Smart agriculture as the embodiment of the symbiosis of the technological and intellectual potential of the agricultural sector

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Abstract. The work examines the features of "smart agriculture" as a concept corresponding to the functioning of the agricultural sector in conditions of large-scale use of digital technologies within its framework. It is noted that, along with their use, its most important driving force is the application of the knowledge and skills of workers, thanks to which these technologies can significantly increase the efficiency of the functioning of agricultural production systems. In this context, it is noted that there is significant potential in this context for improvement, and in a number of aspects, significant transformation of the activities of information and consulting services operating in the agricultural production sector. One of the promising solutions is the formation of a unified digital platform for agricultural consulting, uniting information and consulting services located in various regions of the country into a single network of interaction.

1 Introduction

The current stage of development of agriculture is increasingly associated with the active use of a wide range of different digital technologies, on the one hand, helping to significantly increase the efficiency of agricultural production activities, and on the other, ensuring a reduction in its negative impact on the environment. These technologies make it possible to intelligently intervene in the development of agricultural crops and significantly save the resources necessary for production. Thanks to the spread of digital technologies, not only the quantitative and qualitative parameters of manufactured products are significantly improved, but also the degree of sustainability of the development of the entire agricultural production system increases.

One of the manifestations of this trend was the formation of the concept of "smart farming". The main content of this concept, sometimes defined as "precision agriculture," defines, as the most important postulate for ensuring the environmental and economic efficiency of agricultural production, the implementation of an integrated approach to the use within its framework of various information and communication technologies, such as sensors for monitoring soil, water, lighting, humidity and temperature, custom software

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solutions, Internet of Things platforms, GPS and satellite positioning systems, robotics and big data analytics. Using these tools, growers can access a wide range of data, make informed decisions, and take action without being in the field.

2 Materials and methods

Considering the essence of the approaches used in foreign and domestic scientific literature to determine the essential content of the concept of "smart agriculture", it can be noted. that they are not distinguished by their uniqueness.

Thus, G. Singh and his co-authors define the concept under consideration as a phase of development of agricultural production, replacing "industrial" agriculture and based on the active introduction of digital technologies into almost all technological processes. A group of Chinese experts understands smart agriculture as a new way of agricultural production, which, through the deep integration of modern information technology, promotes information perception, quality decision making, intelligent management, precise investments and personalized service. K. Zinke-Wellmann and K. Charvat note that the smart agriculture system is focused not only and not so much on the introduction of information technologies in agricultural production, but also to a greater extent on the creation and use of new knowledge with the help of these technologies.

Considering the position of Russian researchers, we note that A.N. Anishchenko also connects the content of smart agriculture with the implementation of technological solutions, the target orientation of which is determined by the acronym SMART (Specific, Measurable, Achievable, Relevant, Time bound), that is, specific, measurable, achievable, relevant, taking into account time restrictions. In turn, A. Ivanov and V. Moiseev identify the large-scale use of innovative solutions as its key characteristic.

A number of researchers point to the synonymy of the categories "smart agriculture", "intelligent agriculture" and "digital agriculture".

Many experts identify smart agriculture with the implementation of the postulates of the so-called concept. "Agriculture 4.0", which is understood as a new stage in the evolution of the concept of precision agriculture, the tools of which are complemented by the use of technological solutions of the "Internet of Things", a system for using digital agricultural technologies on a mass scale, a production concept, the paradigm of which is the use of "big data" processing tools » when making decisions, etc.

However, it should be taken into account that the substantive characteristic of "smart" can, in our opinion, be applied to such agricultural production, which, along with the use of modern digital technologies, is based to a very significant and often decisive extent on the application of the knowledge and skills of workers, thanks to which, in fact, these technologies can significantly increase the efficiency of agricultural production systems. It is in this theoretical and methodological context that the concept of "smart agriculture" is considered in this work.

Among the tools used in the research process, monographic, dialectical, empirical, comparative, abstract-logical methods of scientific knowledge should be noted.

3 Results

In general, it can be stated that smart agriculture is understood as an approach that involves the use of human intellectual abilities as a driving force of production, which, in interaction with various digital technologies, make it possible to provide solutions to problems at a qualitatively different level compared to previous stages of development of agricultural

production. , determining the sustainable dynamics of development of agricultural production that meets the requirements of the emerging knowledge economy.

The driving force behind smart agriculture is the Internet of Things (IoT), which, through the use of sensor systems of a wide variety of directions, makes agricultural production processes much more manageable and, as a result, effective within a whole range of areas, the main ones of which can be identified as follows:

- Data collection. One of the most important benefits of using IoT capabilities in an agricultural production system is enabling the collection and presentation of large volumes of data in real time. Thanks to smart sensors, it becomes possible to obtain up-to-date information about a wide variety of factors affecting crops. This allows you to control their development processes using monitoring systems and analytical information processing.
- Product quality. An ecosystem connected to the Internet of Things allows you to optimize the conditions for growing plants and maintain the most important parameters of agricultural production, which inherently contributes to improving the quality of agricultural products.
- Cost and resource management. Smart sensors help reduce resource usage by using them more efficiently and effectively. This situation allows you to optimize costs and manage production processes more efficiently.
- Efficiency of the management system. Smart agriculture technologies help improve management efficiency. Analysis of data obtained from the use of Internet of Things systems. allows you to increase the efficiency of equipment use and work activity.
- Entrepreneurial potential. Smart agriculture opens up new opportunities for agricultural producers in the context of choosing the forms and directions of their activities. In particular, there is an opportunity to implement adaptive approaches to running agribusiness, taking into account a wide range of factors influencing its development, and quickly make adjustments to the strategy and tactics of functioning in a competitive environment.

The cycle of intelligent farming based on the use of the potential of the Internet of Things includes the stages of observation, diagnosis, decision-making based on certain algorithms and the implementation of actions that practically implement these decisions. At the same time, for example, A. Triverdi and N. Nandeja note that this cycle has a cyber-physical nature.

A wide range of IoT tools can help solve various problems in the agricultural production system, with precision agriculture and agricultural automation being two key areas of improvement.

It should be noted that the terms “smart agriculture” and “precision agriculture” are often defined as synonyms, which should be recognized as erroneous. While precision agriculture focuses on identifying differences in parameters characterizing the condition of cultivated lands and the characteristics of the development of agricultural crops on them, smart agriculture is of paramount importance is ensuring access to the data obtained and their use. In other words, data obtained from smart farming practices can be used to optimize precision farming systems.

Precision farming allows for individual processing of individual areas of each field, optimizing the use of resources. At the same time, for example, in North America by 2025, precision farming systems will presumably cover 32% of the total area of agricultural land.

One of the most widely used precision farming technologies is the parallel driving system, which allows field work (plowing, cultivation, sowing, fertilizing, harvesting) to be carried out with maximum precision, including at night. The importance of this opportunity can hardly be overestimated in the context of tight deadlines for carrying out certain work.

The use of a parallel driving system based on the reception of satellite navigation signals allows you to regulate the movement of agricultural machinery across the field with an accuracy of up to 2.5 cm, extremely reducing the area of uncultivated or double-treated sections of the field, the idle length of the equipment and the width of the headland. As a result, the reduction in the specific amount of resources used (fuel, seeds, fertilizers) reaches 20%.

In addition, precision farming technologies make it possible to monitor soil moisture levels around the clock, ensuring rational automatic watering of only those areas where it is necessary.

At the same time, analyzing the experience of introducing precision farming systems in a number of farms in the Rostov region, it is possible to highlight a basic diagram of the practical implementation of this approach.

The initial stage of this process is to clarify the areas of agricultural land using a global positioning system navigation receiver and related software.

At the second stage, a detailed agrochemical examination of the fields and their individual sections is carried out, which makes it possible to determine the variability of the characteristics of the soil cover within each individual field.

The third stage consists of implementing a mechanism for parallel driving of agricultural machines when applying fertilizers, ensuring the formation of more optimal agro-ecological conditions for crops and the environment for their development.

At the fourth stage, remote sensing of the state of agricultural land is carried out, based on the results of which the current state of agricultural land is established and specialized maps and cartograms are drawn up, forming the basis for carrying out appropriate agrotechnical measures.

The content of the fifth stage is to create yield maps using equipment installed on agricultural machinery to monitor it in individual areas of the field, which helps to identify areas with low productivity of cultivated crops.

Finally, at the sixth stage, field data is analyzed and management decisions are made using a decision support system that provides collection, accumulation, processing, storage of data and the formation of programs for the implementation of agricultural technologies.

Unmanned aerial vehicles are also increasingly used in agriculture to assess the condition of crops, carry out irrigation, spraying and implement many other technological functions.

In turn, precision livestock farming allows for monitoring the condition of animals, in particular, in the context of selecting an individual diet, analyzing the health status of each individual animal, selecting the most productive pasture lands for grazing animals, etc.

Automated intelligent farming systems are based on the principles of fuzzy logic, which involves the use of methods that resemble human thinking, and based on the analysis of input data, they allow the final decision to be made. To a large extent, this forms the basis for the development of technologies based on the principles of artificial intelligence in the agricultural production system, which, according to a number of experts, along with robotization processes, will be a key trend in the development of smart agriculture in the coming years.

Automation, for example, plays an important role in “smart greenhouses,” where intelligent systems based on real-time data processing regulate the microclimate, reducing the need for manual intervention. In turn, blockchain technology is used to securely store large amounts of data on a centralized basis. Nowadays, an increasing number of processes are beginning to be based on ensuring interaction between blockchain and Internet of Things technologies. This helps create a secure environment for storing and processing data. For example, smart sensors in a greenhouse can serve as a local blockchain that is centrally controlled by a person.

All of these technologies, together with the application of knowledge and skills of specialists that ensure their effective application, make it possible to provide a fundamentally different content of agricultural production processes, corresponding to the development paradigm of the modern knowledge economy.

4 Discussion

The support of the state and specialized organizations plays an extremely important role in the process of transition of agriculture to the "smart" path of development, which can be demonstrated based on an analysis of the experience of Japan.

In particular, the National Agriculture and Food Research Organization (NARO) places a high priority on the development and use of smart technology solutions in agriculture. In support of its activities, the Japanese government has implemented a number of initiatives to promote the adoption of innovative technologies aimed at improving management processes and increasing productivity in various agricultural sectors. One such initiative involved improving global positioning system (GPS) capabilities for mountainous terrain. It launched the Quasi-Zenith Satellite System (QZSS) in 2010, providing precise geographic and meteorological data to automated agricultural systems.

Government support, including improving the legislative framework, plays a major role in stimulating the development of automated farms, which can achieve impressive results. Thus, the introduction of unmanned tractors increased the efficiency of farms that use such technological solutions by 30%.

However, the cost of implementing such solutions is often a difficult limiting factor for many agricultural producers. To eliminate high price barriers, the Japanese government initiated the formation of farmer corporations aimed at distributing costs among their member farms. Training programs and remote video conferencing consultations with industry experts help farmers gain the necessary knowledge and skills. The ultimate goal of these initiatives is to create a smart value chain that streamlines the entire process of growing, harvesting and distributing agricultural products to ensure maximum efficiency.

NARO carries out research and development in the field of creation and implementation of smart agricultural technologies in order to ensure that the development parameters of the agricultural sector comply with the postulates of the Fourth Industrial Revolution. In particular, the organization's goals for the period until 2030 include the development of smart agriculture systems, cooperation with the private sector in solving innovative problems, the creation of an intelligent value chain, the promotion of basic agricultural knowledge and technologies, as well as the development of fundamental technologies through the Research center for agricultural information technologies, among which the development of robotics stands out.

It is the support of such structures that facilitate the diffusion of modern technological solutions that largely determines the success of the development of smart agriculture. At the same time, extrapolating this situation to domestic specifics, it is necessary to emphasize that there is significant potential in this aspect for improvement, and in a number of aspects, significant transformation of the activities of information and consulting services operating in the agricultural production sector. This seems especially important in the context of the fact that, as we have already emphasized, it is the knowledge and skills of specialists that form the intellectual potential of the agricultural sector that determine the success of the development of smart agriculture systems.

Taking into account the realities of the modern era, a number of experts quite rightly point out the need to focus on the implementation of an innovative digital paradigm for the activities of information and consulting services, which is developing on the basis of the principles of the quadruple innovation helix, combining the efforts of business,

government, scientific and civil communities. The main element within this system is knowledge, which, circulating between subsystems, is transformed into innovation.

In our opinion, it may be more preferable to use a more advanced model of such a spiral, in which the environment serves as its fifth element, which indicates the nature-centric nature of smart agriculture systems.

At the same time, it seems extremely important to ensure network interaction of information and communication services, allowing access to the necessary information resources and joint resolution of emerging problems by interested parties, regardless of their location. One of the promising solutions in this context may be the formation of a unified digital platform for agricultural consulting, uniting information and consulting services located in various regions of the country into a single network of interaction.

Considering the essential features of digital platforms, it can be noted that they are defined as an instrumental environment within which participants in economic relations gain the opportunity to interact with each other and carry out certain operations online. At the same time, the service functionality that such platforms possess provides a significant reduction in the costs of business interaction, helping to strengthen ties between its parties.

Speaking about the relevance of the development of platform technologies in the agricultural sector, it should be noted that in October 2022 it was announced the creation of a unified digital platform for agriculture, which united all information systems of the Ministry of Agriculture and Food of the Russian Federation. In the future, it should become the core of an industry digital ecosystem that will unite multi-level information systems of both the agricultural sector and a number of related industries.

In our opinion, it is advisable to provide the functionality of one of its subsystems to a unified digital platform for agricultural consulting. The capabilities of the platform will provide the opportunity to provide a wide range of consulting services to agricultural producers not only geographically tied to the area of operation of a specific information and consulting service or center, but also operating in other regions of the country, which will allow the involvement of specialists with more extensive knowledge or greater practical experience in this process. within a certain field of activity, including highly specialized ones. In addition, the organization of online interaction between platform participants will undoubtedly be one of the catalysts for the introduction of innovative approaches and innovative technologies in an increasing number of farms of various formats, involving them in the process of organizing their activities on the principles of smart agriculture as a synthetic phenomenon formed by the interweaving of intellectual and innovative potential.

5 Conclusion

The expanding use of smart agriculture technologies has undoubted potential for a revolutionary transformation of the agricultural production sector, contributing to the creation of more sustainable and efficient forms of its organization. Using Internet of Things technologies and analytics based on the processing of received data, manufacturers can not only improve the economic and environmental efficiency of their activities, but also ensure greater transparency in food production chains and, as a result, increase their safety parameters. At the same time, skillful handling of digital tools, on the one hand, and the knowledge of the specialists using them, makes it possible to bridge the technological gap, which, as a rule, occurs between large and small agricultural enterprises, which, in turn, can significantly increase the competitiveness of the latter.

This approach is a form of not only a new organization of agricultural production processes, but also the practical implementation of the postulates of the “green revolution”, the basis of which is the dominant role of environmentally-oriented digital technologies, such as precision agriculture, the Internet of things, big data analytics, unmanned aerial

vehicles and robotics. Overall, it forms the basis for the practical implementation of more productive and sustainable ways of conducting agricultural production activities, ensuring the long-term viability of the systems of environmental-economic interaction that accompany the process of agricultural production.

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