Using of electronic field database for analysis of the effectiveness of agricultural technologies

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***Abstract*—In this article, we are talking about the example of using an electronic database on the state and functioning of agricultural landscapes (fields) which was created in the Kurgan Research and Development Agricultural Institute for the calculation of economic effectiveness for each field, analysis, and design of management solutions in crop production. This method is based on the system analysis of database and cost estimates for technological maps of each field. Production data of 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 were used for completing information in the database. Registered here agronomical information made it possible to calculate economic parameters taking into account the characteristics of each field and to choose the most efficient agricultural technologies. Results 2017-2018 showed a significant difference in the profitability of grain production among the fields from -22% to 119%. Factors that determined high economic effect were highlighted: fallow previous crop, Raduga variety, rust-tolerant, seeding using SKP-2,1 plow planter, using of high-performance Acros 530 combine harvester. Production experience showed differences in responsiveness to fertilizer in different fields in contrast to the same technology of spring wheat cultivation. The following possible reasons were analyzed: differences in particle size distribution (heavy and middle loam ordinary chernozem), humus (3.9 and 3.0%) and phosphorus (71 and 104 mg/kg of soil) content in the soil.**

Keywords—database, field history, economic effectiveness, grain production profitability, technological map, wheat yield.

I. INTRODUCTION

Any innovation in modern agriculture is tested by its economic characteristics and the possibility of production cost-cutting. At the same time, natural factors play a significant part. Adaptation of new technologies to the specific conditions of the farm unit comes to prominence. Decision making in crop production is based on a thorough analysis of the information received.

Reserve for increasing production performance can be found in taking into account the results and parameters in each field: soil and climatic conditions, previous crops, fertility backgrounds, plant protection products, etc. This is about the creating of field history database. Books on the history of fields were legally approved in the USSR as early as 1961. This made it possible to analyze the effectiveness of certain measures, to evaluate the long-term productivity of crop rotations, and to improve other parameters of agricultural production.

Today there are electronic databases. They are convenient, can be stored, copied and transferred, allow analyzing information much faster. Digital technologies allow reducing the time required for information processing several hundred- and thousand-fold. One of such projects is the product of Kurgan R&D Agricultural Institute which is a program for managing the database of fields with linkage to their coordinates; it was registered in Rospatent as "Management of the database on the state and functioning of agricultural landscapes" (certificate No. 2014662258 as of 03.10.2018). The main purpose of this research was to use data from this database for analyzing the economic effectiveness of production and quality of management.

II. LITERATURE REVIEW

In today's context, research development in the field of agriculture is closely related to digitalization, introduction of geoinformation technologies and elements of precision farming that takes into account the characteristics of each field. Innovations based on a program package for working with electronic maps, databases, knowledge bases, expert systems (decision-making algorithms), and GIS technologies receive large development. The most important information component in this sphere is to obtain data on the state of field and plants, their analysis and interpretation, development and implementation of decisions made on this basis [1].

Making of regional databases of agricultural landscapes with linkage to their coordinates for agroecological assessment and land typing is actively being conducted in such scientific institutions as Russian State Agrarian University - Moscow Timiryazev Agricultural Academy. [2], All-Russian R&D Institute of Agriculture and Soil Protection from Erosion [3], in the Stavropol, Altai, Perm Territories, the Novosibirsk Region and other regions that have accumulated vast scientific and practical experience [4, 5, 6, 7]. The following databases are of great importance: on agrochemical survey [8], agricultural land monitoring [9] and creating, for example, of electronic vector maps of soil erosion advancing [10] and of other soil characteristics based on its results.

The development of digital technologies and agricultural production robotization is actively occurring in the Ural region [11]. However, the analysis of information received is limited to the standard accounting of general resources excluding data on the fields. In addition, there are actually no formal decision-making algorithms for non-scientific production experiments. In this regard, an interesting R&D product is universal cognitive analytical system named “Eidos” for determining the share of factor influence in any information flow which was created by Prof. E.V. Lutsenko on a united standardized methodological and instrumental-technological basis of system-cognitive analysis [12]. At the same time, a simple agronomic and economic analysis of field history database of agricultural enterprises may allow to annually obtain new knowledge on agriculture in specific soil and climatic conditions. V.P. Yakushev [13] talked about making the catalogue of agricultural fields in 1986. At the present day, in the conditions of personnel shortages and austerity of resources, an automated mechanism for agronomic decision-making in combination with the economic approach is essential for the efficiency of agricultural enterprise, and making of common information field could become an essential instrument for the whole system of managing agricultural cooperatives [14].

III. 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 method used in the study is system analysis (structural, morphological and cognitive). For creating a field database management program, a relational data model is used which is stored in SQL server, programming language is vb.net.

Economic evaluation was carried out using “Crop Cultivation Technology Design” computer program developed in Kurgan R&D Agricultural Institute, (registration certificate No. 2013767052 as of 03.11.2017), which is based on the calculation of technological maps [15]. All these maps are saved, and on the basis of their data, reports are generated on costs, profitability and other economic parameters. Information on fields was completed and calculated during 2017 and 2018.

IV. Results

The basis of this study is the electronic field database that contains the history of technological operations, agrochemical characteristics and other parameters for each field. This database looks like a table, with each row corresponding to a field with a set of parameters (Fig. 1).

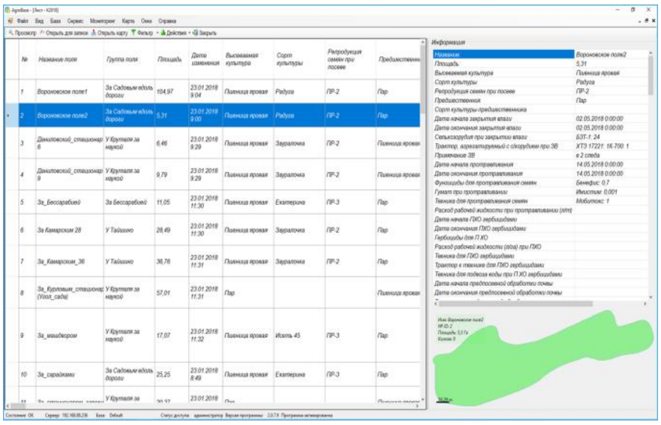

Fig. 1. General view of field history electronic database

The tables are completed for each year, and information for these years is formed in the reports for each field. Each field is linked with the electronic map. Data entered into the database are displayed on thematic maps. (Fig. 2).

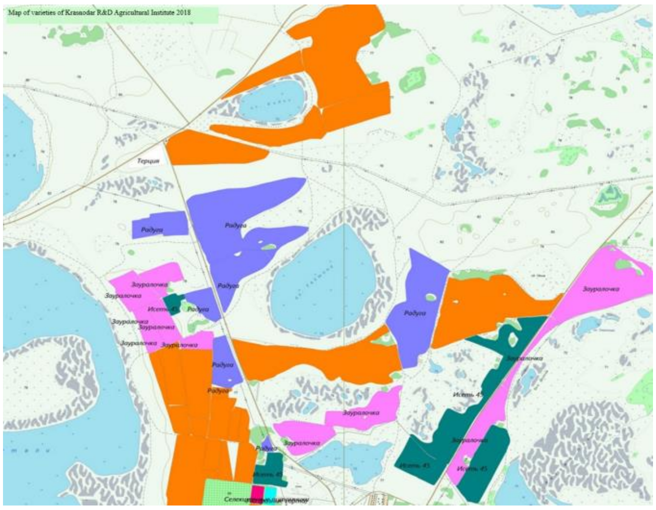

Fig. 2. An example of a thematic map of varieties of planted crops

The advantage and convenience of the developed program are that you can create, change, delete, or add any number of parameters as required and depending on farm unit specialization.

Maintaining field database allows at any point finding out information, for example, type, soil subtype, particle size and agrochemical composition of soils in a particular field, etc., and choosing the appropriate crop and variety for cultivation, prioritizing planting dates, choosing of early ripening varieties, calculating the optimal cost-effective dose of fertilizers and feasibility of their use in this field. Information on previous crops and varieties has an impact on the choice of cultivation technology, variants for the use of chemicals. Data on active ingredients in drugs used will help to avoid reappearance and habituation of weeds, pathogens, and pests. All technological and agronomic aspects form agricultural technologies with specific costs for each field. The resulting yield gives the basis for calculating income and profit for each field.

An open issue is a question of analyzing and formalization of the information collected and decision-making algorithms. In order to increase its own production effectiveness, this program is used in Kurgan R&D

Agricultural Institute; so, it became possible to evaluate its work under real-life conditions and to carry out the economic analysis of agricultural technologies in terms of fields and years.

General data analysis showed that the average yield in 2018 on fields was significantly lower than in 2017 (2.29 vs. 3.35 t/ha), as a result, the cost of grain increased significantly from 542 to 745 rubles/centner. However, the profitability was higher than in 2017 (55 vs. 45%). The first factor giving such result was a higher selling price (10.0 and 11.3 thousand rubles in 2018 vs 7.5 and 8.6 thousand rubles in 2017 for 1 ton of grain of the 3rd and 4th grades, respectively). The program used for the calculation of technological maps allows changing prices for resources and automatically recalculating economic parameters. So, it became possible to find out that at the same sales price (at 2017 prices), profitability in 2018 becomes lower (18 vs. 45%), but is still positive with a significantly lower yield. So, it is necessary to pay attention to the factors that influenced such production result.

Firstly, resource costs were different. In 2018, more fertilizers and plant protection products were used including due to the increase in the area of non-fallow previous crop (266 hectares versus 118 hectares in 2017), but the costs per hectare were lower than in 2017 (Table 1). A significant part was played by price factor and the consumption rate of agents used.

TABLE I. ESTIMATED COSTS FOR SEVERAL RESOURCES FOR WHEAT GRAIN PRODUCTION IN 2017 AND 2018 BY ACTUAL RESULTS OF TECHNOLOGICAL MAPS, KURGAN R&D AGRICULTURAL INSTITUTE

Resource	Resource volume, kg (l)		Total resource cost, RUR		Resource for 1 ha, RUR	
	2017	*2018*	*2017*	*2018*	*2017*	*2018*
Herbicides	915	1446	867745	1203840	963	1012
Vegetation fungicides*	547	225	584671	372260	854	293
Disinfectant*	167	153	111334	147973	111	125
Total protection products	1629	1824	1563750	1724073	1928	1430
Fertilizers	26700	38800	368460	709418	1598	1468
Fuel and lubricants	26143	30352	1578211	1661031	1681	1476

a. including growth regulators

Gross grain output which determined production profitability was lower in 2018, primarily due to natural factors not controlled by man – cold May, arid June and July, hot August. Therefore, the reserve for increasing yields, all other thing being equal, could only be revealed by analyzing technologies in the terms of fields.

During analyzing profitability level, significant differences between the fields were found: technologies were both high and low profitable, and even unprofitable. It turned out that yield increase which ranged from 1.2 to 3.3 t/ha does not always correspond with the costs incurred (Fig. 3).

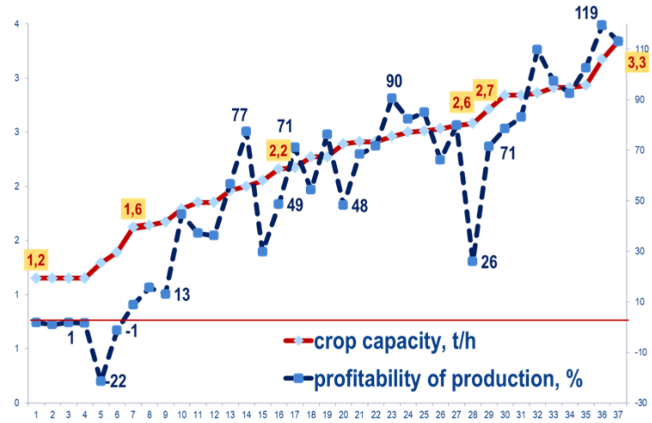

Fig. 3. Dependence of wheat grain production profitability on yields in different fields, 2018

The analysis revealed a variety of factors which influence production economics, even within one type of crop rotation, culture, and general technology. These are different previous crops, varieties, seeders, tractors, herbicides, fungicides, the use of fertilizers, etc., even the distance to the fields and the cost of fallow tillage last year which were also different for each field were taken into account in these calculations. For our purpose, all technologies were divided into groups taking into account main culture peculiarities, previous crop, the use of chemicals.

The greatest cost advantage was connected with the choice of the previous crop. Taking into account the expenses of the previous year, production profitability in terms of fallow previous crop was significantly lower than without taking it into account (66 vs. 124%), however, planting after fallow crop still turned out to be more productive (2.4 t/ha vs 1.5 t/ha), and the profit from additional products substantially exceeded the profit from planting with previous grain crop, even with fertilizers; average field profitability here was only 22%.

However, in terms of fallow previous crop, the yield in different fields varied from 1.3 to 3.3 t/ha. Herewith, there were technologies with the profitability of 26 and 71% (see figure above) despite an equal yield level of 2.6 and 2.7 t/ha. It turned out that this was the same variety, but in the first case, the fungicide was used due to tan spot in the field. In addition, costs per fallow were different due to the different number of tillages.

Variety was of great importance. In 2017, Umka winter wheat and Raduga spring wheat were the most profitable; the profitability of their cultivation was 67 and 58%, respectively. In 2018, Ekaterina variety (99%) was the leader in profitability, followed by Zauralochka and Raduga (68 and 62%) which were planted after fallow crops. The profitability of other varieties ranged from 2 to 51%. According to the results of 2 years, the most economically effective was the cultivation of Raduga variety which is tolerant to brown rust and requires no fungicide treatments.

During years of research when wheat was affected by brown and stem rust, the costs of crop treatment with fungicides were of great importance in costs structure. So, in 2018, the cost for obtaining 1 ton of grain from treated crops (with the use of herbicides) amounted to 7,290 rubles what is 1,200 rubles higher than from untreated ones. Fertilization with the previous grain crop turned out to be even more expensive, even without the use of fungicides, the average cost of a fertilized field was 7,570 rubles per 1 ton of grain, and the profitability of these fields was only 40%. This happened due to the fact that, despite a good increase with the use of fertilizers (from 0.4 to 0.5 t/ha), their cost did not recover in several fields due to the low potential fertility of the soil.

Among other factors that had a positive effect on production results, there were the use of SKP-2.1 plow planter (it allowed to reduce cultivation cost before planting without reducing the yield) and harvesting with the high-performance Acros 530 combine harvester (expenses for fuel, grain losses, wages were reduced in comparison to another less productive combine).

Data analysis allows taking into account errors made during past years and making decisions on the adjustment of technology elements. For example, for making decisions about fertilizer, it is important to conduct production experiments in each field. So, in 2018, the effectiveness of fertilization with sulfoammophos at the dose of 0.8 c/ha in fields with the same technology was compared. The increase in the field No. 27 was 0.5 t/ha, in the field No. 36 – 0.4 t/ha. With the cost of spring wheat of 4th grade of 10 thousand rubles/ton, an additional profit of 1,400 rubles was received from each hectare in the field No. 27 compared with No.36.

Field history analysis showed that field No. 27 also in previous years had a higher yield than field No. 36. Soil data showed that under one type and subtype (ordinary chernozem), soil composition of field No. 36 is heavy loam one, and of No. 27 – middle loam, humus content in the soil was 3.9 vs 3.2%, and phosphorus content – 104 vs 71 mg/kg of soil, respectively. It is obvious that fertilizer for field No. 36 should contain more phosphorus.

Such experience confirms the conclusions and recommendations of long-term researches made by scientists, but additionally gives information on a particular field showing its potential fertility and the possibility of more efficient use. The more information on the field is accumulated, the more accurate and correct the use of scientific recommendations will be.

This example of the analysis of agricultural technologies by fields can be used for another enterprise, and later a decision-making algorithm may be developed based on it.

V. CONCLUSION

Thus, the program for management of field history electronic database is, above all, the instrument for decision-making in crop production. Information in terms of not only crops and varieties, but also fields makes it possible not only to take into account total gross yield, but to analyze the impact of natural and anthropogenic factors, to evaluate the economic effectiveness of works carried out in each field and to take measures to further increase it, to confirm or to deny the effectiveness of these or other agricultural practices, to competently apply scientific recommendations obtained for certain soil and climatic conditions.

Results 2017-2018 showed a significant difference in grain production profitability by fields (from -22% to 119%). Factors that determined high economic effect were highlighted: fallow previous crop, Raduga variety, rust-tolerant, seeding using SKP-2,1 plow planter, using of high-performance Acros 530 combine harvester. Production experience showed differences in response to fertilizer in different fields with the same technology of spring wheat cultivation. Possible reasons were analyzed: differences in the particle size distribution (heavy and middle loam ordinary chernozem), humus (3.9 and 3.0%) and phosphorus (71 and 104 mg/kg of soil) content in the soil.

The accumulation of facts on production over years in electronic form will significantly add to the agriculture knowledge base and increase the efficiency of analysis and decision making using digital technologies.

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