Superfrontiers of Crop Production: Artificial Intelligence in Formation the Grain Production Ecosystem

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Abstract. The paper presents a study dedicated to analyzing the role of crop production superfrontiers in forming the agricultural production ecosystem, with a focus on the grain sector. Special attention is given to the superfrontier - data intelligence analytics as an effective tool for optimizing grain production. The authors consider specific examples of successful integration of intelligent analytical methods into practice, identifying their positive impact on improving production efficiency, including cost reduction and business process management enhancement. Among the main barriers to the implementation and use of intelligent technologies and systems, the lack of a unified methodology for collecting and preparing data for training and configuring intelligent grain production systems as a whole is noted. It is shown that artificial intelligence forms the basis of modern monitoring systems, permeating the ecosystem at all levels (supply, production, sales). Considering these features, the article presents a fundamental scheme for organizing the grain production ecosystem.

1 Introduction

Modern benchmarks for the development of the agri-food complex are integrated into the general concept of the country's socio-economic modernization and are defined by trends in the acceleration of technical and technological innovations based on scientific and technical progress. The most significant area of development is digital innovations, which represent priority directions for the modernization of advanced sectors of the economy or frontiers. It is these that provide leadership in individual industries and define the advanced directions of future changes. According to [1], the collection and processing of big data, ensuring a digital breakthrough, occupy a leading position. Frontiers, marking the boundaries of development or the search for new opportunities, are associated with scientific research and form not only their prospective themes but also develop direct production, modifying business processes and labor competencies.

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Considering frontiers as new horizons of economic activity, it is necessary to highlight those directions that are the most important and promising, covering a wide range of problem-oriented opportunities. They can be characterized as superfrontiers. Today, these include: space exploration, artificial intelligence, biotechnologies, environmental sustainability, and more.

Digitalization is becoming an increasingly central component of the transformation of agriculture sectors. It opens new horizons for obtaining timely and relevant information, acquiring services, access to agricultural product markets, revolutionizing supply chains, breaking down traditional barriers to farming, and offering new solutions for routine operations. Importantly, digital tools create new ways of interaction, ensuring the sustainability of production and creating new opportunities for economic entities. By facilitating the implementation of new analytical, business, and relational models into the practice of agribusiness, digital technologies allow for the optimization of the value creation chain, achieving increased efficiency of the resource base, and as a consequence – maximizing profit in challenging climatic conditions.

Grain production is the most important sector of agriculture, occupying a leading position in the hierarchy of food security. Over the last decade, self-sufficiency in grain has reached 157.8% (calculated according to [2, 3]) with a norm of 95%. Some researchers believe that Russian agriculture is the most efficient in the world since it receives the least amount of preferences from the state. For example, the size of state subsidies in the cost of agricultural products in Russia is only 3%, while in European countries it is 30%, the amount of state support per 1 km² in Russia is $5.3 thousand, whereas in the USA it is $23 thousand, in the countries of the European Union - $58 thousand, on average, state aid per 1 hectare of arable land in Russia is $35, in European countries - $800, in China - $1500 [4]. The data convincingly demonstrates the relatively stable, independent, and self-sufficient state of grain production in Russia.

The future of grain production and its maintenance at a high level is linked to the development opportunities of the industry, which are provided, among other things, by superfrontiers. Among the main ones, the application of data intelligence analytics for production optimization can be highlighted. The widespread use of sensors and automated control systems can significantly increase the efficiency of the grain field. The future transition to "Internet of Everything" technologies will ensure the application of deep learning methods in searching for patterns in grain production business processes, optimizing agricultural operations, and solving predictive tasks [5]. Convolutional neural networks, as superfrontiers, are capable of transforming the very appearance of direct grain production, essentially turning it into a "human-free" production zone. In particular, computer vision technology, using deep machine learning algorithms, allows forming such image recognition systems that, without human participation, give the possibility to perform certain business operations today, offering unlimited opportunities for modifying technological processes in the future [6]. One of the modern directions of superfrontiers is the monitoring of agricultural diseases based on artificial intelligence technologies, which becomes an effective method of plant protection, allowing the creation of systems capable of automatically identifying and classifying various grain afflictions even at early stages when they are still not possible to visualize [7-9].

Today, various systems are used for disease monitoring, for example, agronomist robots equipped with sensors gather information about the condition of plants, cloud technologies participate in data processing, machine learning algorithms, by comparing the collected data with known models, identify diseases. Farmers, armed with mobile applications (which can learn from a large amount of data), have the ability to determine diseases from the photographs taken and sort them by severity, to prioritize agricultural work. Overall, plant disease monitoring allows agricultural producers to respond more quickly and effectively to

plant problems, reduce costs on chemical treatments, and increase production efficiency. However, all these technologies have a significant drawback – they are disjointed and disintegrated, do not always provide complete information about the object, are limited in predicting future actions, are not properly secured, and require constant investments in software, equipment, and training. Most importantly, there is a lack of a unified methodology for collecting and preparing data for training and configuring intelligent systems for grain production as a whole [10]. [10].

The diversity of monitoring tasks dictates the need to create a unified grain production system, the unifying foundation of which is envisioned as its digital ecosystem based on artificial intelligence.

2 Materials and methods

As a methodological premise, elements of sociogenesis theory were used in combination with the main concepts of agribusiness. At the same time, the basic paradigm remains focused on regulatory documents that define the directions for the development of grain production in the near future, informational-technological developments of modern domestic and foreign agricultural economists in the light of laws and trends of digital transformation (Altukhov A.I., Trubilin A.I., Nechaev V.I., Bershitsky Y.I., Moore, Metcalfe, Gilder, etc.), forming new business models, value and life motivations.

In conducting the research, data from the Federal State Statistics Service of the Russian Federation, reports from the ANO "Digital Economy" and APR of Moscow, statistical compilations from the National Research University Higher School of Economics were used.

3 Results

Within the digital transformation of grain production, the concept of a digital ecosystem can be interpreted in various ways. Broadly, it is a self-organizing, scalable, and sustainable system that combines diverse digital components and their interactions for the common good. Such an ecosystem facilitates information exchange, internal cooperation, and innovations, providing a foundation for collaboration and growth.

In a narrow sense, a digital ecosystem refers to a collection of interconnected microservices and applications combined into a global service or product, creating a convenient environment for users. This allows them to meet diverse needs through a single system, often based on a subscription or community membership.

Considering the business practices of both Russian ("Yandex", "MTS", "Sber") and global ("Amazon", "Alibaba", "Microsoft", "Siemens") companies that implement large-scale digital ecosystems, it becomes clear that a key factor in their successful functioning is the presence of a high-quality digital platform. The platform serves as the foundation for integrating innovative products and services provided within the ecosystem and ensures their harmonious interaction, creating value both for the platform-owning company and its customers.

In Russia, the departmental project "Digital Agriculture" [11] aims to create a unified national agro-platform. According to the developed concept, it includes seven sub-platforms, each oriented towards a specific direction and addressing specific tasks, ensuring a comprehensive approach to developing the digital ecosystem in agriculture. The drivers for the development and implementation of the digital platform were factors that facilitate the formation of the digital landscape in agriculture and stimulate the development of digital solutions in the grain sector:

1) Reducing information asymmetry: Digital platforms make a significant contribution to eliminating information asymmetry in the market, which is particularly relevant in the context of the grain sector, where access to information is often unevenly distributed among different market participants.

2) Management of large agro-industrial complexes: With the emergence of large agricultural enterprises and their combination into complexes, there is a need for effective management and monitoring of production processes. Digital platforms provide tools for systematic and efficient management of large data volumes, thereby improving production indicators.

3) Increasing efficiency and competitiveness: Modern challenges and technological changes require agriculture to enhance efficiency and competitiveness. Digital solutions aim to optimize processes, increase productivity, and ensure sustainability in changing conditions.

4) Integration of digital solutions: Digital platforms create a unified information space for farmers and agricultural organizations, promoting the integration of various digital solutions.

5) Development of digital skills: Creating conditions for learning and developing digital skills among professionals in agriculture becomes an important factor, considering the dynamism of digital transformation. Ensuring access to education and training in digital technologies facilitates broader innovation penetration into the sector.

The key point is that the digital platform serves as the foundation on which the grain production ecosystem can be built. This ecosystem is understood as a complex of actors, organizations, institutions, and services united on the digital platform, interacting with each other within the process of grain production across the entire value chain, from planning production activities to the realization of grain (fig. 1).

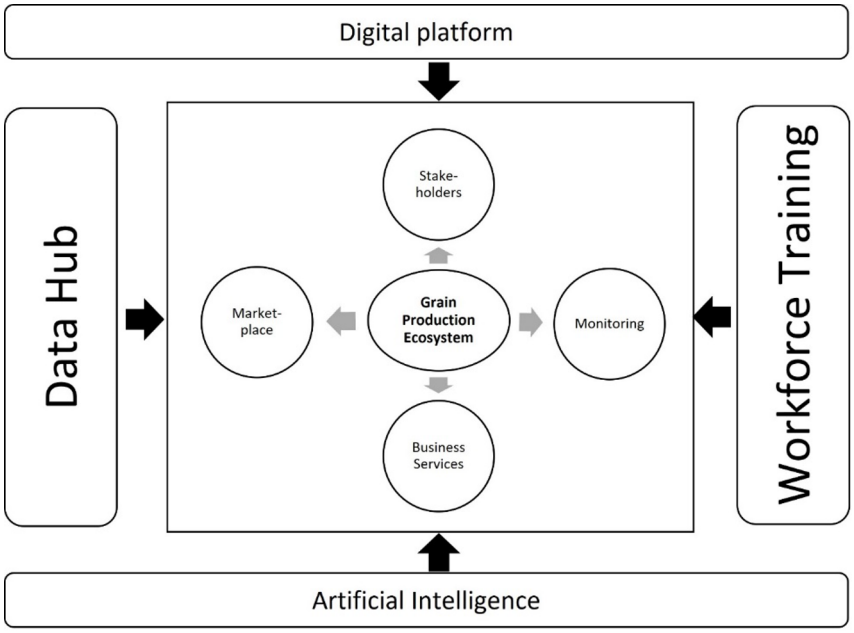

Fig. 1. The Principal Scheme of Organizing the Grain Production Ecosystem

The key element of the grain production ecosystem is the superfrontier – artificial intelligence, which plays a fundamental role by ensuring effective management and optimization of various processes, from field monitoring to warehouse inventory and sales

management. AI in the grain sector facilitates solving complex tasks such as yield forecasting, risk management, and developing managerial strategies to maximize profits. Machine learning processes allow for real-time management adaptation, considering the variability of cultivation conditions, climate, and market dynamics. Efficient data analysis using AI reduces decision-making time frames, crucial in agriculture where timing is of immense importance. Accurate forecasts enable farmers to adapt their strategies based on changing conditions, ensuring a more resilient and effective approach to farming.

To support the training and updating of intelligent systems, which underpin the analytical services and digital solutions for agriculturists, the ecosystem includes a data hub, one of the key elements of its infrastructure. The hub enables the collection, storage, processing, and provision of access to a variety of data necessary for effective management and decision-making in the grain sector, acting as a centralized repository that consolidates information from various sources, such as field sensors, meteorological stations, technical equipment, and other monitoring systems. Another function of the hub is to facilitate interactions not only within the system but also with the external world, including interactions with other economic sectors, financial institutions, and providing access to global agricultural goods markets. Such incorporation allows the ecosystem to adapt to changing conditions, respond to external challenges, and efficiently utilize opportunities provided by the external environment.

Finally, to ensure successful integration of AI into grain production processes, producers must possess the knowledge and skills for effective interaction with digital technologies. In this context, workforce training becomes a strategic task, which can also be addressed within the ecosystem. Given the dynamic nature of changes in agriculture, regular knowledge and skill updates become a key factor in successful adaptation to new challenges and opportunities. Staff training is focused on developing specialized competencies required for working with AI and digital technologies in grain production, such as technologies for intelligent data analysis, computer vision, and digital solutions that integrate information technologies into a unified system of business processing across the entire value chain.

4 Conclusion

The formation of a unified ecosystem within grain production plays a central role in integrating and optimizing all business processes related to the production and sale of grain crops. It's important to emphasize that the ecosystem is not just a collection of independent components, but a well-coordinated mechanism where each part plays its role, contributing to the common goal of effective and sustainable grain production. For instance, farmers can use intelligent services and recommendations from grain production experts to optimize the grain growing process. Financial support and access to sales markets for agriculturists are provided through business services and marketplaces integrated into the ecosystem. In turn, research organizations gain access to a central database on crop conditions and the circumstances under which these conditions were recorded, which can be applied in scientific research. Information transmitted by farmers about the phytosanitary condition of the fields (both directly within data preparation programs and indirectly through communication channels with other participants - forums, platforms, applications) can be processed by big data algorithms, and the knowledge extracted from them promptly passed to the Federal Service for Veterinary and Phytosanitary Surveillance to alert and prevent spontaneous, epiphytotic development of grain diseases.

The superfrontier – artificial intelligence, plays a critical role in building and implementing the ecosystem, which in turn forms the basis of monitoring systems permeating the ecosystem at all levels (supply, production, sale). Based on the results of intelligent crop monitoring, areas requiring special attention and care are identified, including protection from diseases and pests; weather monitoring allows farmers to make decisions on irrigation,

crop treatment, and harvesting; tracking resource expenditure, including water, fertilizers, plant protection products, fuel, and so on, enables efficient use by producers, and for supplying organizations - determining the exact timing and volume of deliveries; results of environmental monitoring help producers monitor the impact of their activities on the environment and, if necessary, take measures to reduce negative impacts, while regulatory bodies monitor compliance with environmental norms and standards by producers; the state of ecosystem protection, its components is ensured by phytosanitary monitoring, and ensuring traceability of grain batches and their processed products - monitoring the market of grain production products.

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