Basic economic principles of the digital transformation in Russian agriculture

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Abstract. The article presents a monographic analysis of global developments in the digital agriculture. The structural-functional model of the system formation of digital agriculture was proposed. The links between its elements and the external environment was established. The system of organizational and economic principles was developed in transition of commodity producers to digital agriculture, ensuring the maximum efficiency of its functioning and establishing the full mastering of technologies of precision agriculture as an obligatory stage. We developed a private methodology for assessing the economic efficiency and riskiness of investments in the development of innovations in the digitalization of regional crop production.

Keywords: digital agriculture, precision agriculture, big data, innovation, economic efficiency

1. Introduction
Currently, the most important factor for the effective functioning and sustainable development of the economy is its rapid digital transformation. The implementation of this strategy in developed countries has made it possible to rapidly increase the gap in the use of modern information technologies compared to less developed countries, which increases the competitiveness potential of their economies as a whole. For example, advanced European countries are actively developing and implementing innovative digital technologies, including the Internet of Things, artificial intelligence, machine learning, etc. At the same time, some regions of the world still lack telecommunication links that provide seamless access to the high-speed Internet. The analysis showed that the world leader in the development level of the digital economy is the USA, where the share of digital products and technologies in the structure of the country’s GDP is about 11%. At the same time, it should be noted that Singapore leads the world in the export of digital products and technologies with a share of about 6% in the total volume of global exports of such products. The Russian economy lags far behind the leading countries in terms of digitalization.

In these circumstances, the digital transformation of the domestic agro-industrial complex becomes particularly relevant, which ensures food security, creates new jobs and improves living standards in the countryside at a time of high growth rates in global food demand and global climate change. It leads to displacing the usual boundaries of agricultural land-use zones and require the use of innovative resource-saving technologies adapted to these changes. The widespread use of modern digital technologies enables agricultural producers to optimize production processes and contribute to a sustainable development of agricultural economics by generating and analyzing big data, using artificial intelligence and machine learning to support decision-making through automation and robotics in production.

2. Methods and materials
This study observes the data on the state of the material and technical base of domestic agriculture, which are in the public domain, as well as the authors' own research in the field of justifying the priorities of their innovation development. The research includes monographic, abstract-logical, analysis and synthesis, statistical, graphic and modeling methods.

3. Results and Discussion
The digital transformation of the domestic agro-industrial sector should be based on a multidisciplinary scientific approach involving specialists mainly from agricultural, agro-engineering, economic and information fields. However, there are still no generally accepted definitions of the categories of "digital economy" and "digital agriculture" in the scientific and practical environment.

The term "digital economy" was firstly used by Don Tapscott in "The Electronic Digital Society: benefits and implications of the Networked Intelligence Era" in 1994. At that time, the author understood the digital economy as an economy based on the use of information and computer technologies [1, 2]. Many authors also identify the concepts of "digital economy" and "information economy", which, in our opinion, unnecessarily narrows the scope of the digital economy and is quite controversial. In considering this issue, the European Commission notes that the digital economy is now a major factor in economic growth and development [3, 4].

According to the United Nations Organizations, digital agriculture refers to the use of new trendsetting technologies integrated into a single system based on the use of the Internet of Things, big data, machine learning, allowing agricultural producers and other stakeholders in the value chain to improve the efficiency of operational processes [4]. There are also other approaches to define the essence of the concept of digital agriculture. Thus, according to the domestic departmental project "Digital Agriculture", it is interpreted as the conduct of agricultural activities based on modern methods of production using digital technologies that create conditions for increasing productivity and reducing the unit cost of production resources. We should note, that the term "agriculture 4.0" is now widely used in scientific and reference literature, which implies the successful transition from the system of precision agriculture using navigation, field mapping, sensors and means of automation and robotization of production processes to the application of digital technologies. It ensures the formation of a common digital space of domestic agriculture across the region and the country as a whole [5].

Therefore, the digitalization of agriculture in our country will be represented by the creation of a unified digital platform to improve the efficiency of production activities, optimize all its parameters and reduce risks when making management decisions at different levels. A prerequisite for the start of successful formation of digital agriculture is the widespread use of precision farming and livestock breeding technologies by agricultural producers, followed by the automation and robotization of production processes. The creation of a digital infrastructure for the formation and accumulation of large amounts of information about agricultural producers, their resource potential, products, prices, etc. is essential.

The Figure 1 shows the diagram of the stages of digital transformation of domestic agriculture. It includes the completion of the transition of producers to advanced precision farming and livestock breeding technologies, organization of training of highly qualified specialists in agriculture, agricultural engineering, economics and management to work with digital technologies. Creating a digital infrastructure ensures the generation and accumulation of big data, its processing, development of recommendations and ready-made solutions using artificial intelligence and machine learning systems and delivering the results to end-users, as well as increasing the number of integrated digital agricultural solutions, such as the "smart farm", "smart field", "smart greenhouse", etc.
Figure 1. Stages in the digital transformation of Russian agriculture

The strategy and programs for the digitalization of agriculture in Russia should be based on a system of principles and priorities that will jointly ensure the coordination of all processes in this complex, interdisciplinary field of activity, as well as the effective participation of producers, their associations and relevant ministries and agencies in its implementation.

We found that the following key points should guide the transition to digital agriculture.

Firstly, the digital transformation of agriculture should follow a comprehensive approach, which involves exploring the object under study in all its diversity, focusing not only on the essence of the content of digital transformation and the use of new technologies, but also on their combination, the combination and joint application with traditional technologies in the context of the existing opportunities of producers to integrate into the created digital environment and their resource constraints.

All currently available digital technologies, processes, methods and means of their application and other elements of the digital infrastructure are interconnected and complement each other, and therefore only their joint use will enable the necessary transformation of the agro-economy [6, 7]. At the same time, it is necessary to develop common approaches to prioritizing the development of these technologies in order to coordinate sectoral and interdisciplinary RD in the studied area using more
flexible strategies and mechanisms of innovation development that allow for rapid adaptation to constant technological changes.

It is also important to note that without widespread adoption of precision agriculture technology, the industry cannot be fully digitalized. However, in the leading agricultural Krasnodar region precision agriculture technologies are implemented only in 14.3% of agricultural organizations and 2% of peasant (farm) households. Almost none of the agricultural enterprises in the region have fully mastered all its elements. Such a low proportion of enterprises using these modern technologies is due to poor awareness of their benefits and a lack of spare cash on the part of producers to finance investments in the purchase of sensors, attachments and software.

The consistency and comprehensiveness of producer transition to digital agriculture through the integration of various technologies is illustrated by the integration of the Internet of Things and precision agriculture to generate and accumulate large volumes of information, process it, analyze it and use the results in the management of production processes. The concept of the Internet of Things as applied to agriculture is designed to unite the industrial means of production on the Internet into a single information-material complex, capable of simultaneously generating, filling with information and solving labor-intensive production-management tasks in a short period of time. Combining the concept of the internet of things with precision agriculture will make it possible in the future to fully automate and robotize the operations performed for tillage, sowing, tending and harvesting, feeding and maintaining animals [5].

Secondly, the implementation of the strategy of digitalization of domestic agriculture requires rapid qualitative changes in the system of agricultural higher and vocational education. Additionally, it is important to take into account the quality requirements for personnel when mastering new digital technologies and their impact on the labor market in general, and to ensure on this basis the timely professional retraining and professional development of workers in the sector. The automation and robotization of production processes greatly reduce the need for human resources and may even pose a major threat to the very existence of certain professions in the future. At the same time, the skills and knowledge required of workers in agriculture are changing at a fast pace. Therefore, a thorough and comprehensive analysis of the list of occupations is required, especially transformed by the digitalization of the sector and the development of more flexible education systems and programs that can be transformed in time to respond to changes in the labor market to train and retrain highly skilled workers with relevant professional knowledge and skills.

At present, many developed Western countries have already established departments specializing in research in the field of digital economy, which are functioning in specialized institutes. There is also a positive domestic experience in the creation of network educational e-platforms for training specialists in this area, examples of which are the online universities "Land of Knowledge" and "University 20.35". However, the integration of such educational institutions and advanced training institutes with agricultural enterprises is currently poorly organized. The solution to this problem would contribute to strengthening applied research and innovation, identifying new poorly understood trends in production processes, forming new methods of on-the-job training, etc.

Thirdly, the formation and development of digital infrastructure plays an important role for the digital transformation of agriculture. The infrastructure is a system of publicly available information technologies, resources, software and computer tools for their implementation that ensure the effective functioning and development of the information space. It unites many production facilities in agriculture in the region and the country as a whole. Unfortunately, the domestic economy is not fully prepared to ensure a rapid transition to digital development under the prevailing conditions. Investments in the development of digital infrastructure, financed on the basis of public-private partnerships, can bring great benefits for the development of the economy of the region and the country as a whole. At the same time, there is a need to develop production, social and logistics infrastructure in rural areas in parallel with digital infrastructure.

The analysis of domestic and foreign literature allowed us to distinguish 3 groups of digital infrastructure elements: basic, auxiliary and hybrid. The first group is represented by elements that are...
digital in nature and create the basis for digitalization of the industry. These include broadband Internet access, networked databases, big data programs, etc. The second group includes elements designed to ensure the availability, efficient operation and maintenance of the main components of a given system, including data centers, server rooms and supercomputers. Hybrid elements combine the properties of production facilities, information technology and other digital components [8].

Currently, one of the priorities in the formation and development of digital infrastructure is the expansion of access of production facilities in rural areas to the high-speed Internet. For example, unfortunately, only 80.2% of agricultural organizations and 27% of peasant (farm) households in the Krasnodar region have access to high-speed Internet.

Fourthly, the digitalization of agriculture should pay special attention to the development of an innovation transfer system that ensures the dissemination of new technologies in the industry and is closely linked to the digital infrastructure. In agriculture, information and advisory centers and specialized scientific and information digital platforms can serve as the basis for innovation transfer, allowing users to exchange relevant and timely information in a short time. Accelerated dissemination of technologies through the most effective channels of innovation transfer will increase agricultural productivity, reduce unit costs of production resources and increase the production of competitive products. An important factor in the effectiveness of technology transfer is the level of interaction in the "science"->"education"->"production" chain within the existing regional programs of scientific and technological development of the sector, which largely determine research priorities.

International agricultural research centers specializing mainly in agricultural research are highly used in developing countries and provide them with advisory, methodological and informational support in conducting research in the highest priority areas in crop and livestock production [9], the experience of which should be considered in Russia.

The organization of an effective system of technology transfer can significantly accelerate the pace of scientific and technological progress, including the implementation of the strategy of digital transformation of agriculture; otherwise, producers and countries that lag behind in the development and implementation of advanced technologies risk losing the competitive advantage of their products forever.

Fifthly, an important principle of the digital transformation of agriculture is to ensure the security and confidentiality of the data coming from producers. Errors in the collection, storage and use of data can have serious legal and operational and economic consequences for enterprises. Therefore, a balance is needed among preserving confidentiality on the one hand, and on the other hand targeting information limited to the legitimate purposes of the digital platforms and resources being created. Therefore, there is a need for transparency and clarity regarding the ownership and use of data, as well as the establishment of liability for the illegal dissemination and use of the collected information.

Digitalization of agriculture requires large investments in research and development of information technology for the collection, storage and analysis of large amounts of data, software, investment in specialized digital platforms, and investment by producers in innovative equipment and machinery for the adoption of precision agriculture technologies.

Currently, the most widespread in assessing the effectiveness of investment are indicators of net present value, return on investment, internal rate of return and discounted payback period. It takes into account the different value of different lump-sum cash flows generated by implemented innovations at different price and financing structure of innovation and investment projects. We have developed a refined methodology for assessing the economic efficiency of investment in the digital transformation of agriculture, involving the mandatory transition of producers to precision agriculture technology, taking into account all components of the economic effect generated by these innovation transformations [10]:

\[ NPV = \left( C_b - C_p \right) \left[ \frac{1 - (1+i)^{-T}}{i} \right] - I_0 + W + E_w + E_p, \]  

where \( NPV \) is the net present value of the proposed project of mastering innovative technologies by a specific agricultural producer, thousand rubles; \( C_b, C_p \) are direct operating costs of mechanized works,
respectively, under the old and new agricultural technologies and the mechanization tools implementing them, thousand rubles; \( I_0 \) is capital investment in technical and technological modernization of production activities, thousand rubles; \( W \) is proceeds from the sale of released obsolete machinery, thousand rubles; \( E_m \) is discounted cash proceeds from savings on technological materials, including fertilizers and crop protection chemicals, thousand rubles; \( E_p \) is discounted additional cash proceeds from the sale of agricultural products with increasing its volume and quality, thousand rubles; \( i \) is discount rate, in shares; \( T \) is normative operating life of purchased machinery, years.

The proposed methodology for assessing the effectiveness of investment in the development of precision agriculture technologies by producers in the digital transformation of the industry can be used in relation to operating agricultural organizations that have their own machinery and tractor fleet, requiring technological upgrading, and in relation to newly established enterprises for comparative economic calculations in justifying the options of completing their technical base. In this case, it is recommended to complement the proposed methodology with the analysis of investment riskiness with the use of sensitivity methods, scenarios and simulation modelling.

An important component of the economic effect of the digital transformation of agriculture is an increase in the income and profitability of individual producers and the industry as a whole through more informed decision-making in determining the structure of crops, pricing and sales strategies, upgrading facilities and other areas of business operations by using artificial intelligence and machine learning to analyze big data on their production, financial and other activities.

4. Conclusion

Digital agriculture should be understood as agriculture based on advanced precision farming and animal husbandry technologies using the internet of things, artificial intelligence, robots, Big Data and other information and computational-analytical technologies. They provide continuously share of operational information about operational processes to generate general and specific recommendations of production, economic, financial and marketing nature for agricultural commodities.

Digitalization of agriculture is a complex, multidisciplinary process that requires the involvement of agricultural, agro-engineering, economic and information specialists in research and development to create integrated digital farming solutions and platforms that connect producers in a common digital space.

To solve the problems of information protection in the use of digital resources in agriculture, it is necessary to develop effective state regulation mechanisms for the use and dissemination of data, adapted to the conditions of agriculture in each particular region. It is important to note, that the distrust and skepticism of producers who refuse to provide operational information about their activities, can significantly hinder the transition to digital agriculture.

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