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Geospatial database for digitalization of agriculture of the Krasnoyarsk territory

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Abstract. The experience of implementation of GIS and web technologies for regional agriculture of the Krasnoyarsk territory is considered. The experimental agricultural enterprise "Minino", located near the city of Krasnoyarsk, was chosen as a pilot project. For this agricultural enterprise, the comprehensive digital model using geographic information systems, remote sensing and web mapping data processing techniques and software is created. A geospatial database, which contains relevant and archival information about agricultural fields, varieties, crops, soil, particle size distribution, soil-forming rocks, terrain features, has been developed. A series of technological digital maps and cartograms have been created in which information on crop rotations and cultivated crops is concentrated. Archives of available multispectral satellite data of high spatial resolution on the considered territory are analyzed. As a result, a multi-layer electronic map of the agricultural enterprise was created, which contains all available information and can be used for modeling and forecasting crop yields, agricultural planning. The developed methods and software and technological solutions can become a methodological basis for a new generation of information and analytical systems and technologies to support management decisions in the agricultural sector.

1. Introduction

Currently, there are many technical and technological possibilities for the creation of remote agricultural monitoring systems at the regional level. Recent achievements in the field of information technology, the development of the Internet, the growing capabilities of new smartphones and other mobile devices, quantitative and qualitative changes in the availability of remote sensing data and various public mapping services have formed a new view on solving the problems of information technology support of the system of agriculture. New opportunities are associated with the operational processing, structuring and analysis of information on agricultural land, its use for economic evaluation and improvement of production efficiency. The use of the terminology "digitalization of agriculture" is becoming increasingly popular. The basis of modern agricultural monitoring systems are now geographic information systems and geospatial information in the form of spatial databases, technologies and methods of remote sensing data processing, cartographic web applications and services [1, 2]. On this basis, applied developments for precision farming systems are being created, ecological forecasts of soil degradation development with intensive agricultural use are being compiled, soil and soil cover protection projects are being implemented, and a digital database for system support of decisions in the agro-industrial complex is being formed.

The fundamental basis for the development of agricultural production in the Krasnoyarsk region is the system of agriculture on a landscape basis. The collection of all initial information related to agricultural activities in the study area, with its subsequent systematization and ordering in the form of a geospatial database is the most important first step in the implementation of the work, the basis for agricultural monitoring. The principle of multivariate schemes is the basis of the method of formation of digital technological maps based on geographic information systems [3].

First of all, it is necessary to assess the natural resource potential of the main typical agricultural landscapes of the Krasnoyarsk territory using the data of ground observations and remote sensing. On this basis, mathematical predictive models of crop yields should be built, taking into account the possible risks caused by weather anomalies, the development of diseases, pests and weeds [4].

The next step is to create digital maps of specific land use fields and individual fields based on land cadastre, land monitoring and remote sensing data. The creation of digital maps allows us to enter tabular information on land use and individual fields, to form the basis for land inventory. This information will form the basis for the assessment and planning of production, will determine the fallow and unused land, with a view to their subsequent use in agricultural turnover, to assess the landscape characteristics of the territory [5].

Then, based on the formed digital field map it is necessary to create a series of technological maps (cartograms). They should be provided information about the crop rotation, cultivated crops, soil cover, soil properties (humus content, granulometric composition, pH, supply of phosphorus, potassium and trace elements, the degree of manifestation of erosion and deflation), the original of the phytosanitary condition of the soil, environmental load, etc. The analysis of this cartographic material makes it possible to assess the state of the land and the level of soil fertility, to determine the need for seeds, fertilizers, plant protection products, machinery and fuels and lubricants.

Another important auxiliary source of information is operational digital maps of the area, formed according to remote sensing. They provide the ability to quickly assess the different characteristics of steam fields and winter crops, complementing the above technological maps. According to the remote sensing data, the zones of plant damage by various pests and diseases are determined; the yield of agricultural crops based on the analysis of the time dynamics of changes in vegetation indices is predicted [6].

The aim of the work is to develop the scientific foundations, technologies and methods of digitalization of the system of agriculture of the Krasnoyarsk territory, the creation of a geospatial database with information on the experimental agricultural enterprise (EAE) "Minino" as a pilot project for the digitalization of the entire regional system of agriculture. Geographic information systems and web technologies are considered as a software-technological, information-technical basis [7].

The following tasks in the formation of the geospatial database were solved: 1) inventory and systematization of all known and available geographical spatial data on the subject; 2) development of a digital map of land use based on remote sensing and ground-based monitoring; 3) design and creation of a geospatial database containing tabular information on the main technological operations (stages of tillage, data on fertilization, plant protection from weeds, pests and diseases, information on sowing and harvesting); 4) formation of a digital integrated agriculture system of EAE "Minino", to solve various management problems.

2. Materials and methods

EAE “Minino” is the basic test range of the Krasnoyarsk Research Institute of Agriculture of Russian Academy of Sciences, located in the Emelyanovsky district of the Krasnoyarsk territory, in close proximity to the city of Krasnoyarsk. Details about this agricultural enterprise are presented in [8].

All the initial tabular, graphical and cartographic information in the course of the work was systematized and ordered, converted into a standard format with the help of geographic information systems (GIS) software. In addition, a series of thematic maps on satellite images to the study area was prepared. A geospatial database containing all the information received was created. Based on many years of experience in the field of web GIS technologies, a user interface to this geospatial database was developed [9]. The advantage of this approach is that access to the results can be provided to interested users from any computer on the Internet through a regular web browser; any additional programs and special training of users is not required.

Figure 1 shows the EAE “Minino” web GIS user interface. The legend (left part of the image) includes visualization of thematic layers of geospatial data (maps) of the system, such as "Fields" (their numbers are indicated) and "Soil-forming rocks" (thematic color coloring). By clicking the mouse, an information window is opened (top right) with the characteristics of the field selected by the user ("Soil names", "Granulometric composition", "Soil types", and so on.

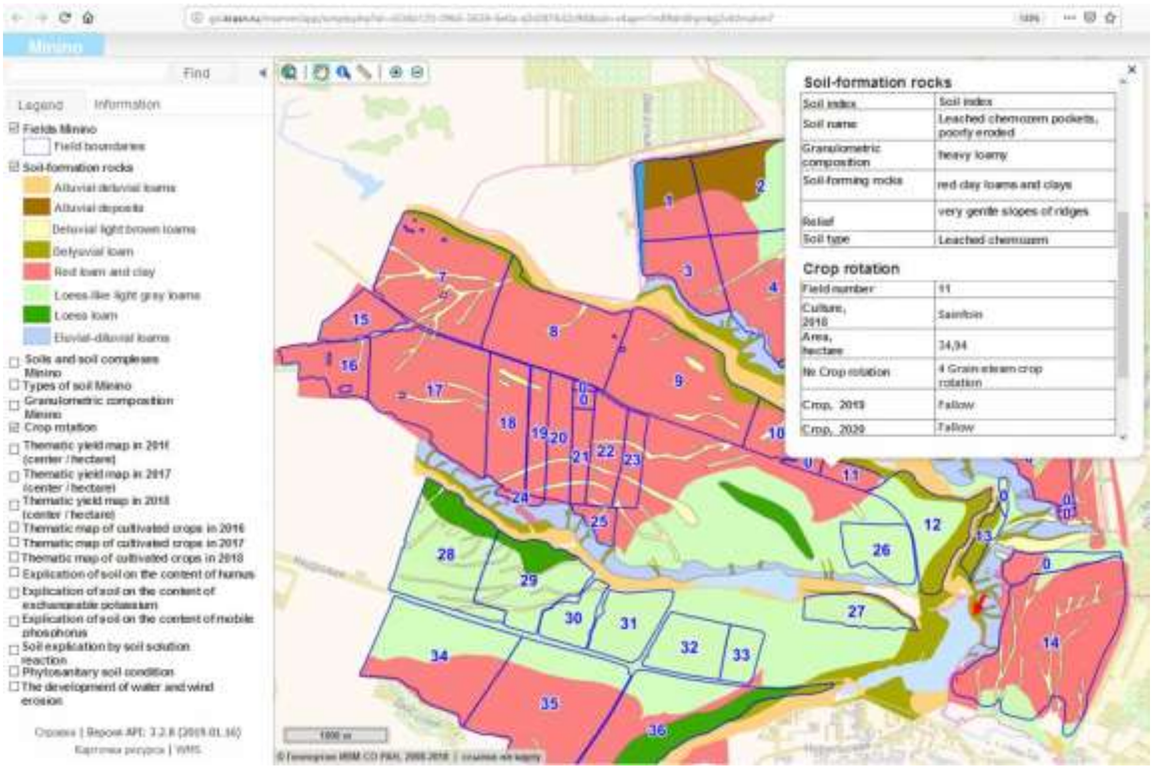

Figure 1. EAE “Minino” web GIS user interface.

3. Results and discussion

Modern methods of digital cartography provide opportunities to expand and systematize information about the soil cover, to analysis of the relationship of various factors of soil formation. They determine the technical basis for solving the actual problems of inventory of soil maps and data on soil sections, information on soil-geographical contours [10]. Modern technologies help to solve the problems associated with significant differences in the methods of classification in different years, used in soil studies and soil sections, in the formation of legends of the maps.

The use of geographic information systems ensures the formation and implementation in practice of common terminology, taxonomic basis of soil-geographical contours, soil sections.

The basis of the geospatial database of EAE “Minino” is a detailed soil map, which was transformed into a set of vector layers [10]. The following thematic geospatial data layers were created: soil selection, conditions of occurrence on the relief, granulometric composition of soils and soil-forming rocks.

The results of the digitization of the soil map were clarified by the actual satellite images, as now part of the territory has changed greatly. In particular, in recent years, the development of Minino village has increased, a new agricultural infrastructure has been built, fallow lands have appeared, the area of arable land has been reduced (figure 2).

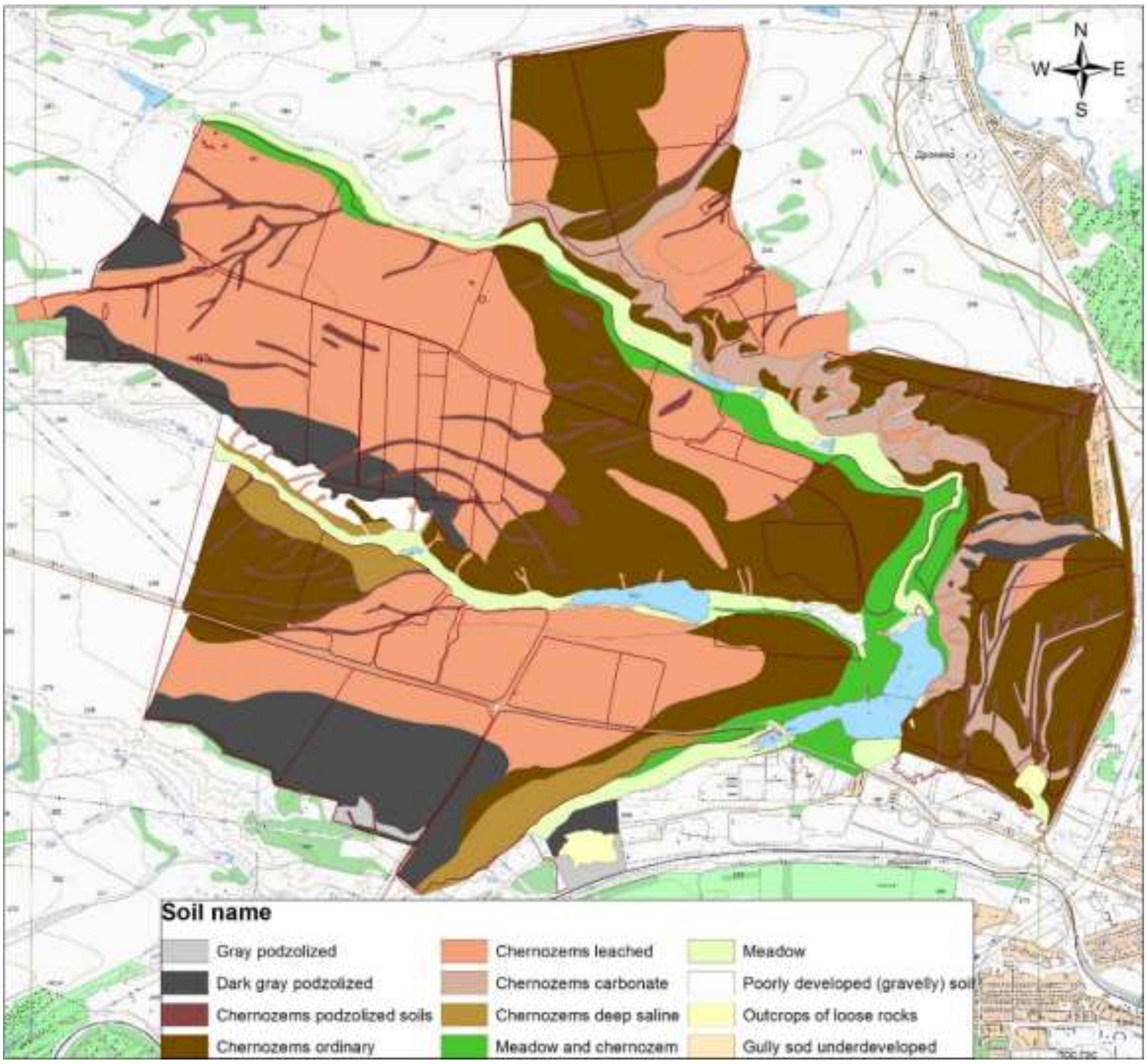

Figure 2. Digital soil map of EAE “Minino”.

The creation of a series of technological, digital maps (cartograms) was the next step in the formation of the geospatial database of the digital system. The following data have been prepared: information on soil properties (humus content, particle size distribution, pH, availability of mobile nitrogen, phosphorus, potassium and trace elements, the degree of manifestation of water and wind erosion); the phytosanitary condition of the soil; information on crop rotations and cultivated crops; forecast of crop yields.

Crop yield forecasting was carried out on the basis of NDVI vegetation index clustering. NDVI is a dimensionless indicator of the reflectivity of vegetation, which characterizes the activity of vegetation, correlating with the content of chlorophyll, leaf area, plant coating. It determines the absorption of photosynthetically active radiation and as a consequence the biomass of plants. The dependence between crop yields and NDVI was revealed. These data provide an opportunity to analyze the uneven yield of crops within the study area, depending on soil, agro ecological and meteorological conditions, form the basis for the transition to precision farming [11].

As is known, the main element of precision farming technology is the introduction of reasonably differentiated doses of fertilizers and plant protection products in accordance with the diversity of the soil cover, the current state of crops and limiting factors of fertility.

In accordance with the system of agriculture of EAE “Minino”, natural resource potential of the agricultural enterprise allows to produce 1,500 tons of seeds of grain crops of higher reproductions per year. Farming system scheme seed crops, organizational-economic, agro-technical, soil protection measures.

Due to the high erosion danger of the territory of this land ownership, it was necessary to develop five 4-field crop rotations, including annual and perennial (including green manure) crops (figure 3).

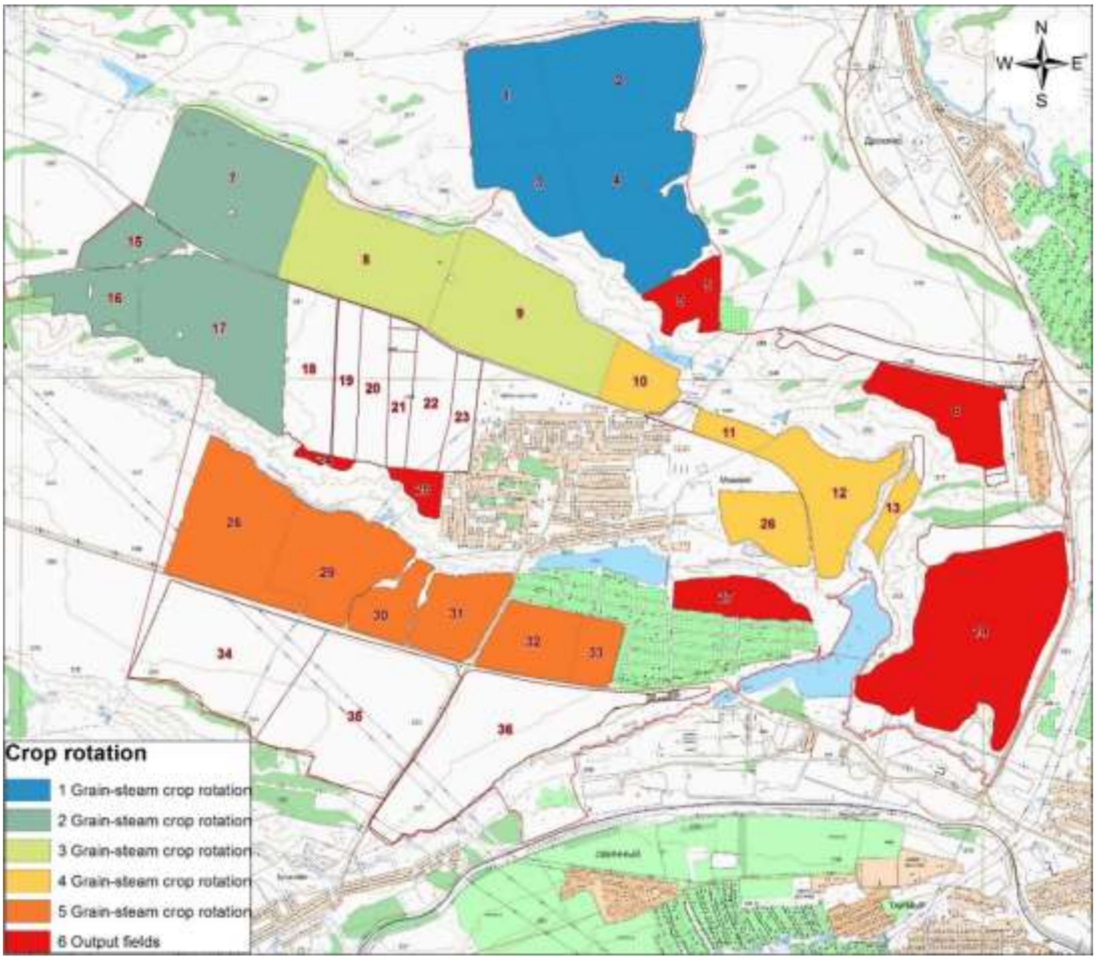

Figure 3. Digital map of EAE “Minino” crop rotations.

The structure of crop rotations is adjusted depending on market conditions, phytosanitary situation, organizational and technical capabilities. Placement of field crop rotations is presented in digital format, indicating crop rotations, field area, and alternation of crops and varieties by year.

The development of special software based on the technologies of geoinformation web systems was an important part of the work. Geoportal services provide the ability to visualize data in two ways – in a normal web browser and on the basis of standard web mapping services. Each of these two options has its own advantages. In the 1st case, there is no need to use any additional programs. Standard web browser is sufficient for interactive viewing of pre-prepared thematic maps. Any user can work with such data, any user training is not required. In the 2nd case, it is assumed to use specialized GIS software, such as MapInfo, QGIS, ArcGIS, etc. In this case, special training of users is assumed. The user can connect to the map data located on the geoportal using GIS software on the computer, perform a joint

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analysis of information with their own data. Geoportal spatial data can be edited, deleted or created depending on user permissions.

4. Conclusions

Modern GIS technologies are an effective tool that allows to present the results of agricultural monitoring through the cartographic interface on the web.

A series of technological digital maps on the content of humus, particle size distribution, pH, availability of mobile phosphorus, potassium, trace elements, crop rotation and cultivated crops was prepared on the basis of satellite images of EAE “Minino”, ground monitoring data, soil materials, agrochemical, environmental and toxicological surveys using QGIS geographic information system.

The developed cartographic website organizes access to the formed geospatial database via the Internet, which contributes to the introduction of the technologies among a wide range of users, the development of digitalization of the farming system of the Krasnoyarsk territory.

In addition to the technological maps, the technologies of working with operational satellite data are proposed. The created satellite auxiliary digital maps allow to estimate on-line the condition of steam fields, winter crops, to reveal the zones of damage of crops by diseases and pests, and by means of vegetation indices to predict the level of crop yields.

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