Geoinformation technologies in land management projects on the agro-landscape basis

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Abstract. At present, the issue of fundamental change in the formation of agronomic solutions through the introduction of ecologically balanced farming systems with the large-scale application of modern technologies is quite relevant. Modern GIS technologies serve an important element in the development of land management projects on an adaptive landscape basis. A geographic information model was developed for the creation of land management projects for agricultural enterprises, and an adaptive land management project for specific land use was improved.

1. Introduction
Objective information on the size and condition of farmland is required to manage any agricultural enterprise producing crop production. A large amount of spatial and attributive information may be qualitatively processed and analyzed only using special software that takes into account both spatial reference and special field information.

The most effective mechanism for the formation of sustainable land use is the development and implementation of projects for the rational use of land of agricultural enterprises on an environmental-landscape basis in conjunction with adaptive-landscape systems of agriculture [1].

The rationalization of land use is based on an agro-landscape approach, which may be implemented using a landscape-ecological information base. It is possible to create such a base tied to digital maps using geoinformation technologies. They provide an opportunity to analyze the vast spatial and thematic information bases necessary for the transition to adaptive landscape agriculture.

The mapping materials available in a farm may be conditionally divided into three groups: land management, soil, and agrochemical. Land management materials are presented either by plans for internal land management of the Soviet period, or by modern cadastral plans. Soil materials include soil maps most often compiled 20-30 years ago and maps of agro-industrial soil groupings. But in reality, both are absent in most farms. Agrochemical materials are represented by agrochemical cartograms (content of humus, mobile phosphorus, mobile potassium, pH) of various periods.

The lack of reliable information on the state of the fields does not allow making a verified decision on the main cultivated crop and the agricultural technology for its cultivation. The task of intra-farm land management is to create, through the correct placement of land and means of production, an economically feasible combination of natural and economic factors that ensure minimum costs for the production of a particular product. The effect of these factors should be such that environmental conditions are observed on an equal basis with economic factor. Successful solution of this task is impossible without geoinformation modeling.
Through the creation and implementation of GIS, environmental monitoring of the terrain is greatly facilitated and the management of natural resources is streamlined. Using the simulation function, it is possible to detect problems and proactively prevent them from increasing in the future. Geoinformation systems allow determining the relationship of concerned parameters (for example, climate and soils) and drawing a conclusion on the state of the area.

GIS takes into account the location and area of objects in detail. Complex analysis carried out by the system on the basis of several factors allows obtaining the most accurate and objective assessment of the territory with respect to specified parameters [2]. GIS technologies are a necessary component in adaptive landscape systems of agriculture, which allow improving the yield and quality of products, optimizing the application of fertilizers, plant protection tools, harvesting operations, as well as more effectively organizing the use of equipment and preserving the history of applied methods and results [3]. The design of adaptive landscape systems of agriculture implies that the geoinformation systems provide all the necessary information for design solutions on the placement of crops, differentiation of their cultivation technologies at various levels of production intensification, territory taking into account landscape bonds, i.e. the development of agricultural systems [4, 5].

Land planning based on geoinformation technologies should promote the rational use and environmental orientation of the land management project of the agricultural enterprise taking into account all factors affecting spatial, quantitative and qualitative indicators of soil cover at all stages of the study. Among the various properties of land as a natural resource and a means of production, land management science identifies those that have a permanent influence on agricultural or other production, not eliminated by artificial methods in a global sense and determine the land planning nature. First of all, these include space and relief; soil and vegetation cover; hydrogeological and hydrographic conditions. Due to the fact that these properties are manifested simultaneously, their integrated accounting is necessary for land management [6].

The assessment of natural resources, including land, should be considered from three perspectives: ecological or environmental, in terms of preserving the quality of the natural environment; economic (taking into account the profitability of using a natural resource); social (in terms of meeting the needs of the society). The ecological state of land resources of Samara Region, especially the most valuable land – agricultural land, is currently defined as critical, and in some areas it is becoming an environmental disaster.

Currently, in most constituent entities of the Russian Federation, including Samara Region, soil fertility continues to decline, the state of land used or provided for agriculture is deteriorating. Soil cover, especially agricultural land, is susceptible to degradation and pollution, loses resistance to destruction, ability to restore properties and fertility reproduction [7, 8]. Agricultural land holds the largest share in the structure of the land fund of Samara Region – 76%. The analysis of the quality of land shows that there is a persistent trend of active land cover degradation in the region, which affects land productivity and causes an increase in the range of problematic and crisis environmental situations. The predominant soils in Samara Region are chernozems. Their area amounts to 97.5% of the total amount of arable land. On average, the region is dominated by low-humic and slightly humic soils. Over a number of years of observations, the specific weight of medium-humic soils in the arable land decreased from 31.9 to 10.7%, and the slightly humic soils increased from 19.3 to 40.0% [9].

According to available literary data, the loss of the fertile layer in Russia reaches 1.5 billion tons per year [10]. According to the results of a survey conducted by the specialists of the VolgoNIIGiprozem Institute in Samara Region, the annual losses of humus in the arable layer were at the level of 0.7 tons/ha, and in certain areas – more than 1 ton/ha.

2. Materials and methods

One of the most common tool-in-hand and table-top GIS in our country is MapInfo Professional, which allows creating spatial objects by putting the coordinates using a keyboard, digitizing by raster image, entering information from the GPS receiver and other geodetic devices, as well as importing
graphic data from other GIS. Besides, MapInfo allows makes it possible to view and process graphic images, place and edit maps, build graphs and charts, work with databases, search on demand, and much more. MapInfo Professional has a fairly well thought-out interface, an optimized set of functions for the user, a convenient and understandable concept of working with both cartographic and semantic data [11].

The Kuibyshev Agricultural Production Cooperative is located in the southern part of the Kinel district of Samara Region. Its main activity is dairy cattle breeding and the production of raw milk. The total land use area is 13193.0 ha, of which 6991.3 ha – arable land.

The first step in assessing the quality of agricultural land is local monitoring. Local monitoring (at the level of individual land uses) uses remote sensing data, mapping materials and satellite survey data. The method of estimating the qualitative state of agricultural land with subsequent spatial-structural modeling of the forecast state of the studied area includes the following sequence of operations:

1. Study of long-term dynamics of agricultural land subject to erosion and overgrowth processes by weeds.
2. Analysis of qualitative and quantitative characteristics of the state of the studied territory.
3. Classification of agricultural land according to the point scale for assessing the qualitative and quantitative characteristics of the territory.
4. Assessment of the current and potential risk of erosion and overgrowth of agricultural land.

The development of the adaptive land management project should include an integrated approach to the assessment of a relatively large list of criteria forming the basis for land planning, crop rotations and choice of agricultural technologies.

At the initial stage, thematic maps were compiled (soil map, map of agro-production groups of land, map of slope steepness, maps of humus, nitrogen, phosphorus and potassium, etc.) allowing specifying land use conditions and drawing up an algorithm for subsequent actions.

The soil map is the main scientific document on the basis of which a competent assessment of land funds is possible, as well as the development of a system of practical measures aimed at improving soil fertility. The most important condition for sustainable agriculture is the renewal of obsolete soil maps and information on the state and properties of the soil cover.

3. Results

1. Assessment of soil fertility. According to the latest survey, the weighted average content of humus was 3.2%, mobile phosphorus – 128 mg/kg of soil, exchange potassium – 124 mg/kg.

Soils with a very low humus content amounted to 23.4% (1601 ha), low – 58.1% (3972 ha) and average – 18.5% (1264 ha). The farm is dominated by soils with an increased and high phosphorus content, and 33.5% (2291 ha) of soils have an increased potassium content. The analysis of the dynamics of soil fertility showed that there was a decrease in the area of low-humic soils by 23.1% and an increase in slightly humic soils by 22.9%.

The dynamics of arable land soil areas in terms of the content of mobile phosphorus and exchange potassium during the period between agrochemical surveys shows that over the past 17 years, arable land areas with very high and high mobile phosphorus content passed into gradations with increased and average content. Thus, the area of lands with increased (by 16.7%) and average (by 12.9%) content increased, as well as 150 hectares with low content of mobile phosphorus were identified. There was also a decrease in areas with very high content of exchange potassium – by 26.8%, as well as with increased – by 0.7% and average content – by 16.9%.

One of the modern methods of monitoring the state of natural resources is the method of compiling maps of the state of land fertility at a certain point in time. They provide comparable and systematic information on the state and use of agricultural land, the degree of its degradation. This information is necessary to identify the dynamics of the main properties of soils, conduct state cadastral assessment of land, make decisions related to the protection of land resources and their rational use, and conduct land monitoring.
2. Calculation of anthropogenic impact on the agroland landscape. The assessment of the territory showed that the level of load is significant, since the anthropogenic impact on the territory exceeds its natural capacity. The ecosystem stability is being lost.

3. Erosion hazard assessment of farm lands. In the process of compiling and studying the erosion hazard map, the following conclusions may be drawn: most of the land is subject to water erosion of weak intensity; farm land holds the category II of erosion hazard of land; outwash from the entire area is 13.0 t/ha.

The agrolandscape is characterized by a high degree of plowing, which on the one hand ensures successful production of crop and livestock products, and on the other, negatively affects the ecological state of the territory.

The use of GIS technologies makes it possible to form an information basis for agroecological assessment, the results of which are used in agroecological land typification. An agroecological assessment of land use showed that the territory of the farm has interfluve and slope terrain. The predominant slope includes the slopes from 0 to 3°, which is 76% of the total farm area. The slopes with a steepness of 3-5° account for 8% of the studied territory. A digital terrain model is an additional and informative measure that solves many land management problems.

4. Agroecological classification of land by crop suitability. The agroecological grouping of arable land was carried out according to its suitability for cultivation of zoned crops on the basis of quality characteristics of arable land taking into account types of soils, topography, degree and types of erosion. Ten agro-production groups were identified. Recommended erosion control measures and recommended crops are indicated for each group.

After the agroecological monitoring of arable land, the construction of a cartogram of the content of humus, mobile forms of phosphorus and potassium, digital models of the area using geostatistics methods, the project of internal land management of this farm was improved.

In total, 3 erosion control complexes were designed on the territory of the farm. Agrocomplex No. I is used on soils subject to erosion to a low degree and potentially dangerous for the development of erosion. Agrocomplex No. II is intended for soils subject to medium and heavy erosion. Agrocomplex No. III implies plowing across the slope on improved pastures and on medium washed soils, late autumn para-plough of perennial grass after 6-8 m.

Crop rotations require the best conditions to increase soil fertility. This will ensure a continuous increase in the production of field products and an expanded reproduction of soil fertility.

The use of cartographic material allows designing crop rotation fields with homogeneous massifs in terms of soil composition, relief and humidification conditions, and in terms of area, configuration and location – convenient for agrotechnically correct and productive performance of field mechanized work. The fields are located on aligned areas, the average slope of the terrain, as well as the working slope are within the optimal limits.

The main indicators for assessing the economic efficiency of crop rotation massifs are the volume of gross harvest of crop products, the level of fixed and variable costs, as well as the net income and the level of profitability. The cost of production from the entire area in existing crop rotations amounted to 84847.1 thousand rubles, in design crop rotations – 83537.6 thousand rubles. The total production costs before land management – 60389.7 thousand rubles, according to the project – 56653.6 thousand rubles, hence, the net income – 24457.4 and 26 1884.0 thousand rubles, respectively. The economic benefit of the design crop rotation project with developed agricultural complexes will make 2426.6 thousand rubles.

4. Conclusion

The GIS model design includes the definition of data, geo-processing tools and the links between them, namely:

- input data – existing data added to the model; input data must be consistent and meet the necessary criteria for correct operation of the model;
- intermediate data, which were generated during model operation and serve only for further...
transfer are basically not required and contain “raw” information;
  • resulting data – new data created by GIS models “at the output”;
  • geo-processing tools – model elements that perform data conversion; in addition to built-in tools,
    scripts and other models may be used;
  • links connect data to tools and point to the direction of the information flow.

Land management projects for crop rotation design utilize the following source and resulting
geospatial data:
  • relief;
  • agro-production soil groups;
  • agricultural plots (agricultural land);
  • ecological and technological groups of arable land (take into account the potential danger of
    erosion processes and the intensity of land use).

All other data are intermediate. Their standardization may be neglected because they are less
significant. All spatial object classes may be supplemented with attributes as needed.

To achieve the purpose of the study, a geographic information model was developed for the land
management projects to ensure the environmental and economic justification of crop rotation and land
regularization (Figure 1).

![Diagram](image)

**Figure 1.** Scheme for data bank creation for integrated agro-environmental information accounting

Thus, at the present stage the application of GIS technologies is the most appropriate mechanism
for the development of sustainable ecological agricultural production. Adaptive land management
projects should be developed using GIS technologies based on an integrated assessment of a wide
range of indicators. The use of GIS technologies helps to reduce the time of work and improve the
quality of results, increase the overall efficiency of agricultural production by providing up-to-date
analytical information on the entire set of necessary parameters for optimal and timely management
decisions.

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