Digital design and monitoring of farming systems

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***Abstract*—In the course of digitalization, not enough attention is paid to the design and monitoring of farming systems that in most cases are created in text format on paper and electronic media. This form does not meet the requirements of information technology development of the industry and the needs of agricultural organizations. Farming systems are characterized by complexity, a vast variety of elements and interconnections, by having biological, technical and economic components, by dynamic nature. Digital format allows to overcome the shortcomings of text formats and, above all, to take into account the dynamic nature of the farming system. Analysis of production data and the feedback linkage of information databases of enterprises with the database of the farming system regional unit become relevant. Kurgan R&D Agricultural Institute, a branch of the Federal State Budgetary Scientific Institution "Ural Federal Agrarian R&D Center" of the Ural Branch of the Russian Academy of Sciences, developed an information and analytical farming system package consisting of several blocks: a base of general agricultural knowledge, a unit for designing crops growing technologies, a software and hardware package for monitoring equipment and technologies, an analytical system for learning data of agricultural landscapes and agrocenoses of agricultural enterprises. This package allows you to create the project of farming system in digital format, to quickly edit it, to monitor its implementation and, on the basis of analyzing the data from agricultural enterprises, to obtain new knowledge on agriculture.**

Keywords—database, design, software package, farming system, technologies, technological map, electronic map.

I. Introduction

The need of active moving of agriculture towards digital intelligent and robotic systems has both economic and social background [1]. In crop farming, the transition to digital technologies is in large measure associated with the development and implementation of precision agriculture technologies which include decisionmaking support technologies for agroindustrial complex, locally differentiated and adaptive fertilization and using of plant protection products, precision irrigation, "big data" and Internet of things in agriculture, robotics based on artificial intelligence, using of drones, and so on [2]. Information flows via navigation equipment, mobile communications, and the Internet, and is processed by computers. Agriculture is becoming a sector with a very intense data stream. Information is collected from various devices located in the field, on the farm, from the sensors of devices, from meteorological stations, satellites, drones, external systems, suppliers. General data from various participants of production chain collected in one place allow to receive information of new quality, to find common patterns, to create added value for all involved participants, to apply modern scientific processing methods, and to make right decisions based on them that minimize risks and improve the business of manufacturers [3].

At the same time, the digitization of agriculture management, including farming, is at the initial stage. Navigation equipment is used mainly for accounting and for the control of the use of resources and not enough for agricultural technologies management. Little attention is paid to the basic elements of the farming system which include agropedologigal regionalization, soil characteristics, climatic conditions, structure of arable land using, crop management system, soil treatment systems, fertilizers, plant protection from weeds, diseases and pests, seed growing and others [4]. These areas are developed in regional scientific institutions and are published in text format on paper and electronic media that have the following shortcomings – inability to organize remote monitoring of farming systems, to analyze and take into account production experience, to ensure flexible changes in agricultural system and technologies, to automate technological processes.

An important stage in moving towards precision farming is an adaptive landscape approach which takes into account the peculiarities of each agricultural landscape and is widely developed and spread in agricultural science and production. In order to specify technologies for the fields and to manage adaptive landscape farming in the Russian Federation, the appropriate scientific recommendations were developed, as well as provisions and standards for the design of adaptive landscape farming systems [5]. The team of Siberia R&D Institute of Agriculture and Chemization under the leadership of academicians V.I. Kiryushina and A.N. Vlasenko created a package of technologies for the cultivation of agricultural crops in Western Siberia adapted to different agricultural landscape regions, agroecological groups and types of land, previous crops, levels of intensification and variability of agrometeorological resources [6]. In 2010, the All-Russian R&D Institute of Agriculture and Soil Protection from Erosion developed the methodology for designing the basic elements of an adaptive landscape farming system [7]. Later, relevant recommendations were developed in other regions. The team of scientists of the Kurgan R&D Agricultural Institute under the leadership of academicians A.L. Ivanov and V.I. Kiryushina developed the system of adaptive landscape farming for the Kurgan region [8].

At the present stage, adaptive landscape farming systems are closely connected with geoinformational technologies which make it possible to connect information bases with field coordinates. Herewith, the leading factor for increasing of modern agricultural production efficiency and for carrying out research in this sphere is the collection, processing, and analysis of the maximum amount of information in the form of common information space. At the same time, programs for designing machine systems are being created that allow not only selecting necessary equipment but also optimizing costs for agricultural technologies.

In Kurgan R&D Agricultural Institute, a branch of Federal State Budgetary Scientific Institution "Ural Federal Agrarian R&D Center" of the Ural Branch of the Russian Academy of Sciences, a package was developed for digitization of the design and monitoring of farming systems which includes databases of farming conditions, typical technological maps of growing agricultural crops, computer programs for creating electronic field maps, database management data, design and management of agricultural technologies which allow to overcome the shortcomings of text formats and to start the transition to the automation of crop management and precision farming.

II. Research methodology

The study was carried out at the Kurgan R&D Agricultural Institute, a branch of Federal State Budgetary Scientific Institution "Ural Federal Agrarian R&D Center" of the Ural Branch of the Russian Academy of Sciences, in the Laboratory of Economics and Innovation Development, within the framework of the State task of the Ministry of Science and Higher Education in the field of study 142 of State Academies Fundamental Scientific Research Program on the subject No. 0773-2019-0027 "Improving the system of adaptive landscape farming for the Ural region and creating agricultural technologies of new generation based on minimizing tillage, diversifying crop rotations, integrated protection of plants, biologization, conservation and improvement of soil fertility, and development of an informational and analytical package of computer programs and databases providing innovative management of farming system".

The main research method is system analysis. Farming systems are characterized by complexity, a vast variety of elements and interconnections, by having biological, technical and economic components, by dynamic nature [9]. The dynamic nature of farming systems with changing of position and state and retaining the nature and identity throughout the life cycle contradicts the static text formats of farming system projects [10]. Agrochemical composition of the soil, the structure of weeds, the set of pests, and disease strains are constantly changing. Prices for resources and products change in accordance with technical and economic conditions. In connection with price changes for the products, enterprises need to constantly change the structure of arable land use, in order to increase revenues they have to increase the share of more profitable crops, and consequently, to make changes in the strict alternation of crops during crop rotation. Changes in resource prices have an impact on the choice of crop growing technologies. With the increase of fuel prices, the number of mechanical tillage decreases and the use of herbicides increases, and vice versa, with the growth of prices for herbicides, their use decreases and the intensity of mechanical tillage grows.

The digital format allows taking into account the dynamic nature of the farming system, to obtain new knowledge on farming based on agricultural data analysis. It is hard to overestimate the importance of production information for testing of scientific knowledge. Currently, due to the increasing complexity and diversity of technologies, its role is also increasing. The set of varieties, means of plant protection, brands of agricultural machines, the number of methods for tillage, planting, harvesting is growing [11]. It takes place at a time of the reduction of the research base, experimental fields, areas for testing crop varieties which are no longer able to study all technological variants, especially for different soils and climatic conditions. In this connection, production data analysis and the feedback linkage of the information databases of enterprises with the database of the regional farming system becomes relevant.

Implementation of information technologies in agricultural enterprises goes quite differently. There are still a lot of farms that use extensive technologies, and the need for information systems is minimal there. Other farms successfully use intensive technologies. In this case, the use of information systems is necessary; it requires design, development of parameters (seeding rates, doses of fertilizers, pesticides, and biologics), control and analysis of their achievement. Most enterprises are not yet ready for the transition to precision farming when technological parameters are changed with the help of automatic systems installed on agricultural machinery and on elementary parts of fields. At the present stage, agricultural organizations have not yet implemented the adaptive landscape farming system when technology parameters are differentiated by fields.

For precision farming implementation, information technologies should also be applied at a lower level, for creating information and analytical systems of intensive and adaptive landscape farming, and only after their implementation it is possible to move towards precision farming. It should be noted that after the liquidation of "Giprozem", the development of farming systems and land organization, and technology design stopped in most farms. The gap in agriculture management was to a large extent the cause of the decline in sustainability and profitability of crop production. Restoration of design and analytical work is a necessary condition for improving farming efficiency.

The farming system of an enterprise should be integrated with a single federal information system of agricultural lands where, besides information on the location, state and actual use of each land plot in the regions of Russia, a function for selecting the most profitable crops is planned to be introduced, taking into account the transport leg to the place of processing or consumption [12].

III. Results

The digital format of the design and monitoring of farming system created at Kurgan R&D Agricultural Institute has a block structure. The block of general knowledge contains soil characteristics, description of crops, weeds, pests, diseases, microflora, types of fertilizers, plant protection products. The block of knowledge on the soil and climate zone includes data on climatic conditions, soil, agriculture technology packages for adaptive landscape farming systems, analytical information of production experience in farming [13]. Enterprise information block consists of databases of soil and climate and technical economic conditions of production, software for adapting typical technologies to the production conditions of enterprises, and software and hardware package for monitoring and analyzing the farming system (Figure 1).

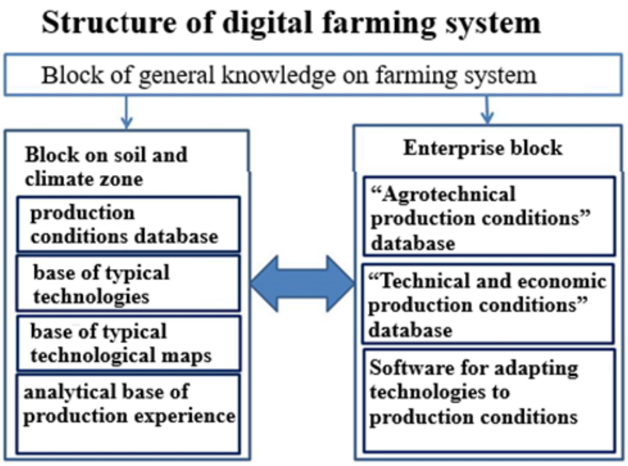

Fig. 1. Scheme of the digital format for design and monitoring of farming system.

The base of general knowledge on agriculture created in the form of a web application consists of three sections. The first one includes the description of farming conditions: agroclimatic requirements for crops, their bioclimatic potential, types, and subtypes of soil, yield of nutrients by crops, description of harmful objects (weeds, pests, diseases). The second section contains the description of farming system elements: crops and varieties with the detailed description, tillage systems, methods of sowing and preparation of fallow land, plant protection, soil characteristics, planting dates, seeding rates, harvesting, calculation methods for fertilizer doses and other information. The third section includes recommendations for farming system and agrotechnology management.

Based on the data of field experiments and generalization of production experience in digital format, a database of typical technological maps of crop cultivation by agrolandscape zones, 15 crops, three levels of intensification and two previous crops was developed. There is a standard set of operations during field works: harrowing, deep or shallow tillage, spraying of crops with biologicals and pesticides, mowing and threshing of crops, and so on. This will determine the feasibility of creating a digital database of typical technological maps. It is easier to make a map for a field by editing of the existing standard map than to create a new one. The most variable parameters in technologies are doses of fertilizers, plant protection products, and seeding rates. In modern precision farming, it is the doses and rates of these items that are calculated and linked to the elementary parts of fields. Technological maps contain operational parameters, resources required (seeds, fertilizers, plant protection products) and economic parameters [14, 15]. The block of technical and economical production conditions contains data on equipment, performance rate and fuel consumption, labor remuneration, including surcharges, bonuses, and accruals to extrabudgetary funds; prices for resources and products.

Structure and management program for the database of agrocenoses and agrolandscapes were created for the storage, accumulation, systematization, and analysis of agronomical information for each field; for further use in the design of farming systems taking into account actual features and parameters of each section: culture, previous crop, fertilizer, crop rotation, etc. Information classified in the database is the basis for obtaining new knowledge on agriculture. The database is integrated with the electronic map of fields and presents visual information in a large number of thematic maps (Figure 2) [16].

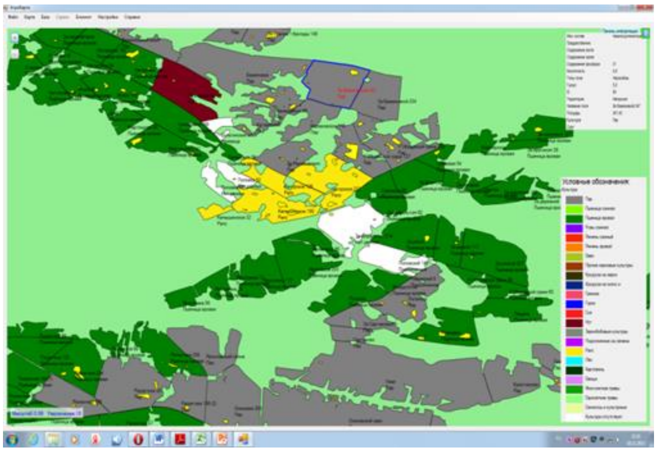

Fig. 2. Scheme Electronic field map

Adaptation of typical technologies to the production conditions is carried out using "Crop Cultivation Technology Design" program where the choice of the standard map is provided using a special form and dropdown lists of administrative regions, crops, intensification levels, previous crops. [17]. The map can be edited using a special form where you can change operational parameters (composition and doses of fertilizers, seeding rates, set and doses of plant protection products, as well as change devices, performance rates and fuel consumption, electricity, the distance between the warehouse and the field, labor remuneration, etc.) (Figure 3). The program also allows generating reports (summary tables) on all or on several maps: gross production yield and crop area; fuels and lubricants required; wages, including surcharges, bonuses, and accruals to extrabudgetary funds; fertilizers, dressers, plant protection products required, amount of costs. Together, these reports represent crop production plan of agricultural enterprise. The program provides access to the blocks of general knowledge on agricultural system and soil and climate zone. Adaptation block is filled with software modules for the automatic design of individual technology elements, for example, by determining fertilizer doses according to the fields.

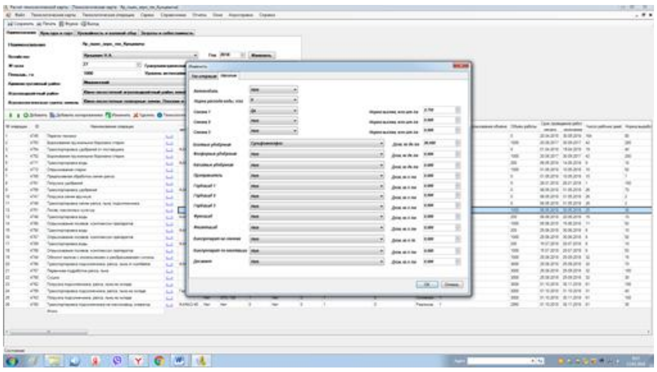

Fig. 3. Technological operation editing form

An important block of this system is software and hardware package for monitoring and control of farming system which, with the help of navigation equipment, communication equipment, server and data visualization devices, allows recording tracks and running speed, downtime, and in the presence of appropriate sensors – technological parameters, fuel consumption (Figure 4).

Fig. 4. Scheme of data transfer from devices to enterprise server

Monitoring block provides the implementation of adapted farming system. Adding of the technology of remote monitoring of crops and yield mapping to the navigation control allows making changes to the farming system and to efficiently manage the production process [18]. In addition to technology monitoring, this system allows to increase the quality of standards for device performance and fuel consumption. By program requests, information (type of work, device, year, work start date and end date) is taken from the database in a table where the hourly performance and fuel consumption of the device per work unit are automatically calculated. In comparison with manual measurement, this one is carried out not once, but constantly, the human factor is excluded, and data reliability increases.

Technology monitoring data transfer from several enterprises to common information and analytical center will increase the amount of knowledge on agriculture. It is reasonable to create centers on the basis of research and development institutes with a scientific base, technical facilities and qualified team for performing analytical work.

Information and analytical package for farming systems consisting of the base of typical technological maps, knowledge base, database management programs, technology design, and monitoring is used in several agricultural enterprises: “APO MUZA” OAO, Suslova S.A. farm enterprise, Ivanova V.V. farm enterprise, Elantseva I.A. farm enterprise and others, in total on the area of more than one hundred thousand hectares.

IV. Conclusion

The future of agriculture is connected with digital management. The package for digitalization of design and monitoring of farming systems developed at Kurgan R&D Agricultural Institute including the database on farming conditions, typical technological maps for growing crops, computer programs for creating electronic field maps, database management, agricultural technology design, and management allows you to overcome the shortcomings of text formats and to start moving towards automation of plant management and precision farming.

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