Digital transformation of grain complex enterprises and development of standards for their digitalization in the BRICS countries

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Abstract. The article is devoted to the issues of substantiating the choice of digital technology elements for individual subjects (actors) of the grain subcomplex and the development of standards for their digitalization, including considering foreign experience on the example of the BRICS countries. The object of the study is the problematic of the activities of grain market participants, which is presented in the form of a hierarchical business process model. The business model covers various business participants - farmers, processors, suppliers of resources, technologies and equipment, intermediaries (traders), government agencies, etc. The subject of the study is digital tools (services) presented on the domestic market, as well as available in foreign markets, in particular in the BRICS countries ensuring an increase in the efficiency of agricultural producers, considering various production, technical, organizational, and other business conditions. The purpose of the study is to develop approaches to substantiate the standards for equipping various types of producers with digital solutions as a basis for ensuring production efficiency.

1 Introduction

In recent years, the BRICS countries have gained a stable position in the main international markets for grain and processed products. Based on this, it can be argued that the grain complex will be a driver for the further development of the agro-industrial complex of the BRICS countries in general and crop production in particular.

The grain complex is the largest sub-sector of crop production, which is entrusted with the primary tasks of meeting the needs of countries for agricultural raw materials and food products, increasing export potential and maintaining the country's food security. Grain and its processed products (bread, cereals, pasta) are the main human food product, forage grain plays a major role in the feed supply of meat and dairy cattle, pig and poultry farming.

Maintaining the current state and ensuring the confident development of the industry are directly dependent on the objectives of its participants (the state, agricultural business, banking sector, insurance organizations and others), as well as the complex interaction of internal (at the enterprise level) and external (at the industry level, country) factors that are

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inherent in its participants. Let's consider the factors that characterize the activities of participants in the grain complex on the example of the Russian Federation, the largest grain producer and exporter [1, 2, 3, 4]:

the high and constantly growing costs of raw materials, services, fixed assets, infrastructure maintenance, as well as the continuing high price disparity (for comparison, the cost of 1 kg of industrial products exceeds the cost of 1 kg of grain by 200-300 times). As a result, the main share of costs in the cost of grain falls on material resources, depreciation and maintenance, logistics costs (in total more than 60%);

insufficient level of provision of agricultural machinery. For most regions of the country, the supply of energy capacity per 100 hectares of acreage ranges from 208-223 hp and the load on 1 reference tractor is about 190-200 hectares, which is 1.5-2 times lower than recommended values;

insufficient level of chemicalization. The volume of mineral and organic fertilizers applied, as well as the activities carried out for liming, phosphorizing, gypsum, etc., is 2.1-3.4 times lower than the current needs of the industry. In addition, about 38% of crops are cultivated without the use of chemical plant protection products;

domestic market saturation. High yields in recent years have led to the formation of significant grain reserves (more than 29 million tons with typical average residues of 14-15 million tons) in most grain-producing regions, which resulted in an increase in storage costs. On the other hand, the growth of stocks led to the fact that domestic grain prices began to decline (especially for low-grade varieties of rye, wheat, barley, corn);

increase in logistics costs. A significant increase in the cost of grain transportation operations, especially in export-oriented directions, is caused both by an increase in the cost of the rolling stock (due to the heavy load of manufacturing plants for years to come), a decrease in the level of subsidizing grain transportation (considering high yields), and an increase in demand for transportation services, port terminal services, storage facilities and others;

the growing level of government influence on the industry in terms of statutory regulation, mandatory requirements for the use of information systems (traceability, accounting, registration, etc.), increased administrative barriers to obtaining export quotas, subsidies, activation of specific local phytosanitary restrictions, etc.

The decomposition of the business chain of value-added formation on the example of enterprises of the grain complex of the Russian Federation shows that agricultural producers and processors make the main contribution to the overall result – 43% and 30%, respectively, retail (wholesale, retail and distribution networks) occupies 16%, suppliers of various resources (material, energy, financial) occupy 10% etc.), about a percent is accounted for by various operations with government agencies (coordination and licensing procedures) (Fig. 1).

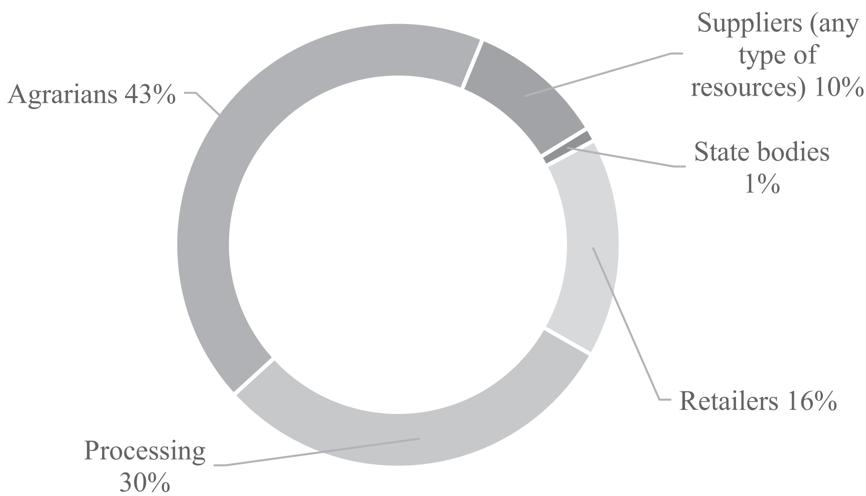


Fig. 1. Contribution of participants in the value chain (in proportion to the number of business operations during the product lifecycle) in the Russian Federation, %.

From the point of view of a systematic approach, the chain of formation (creation) of added value is a set of actions that an economic entity undertakes to provide its goods and services to the market. The value chain is determined by the life cycle of agricultural products. The life cycle is an integral set of interrelated elements (operations, participants) that interact with each other in the process of production and turnover of products. At the same time, in the process of production and turnover of products, the object of labor very often changes its shape and content (Fig. 2).

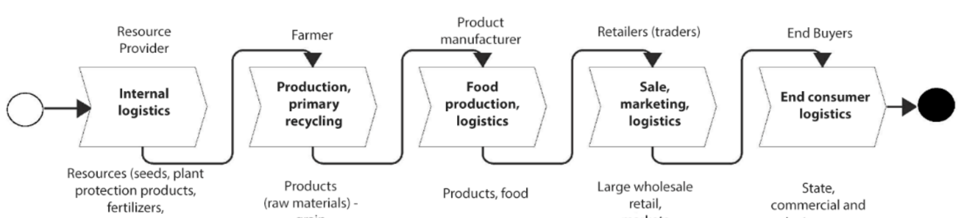


Fig. 2. Participants of the business model in the grain complex.

The key distinguishing features of the value chain in agriculture are the following:

the production cycle has a complex structure that is not evenly distributed over time (seasonality of production);

the conditions and factors affecting the production cycle are probabilistic in nature (weather conditions, yields, soil fertility, etc.) and poorly adaptable;

all operations of the production process are performed with living organisms in space (for example, in a field, building, water area, etc.) and in a strictly defined time interval;

a large number of participants are involved in various operations of the production process and product distribution – farmers as primary producers of products, processors engaged in primary and deep processing of raw materials, companies supplying resources and various materials (seeds, fertilizers, plant protection products, feed, veterinary drugs, young animals, and others), service campaigns (suppliers of technologies and equipment), intermediaries (retailers) carrying out purchase operations and (or) sales, financial and banking organizations, marketing and retail companies that "bring" the product to the consumer;

all actors (participants) control and coordinate their participation and activity in accordance with their own targets that have economic feasibility;

the interaction of the participants among themselves is a complex structure with a horizontal distribution of multiple cross-links and a different hierarchy, while each of the participants specializes in its own type of activity and does not compete with the operators of the previous or subsequent stage of production and sale of products;

during the entire cycle of production and turnover of products, its participants have to make a large number of management decisions, receive and process a large amount of information in accordance with the emerging production, commercial, logistical, financial, etc. constraints under conditions of uncertainty, on which the success of production and the competitiveness of the products obtained depend. Based on this, in agriculture, the chain of creation of a new product has a "long" length, since the number of participants is large and their contribution is not uniform;

to assess the effectiveness of individual business operations or the business model as a whole, the following indicators can be used: yield, protein (gluten) content, gross receipts, production cost of 1 ton, sales price of 1 ton, labor productivity and labor intensity of products, and others.

In the production process, contractors strive to ensure the effectiveness of their actions at all stages of the product life cycle. Ensuring efficiency necessarily leads to the need to analyze and optimize business operations in terms of more fully realizing the genetic potential of plants, reducing costs and using resources most accurately based on optimal production organization.

Based on the above, it becomes obvious that the agricultural business is complex, dynamic, and competitive, in which all its participants constantly face challenges and opportunities in accordance with their goals and objectives. To ensure the overall effectiveness of the digital transformation of the enterprises of the grain complex of the BRICS countries at all stages of the value chain, it is necessary to solve the following tasks:

increase in yield and formation of an optimal acreage structure;

improving the competitiveness of grain and its processed products on the world market by reducing cost, compliance with phytosanitary standards;

reduction of infrastructure and logistics costs due to the development of storage facilities and transport infrastructure;

development of the concept of digitalization standardization in the field of application of new agrobiotechnologies, including the definition of criteria for the selection and implementation of digital technologies in terms of new agrobiotechnologies, the establishment of guidelines for the use of new agrobiotechnologies, such as precision farming, the preparation of recommendations on data management and compatibility of systems used in the application of new agrobiotechnologies in agriculture, considering the requirements of environmental safety, regulation and ethics.

Thus, to maintain and increase the profitability of production, farmers of the BRICS countries need to use basic digital tools based on the developed standards, which will allow unifying digital transformation. According to market experts, using technologies, for example, it is possible to reduce the cost of seed by up to 25% and at the same time increase yields by 10%, optimize energy and labor costs by 4-12%, increase the reliability of equipment (condition monitoring), as well as optimize logistics processes [5, 6].

2 Materials and Methods

The work used general scientific (analysis, synthesis, comparison, generalization) and special (systemic) methods of scientific cognition (monographic, comparison, functional and cost analysis). The methodological basis was provided by industry regulations, the results of the work of specialized scientific and industrial organizations (institutions), as well as published works of practitioners on the activities and management of the grain complex.

Official regulatory documents, statistical materials, as well as open data samples from the Ministry of Agriculture of the Russian Federation, Rosstat, the Ministry of Industry and Trade of the Russian Federation, the Ministry of Commerce of the People's Republic of China, the Ministry of Statistics and Program Implementation of India, and the results of the authors' own observations are used as data sources in the work. Monographic, abstract-logical, computational, and constructive methods, as well as information (BPMN, ARIS) and economic and statistical modeling (MS Excel) tools were used to disclose the issues raised in the work.

3 Results and Discussion

Today, for the agricultural business in general and for crop production in particular, a fairly wide range of solutions is offered for most of the processes and tasks faced by agricultural producers and other participants in the production and turnover of agricultural products.

The variety of available technologies and means of digitalization, such as the Internet of things, artificial intelligence, robotics, distributed registry systems, big data, wireless communication technologies, virtual and augmented reality, etc. lead to an abundance of possible options for their use, due to the specifics of doing business. In an effort to carry out production, trade and investment activities as efficiently as possible, farmers need to choose such implementation options that would guarantee an increase in production, economic returns or a reduction in environmental impact. providing services and new types of products, which together allows to receive and analyze more data, make transactions on a fundamentally new basis, dynamically changing the business model depending on external factors (Fig. 3).

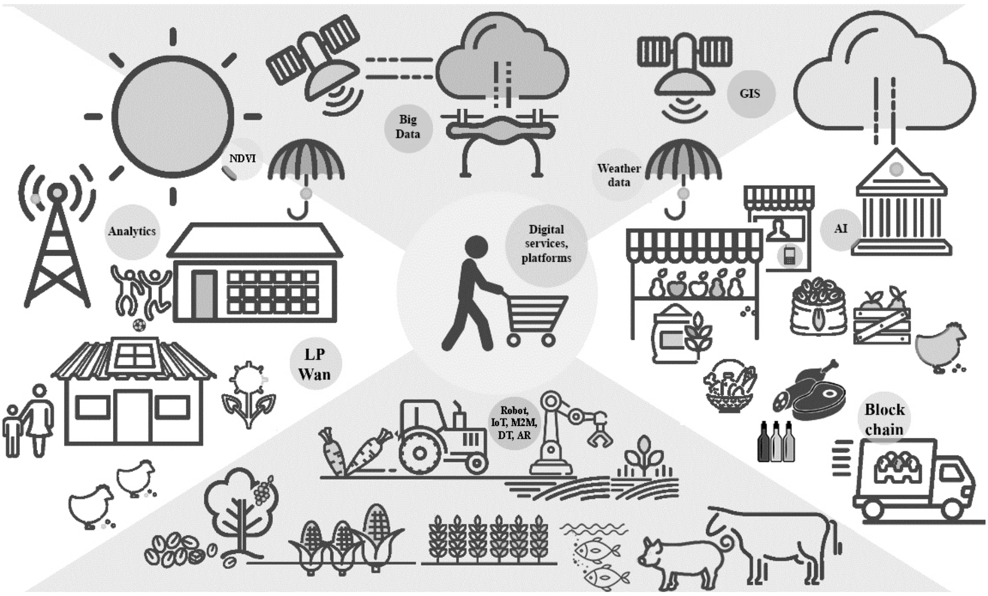


Fig. 3. Digital technologies used in the agricultural sector [7].

Nevertheless, the costs of implementing such measures are quite high, and the benefits received are not always unambiguous (possible in a short period) and are available especially for small producers. For further analysis and justification of the choice of digital solutions for their standardization, it is necessary to build a business model that focuses on the stages of the life cycle of products (raw materials) and can be represented as a set of sequential business operations based on the BPMN standard (Fig. 4).

Figure 4 shows a hierarchical model of real processes (business operations), their interrelationships (logic and state), including the physical flow of raw materials and final products, as well as the main objects involved (including participants), information systems and documents.

The research of the subject area was organized in the following areas:

defining the business architecture considering the perspective (point of view) reflecting the needs for digital transformation of specific participants;

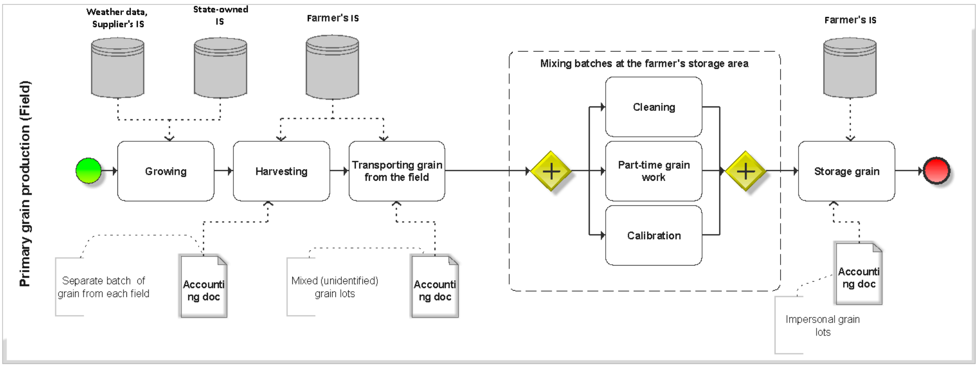
identification and aggregation of requirements of specific participants;

the study of relevant practical experience in the application of digital solutions in the industry (available literature, commercial materials, selective interviews), proposals from vendors, system integrators, and technology companies supplying digital solutions to the market (mainly of domestic origin, as well as a number of suppliers from the BRICS countries) [5-6, 8-10];

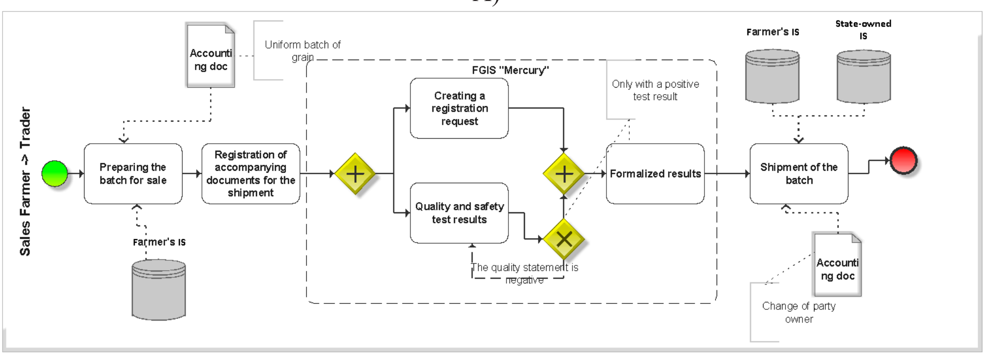
identification and general analysis of use cases for various digital solutions;

development of such use cases that would support a smooth transition to digital solutions with minimal cost of resources, their standardization for the grain complex of the BRICS countries;

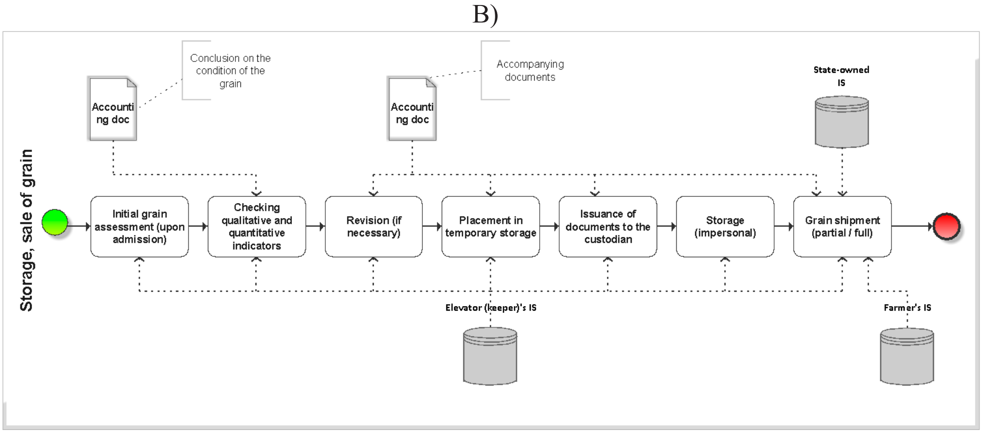
The materials obtained in the previous step were sent to leading industry experts (Rostelecom, ER-Telecom, LANIT, KROK, Agrosignal, etc.) for clarification and certification, considering their existing practices.


Primary grain production (Field)
Weather data, Supplier's IS
State-owned IS
Farmer's IS
Farmer's IS
Growing
Harvesting
Transporting grain from the field
Mixing batches at the farmer's storage area
Cleaning
Part-time grain work
Calibration
Storage grain
Separate batch of grain from each field
Accounting doc
Mixed (unidentified) grain lots
Accounting doc
Accounting doc
Impersonal grain lots

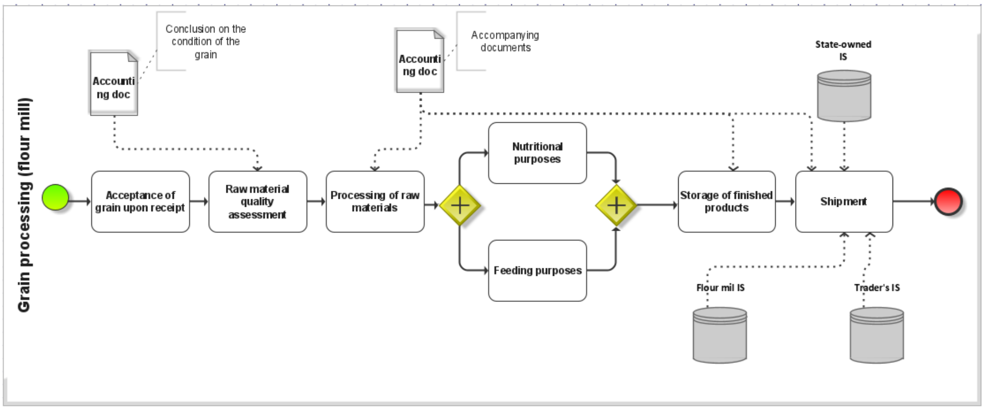
A)


Sales Farmer -> Trader
Accounting doc
Uniform batch of grain
FGIS "Mercury"
Farmer's IS
State-owned IS
Creating a registration request
Only with a positive test result
Preparing the batch for sale
Registration of accompanying documents for the shipment
Formalized results
Shipment of the batch
Quality and safety test results
The quality statement is negative
Farmer's IS
Accounting doc
Change of party owner

B)


Storage, sale of grain
Conclusion on the condition of the grain
Accompanying documents
Accounting doc
Accounting doc
State-owned IS
Initial grain assessment (upon admission)
Checking qualitative and quantitative indicators
Revision (if necessary)
Placement in temporary storage
Issuance of documents to the custodian
Storage (impersonal)
Grain shipment (partial / full)
Elevator (keeper)'s IS
Farmer's IS

C)



D)

Fig. 4. Decomposition of business processes in the domain (A – cultivation, B – sale, C – storage, D – processing).

Depending on the specific goals (objectives) and mainly the capabilities of the consumer (enterprise), various classes of digital tools can be used for transformation. An analysis of practical experience shows that most often all kinds of elements of Internet of Things technology are used, which serve to organize the collection and transfer of information between executive devices (for example, a machine-tractor unit or a separate tractor) and the relevant services of the enterprise, which collect and process information in an automated mode to improve the efficiency of managerial decision-making. Another common digital solution is special software that provides processing of large arrays of primary data (structured and unstructured information) obtained by collection, or integration from several external sources (other enterprise information systems, Internet of Things devices, public banks and databases, etc.) to obtain predicative (prescriptive) analytics.

The use of a combination of the above-mentioned digital solutions usually gives the fastest effect. Using the example of farmers (as the most important participants in the business model), typical options for the use of digital tools (services) and the expected results from their use are shown (Table 1).

The considered solutions provide an acceptable result in a relatively short time in such areas of activity as:

monitoring of soil condition and fertility;

formation of optimal crop rotation;

calculation of rational application rates (ratios) of fertilizers, plant protection products, seeds;

monitoring of weather conditions;

accounting for the movement of resources, raw materials, products or means of production (traceability);

monitoring of storage parameters, equipment for primary part-time work;

monitoring of machinery and the train of machines (detection of movement, malfunctions, forecast and prediction of condition).

Table 1. Elements of technological solutions used for grain complex digitalization.

Name of the business process	Composition of the digital solution	Purpose of the digital solution	Controlled parameters	Expected business effect (calculation)
Basic tillage	Set of sensors for a combine harvester, tractor, train of machines, software	Monitoring (control) – location and movement (downtime) of equipment, fuel consumption, condition of units and drives, ecological parameters of the environment	Amount of work performed	Improvement of the physical, chemical and biological properties of the basal soil layer by 1-3% (considering the applied agricultural technology, land reclamation/irrigation)
Sowing (with fertilization)	Set of sensors for a combine harvester, tractor, train of machines, software	Monitoring (control) – execution of technological operations	Accuracy of seeding, accuracy of fertilization, amount of work performed	Increase of germination energy and total germination by 5-7% (together with applied fertilizers)
Crop care	Set of sensors for a combine harvester, tractor, train of machines, software	Monitoring (control) – execution of technological operations	Accuracy of PPA introduction, amount of work performed	Reduction of the consumption of PPA and fertilizers by 12-14%, increase in yield by 2-10% (cumulative result)
Harvesting	Set of sensors for a combine harvester, tractor, train of machines, software	Monitoring (control) – execution of technological operations	Quantitative and qualitative characteristics of the resulting crop, the amount of work performed, traceability (production)	Reducing the likelihood of product theft by 90-100%
Transportation (any)	Set of sensors for a combine harvester, tractor, train of machines, software	Monitoring (control) – performance of transport operations	Amount of work performed, traceability (during transportation)	Reduction of fuel and lubricants consumption by 14-23%, reduction of the probability of products theft by 90-100%
Storage (primary processing) of products	Set of sensors for storage, software	Monitoring (control) – execution of	Quantitative and qualitative characteristics of the grain pile	Increase in crop safety by 5-8% (cumulative result)

Name of the business process	Composition of the digital solution	Purpose of the digital solution	Controlled parameters	Expected business effect (calculation)
		technological operations	after part-time work	
Material and technical support (for all operations)	Set of sensors for a combine harvester, tractor, machine train, software, analytical platform	Monitoring (control) of fuel and lubricants consumption, consumption of inventory items	Fuel and lubricants consumption, consumption of inventory items (goods and materials)	Reducing the likelihood of theft of fuels and lubricants, goods and materials by 90-100%
Technical support (for all operations)	Set of sensors for a combine harvester, tractor, machine train, software, analytical platform	Monitoring (control) of machinery and equipment condition	Technical readiness of machinery and equipment	Reducing the probability of failure by 10-15%, ensuring the highest possible readiness
Management and documentation	Analytical platform	Monitoring (control) of economic and technological parameters, completed works, document flow	Yield (humidity, weight, contamination), weather conditions (precipitation), soil condition (in the context of fields), consumption of raw materials	Reducing the complexity of accounting and analytical operations (on all processes) by 6-11%

When determining the most appropriate options for digital modernization of the grain complex, it is necessary to proceed from the requirements of ensuring the competitiveness of the products received (primarily the selling price of products), consdiering the existing potential of commodity producers. Depending on the level of production concentration, it is currently economically feasible to implement several options for technical re-equipment of enterprises (Table 2).

Table 2. Options for digital modernization of commodity producers (the "+" sign means the use of a digital tool/service for this category of producer).

Name of digital solutions	Type and size of the enterprise		
	Small	Medium	Large
Transport monitoring system	+	+	+
Field processing and agricultural machinery operation control system		+	+
Equipment condition monitoring system	+	+	+

Navigation system (course indicator)		+	+
DGPS service		+	+
Set of "smart" machines (plows, precision seeding system, precision application of PAA and fertilizers)			+
Service for differentiated application of PAA and fertilizers		+	+
Field mapping service	+	+	+
Yield mapping service (NDVI)		+	+
Crop accounting system		+	+
Grain storage parameters management system			+
Weather station			+
Analytical platform		+	+

For commodity producers with a low level of production concentration (having no more than 5 thousand hectares in economic turnover), it is preferable to use the simplest digital elements for a limited part of business processes:

control of equipment location and movement;

fuel consumption control;

control of the products received (weight only).

For enterprises cultivating from 5 to 25 thousand hectares, it is advisable to use the following elements of digital solutions (on separate technological operations):

control of equipment location and movement.

control of the use of material resources (fuels and lubricants, PAA, fertilizers);

weight control of products during harvesting and grain movement;

control of machinery and technological equipment operation;

For large enterprises (land fund of more than 25 thousand hectares), to ensure the greatest efficiency, it is justified to use the digital solutions mentioned above, as well as:

a comprehensive system for monitoring and controlling the parameters of machinery and equipment in real time, considering differential correction;

a comprehensive system for collecting and processing statistical data on the state of soil, weather, plants, yields, etc.;

tools that ensure transparency of the work of employees in terms of the amount of work performed and the absence of theft of material assets;

an analytical platform for fixing the facts of economic activity, as well as the formation of predicative analytics and an optimal strategy for the company's activities for the planned period [11].

To evaluate the effectiveness of the proposed options for digital modernization of business processes of agricultural enterprises, as a criterion for the effectiveness of using certain digital solutions, a hierarchical system of indicators - intermediate (operating costs, capital investments), basic (cost, selling price) per hectare of cultivated area or a ton of products.

Figure 5 graphically shows the results of evaluating the effectiveness of various options for technical re-equipment of agricultural enterprises. To build this figure, a number of assumptions were made: the calculated efficiency indicators of the introduction of digital solutions were determined for the average conditions of winter wheat cultivation, the cost of basic material resources (fertilizers, PAA, fuel, shift, wages) according to Rosstat data for 2022, the technological map is a typical 100 ha with elements of adaptation to modern equipment and agrotechnical techniques, yield – 32.0 c/ha, consumption of material resources according to the technological map.

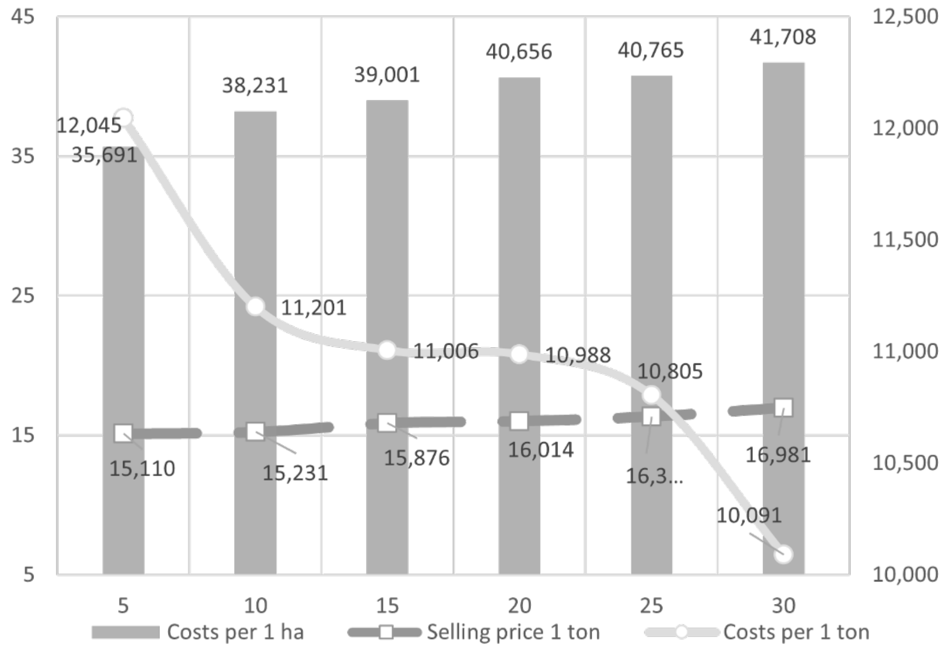


Fig. 5. Calculated indicators of the effectiveness of the implementation of digital solutions (abscissa axis – cost, thousand rubles, ordinate axis – area of cultivation, thousand hectares).

The calculations show that the total costs (operating costs, cost) per ton of products received and per hectare of cultivated area vary in different directions. Depending on the concentration level (the size of the treated area), the minimum is achieved by using advanced technologies and technical means in most business processes. An increase in yield and, as a result, a decrease in the total cost of producing a unit of production should be considered as the source of the effect formation [12, 13].

Thus, for enterprises with a high level of digitalization of business operations and a high level of production concentration (25 thousand or more hectares of land), the cost of cultivating a ton of grain will be lower by 5.1-16.2% compared with enterprises using the simplest digital solutions only for individual business operations. At the same time, per hectare of cultivated area, the total costs for high-intensity enterprises are 8.1-14.4% higher compared to enterprises with a low level of concentration.

A generalizing indicator showing the effectiveness of the technologies used is the price of the products sold. Calculations show that products produced using more advanced technologies equipped with digital solutions will cost 6.7-11.0% higher on the market due to higher quality (protein, gluten, vitreous) and quantitative indicators (yields are higher by 33-39.1%).

4 Conclusions

As the conducted research has shown, various groups of subjects with their inherent goal-setting participate in the process of grain production and processing. To study the semantics and effectiveness of their activities, the following business models were built: behavior (activity), architecture; functional and cost assessment of business processes was performed. As a result, the costs (in value and in kind) attributable to the implementation of business processes throughout the product lifecycle were determined. The most important factor influencing the reduction of production costs is the use of advanced technologies and technical means on a modern digital basis.

Today, the market offers a large number of domestic and imported tools and technologies for the digital transformation of basic, auxiliary and managerial business processes for various participants in the production chain of the grain complex [14]. Based on this, commodity producers, especially small and medium-sized ones, face the question of forming a rational structure of the agricultural machinery fleet, considering various natural and climatic conditions (type and quality of soils, precipitation, stability of weather conditions), organizational and economic (the state of the material and technical base, the presence of outdated energy capacities and a plume of machines, the use of modern agricultural technologies), financial (availability of state support measures, availability of financial resources) and other conditions. Solving this problem is a multifaceted task, which in most cases cannot be solved by commodity producers on their own. A commodity producer should have information in the simplest possible way about the availability of technological and technical solutions that are available and suitable for him to increase the efficiency of his activities. The implementation of such an approach should be based on the identification of typical business processes and linking the technical and economic parameters of all participants in the business chain of production, which at further stages of deployment and adaptation should contribute to a more accurate achievement of the strategic goals of each participant.

It seems appropriate that such an approach should be reflected in the unification of digitalization standards and the implementation of standardized solutions in the BRICS countries (up to a separate machine-tractor unit) at the level of the federal (regional) machine system, which includes a flexible mechanism for assessing the attractiveness (investment, commercial) projects for the digital transformation of the activities of participants in the production chain of the grain complex.

Acknowledgment

This study was carried out with the support of the Priority 2030 program.

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