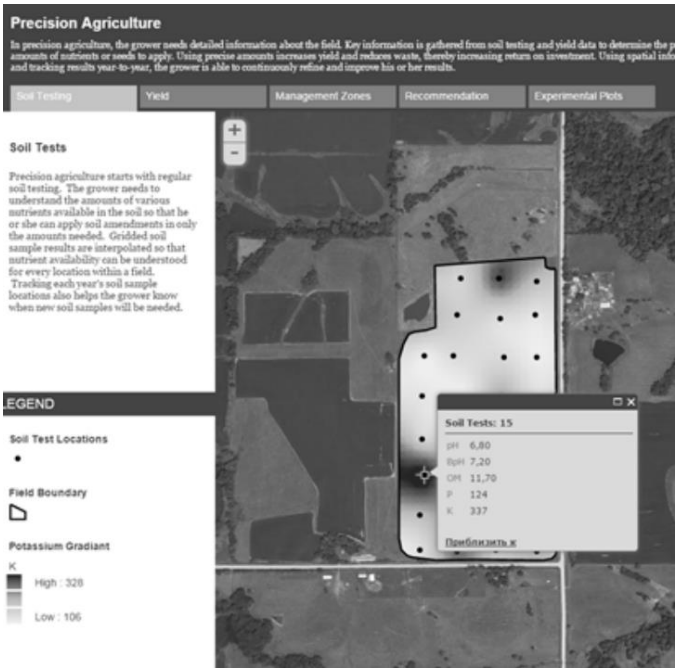

Fig. 2. Quantum GIS Interface with specialized methods for precision agriculture

ArcGIS is a complete platform for visualizing, analyzing, and conveniently storing and distributing data based on the data collected. This is quite a complex tool with a huge load of various possibilities, including the use of many additional modules.

DIVA-GIS is another open source system that Robert Hijmans [8] worked on the latest versions. The main purpose of the development is to create a freely distributed system for studying the distribution of biodiversity. The launch of GIS was supported by several CGIAR institutes, such as the Bioversity International, the International Potato Center, the International Rice Research Institute, and the University of California, Berkeley, the Museum of Vertebrate Zoology, and others.

The overall impression of the program coincides with the impression of working with QGIS. The program focuses on working with the collected data, but there are no image processing methods. There are opportunities to work with layers, popular geodata formats, histogram construction, regression, modeling, etc. [9].

Developers provide documentation, training materials, and training data. The system makes the impression is not very

clear and takes time to learn for a new user. An experienced GIS user takes significantly less time to learn, but there is a need to know basic information.

IV. Conclusion

Today GIS has a wide range of applications, there are trends to the development of universal systems. Systems solve the maximum range of tasks, which leads to overloading and the need to study individual software solutions for effective use. The main features of the systems are cross-platform, availability of web services, applications for various operating systems with specialized methods for precise agriculture, integration with databases, a wide range of data types, supported by the system and a powerful visualization tool.

The features of the systems also include easy access to the maps through the use of the capabilities of the Internet and cloud storage. Insufficient attention to digital raster image processing capabilities is perceptible, despite the development of unmanned aerial vehicles (UAVs) to form a preliminary assessment, to identify areas of greatest risk that require attention from specialists. A preliminary assessment of the cultivated area based on the analysis of digital images can facilitate decision making and improve the speed of response to any changes in crop production processes. This will especially help in a situation of insufficient quantities of data ready for analysis after collecting soil analyzes and the lack of historical data or a change in seed culture.

It may be advisable to develop a geographic information system based on continuous monitoring of territories using UAVs, which will build the actual map with the results of the analysis of new data. Thus, by defining the areas of intervention needed, for example, lack of fertilizer, watering, or fire identification, a list of problems is formed with possible solutions to them in order of priority.

Such a system can be automated with the use of equipment Global Positioning System (GPS), which can be sent to the place of necessary intervention with GIS data on the coordinates of the target.

Therefore, prompt intervention or prevention of problems based on the analysis of digital data from aerial photography can provide a significant increase in the efficiency of farming. This is relevant in the world and especially in Russia, where the prospects for the development of agriculture are determined by the fertility and high quality of the soil.

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