Trends in the development of digital agriculture: a review of international practices

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Abstract. In the modern world, information and communication technologies play an important role in the development of agricultural production, influencing the social, economic and political life of society and the state as a whole. The introduction of such technologies makes it possible to improve the quality of products and services, and to increase the export of agricultural and food products. Existing agricultural technologies make it possible to analyze and process large amounts of information, combine various information resources on one platform, control and reduce production risks, meet the information needs of a wide range of stakeholders, from the state to the end consumer, and guarantee security in cyberspace. An important role in the digitalization of agriculture is played by the resource potential of people employed in agriculture. Particular attention is paid to the development of scientific centers, training courses, where modern high-precision agricultural technologies are studied in-depth. The authors of the article examined the trends in the development of digital agriculture in the countries of Europe and Central Asia, where agricultural production is the fundamental basis of state policy.

1 Introduction

In 2020, the United Nations has determined the directions for the sustainable development of the world economy for the period up to 2030. One of the key areas was the development of information and communication technologies in the field of agriculture. On the basis of digital technologies, it is supposed to guarantee the sustainability of the social and economic spheres of society and the state, which will allow by 2050 to provide more than 90 % of the demand for global agricultural production through the introduction and development of an innovative agricultural ecosystem.

Modern digital technologies are able to instantly solve the assigned tasks, offer the most cost-effective production models, analyze and process large amounts of information, combine various information resources on one platform, control and reduce production risks, and satisfy the information needs of a wide range of stakeholders. This is not a complete list of the possibilities of modern digital technologies that can be adapted to the needs of agricultural activities [4].

Many countries have adopted a systems approach in the development of digital agriculture, which included:

1) the conclusion of international agreements, within the framework of which assistance was provided, with the participation of the UN Food and Agriculture Organization in the development of a national strategy and the formation of digital agriculture (Albania, Armenia, Georgia, Macedonia, Tajikistan, Turkey, Ukraine);

2) development of long-term government programs for the development and maintenance of digitalization of government and departmental services (Moldova, Georgia, Albania, Armenia, Russia, Kyrgyzstan, Belarus, Kazakhstan);

3) the development of a Digital Roadmap, within the framework of which digital transformation was implemented and information and communication technologies were introduced into the agricultural sector (Kyrgyzstan, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Moldova, Montenegro, Tajikistan).

Based on the data of the report of the International Telecommunication Union and the Food and Agriculture Organization of the United Nations [3], the authors considered digital agriculture in Europe and Central Asia (Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Montenegro, Northern Macedonia, Russian Federation, Serbia, Tajikistan, Turkey, Turkmenistan, Ukraine and Uzbekistan). The choice of these countries is not accidental, they are actively developing digital technologies and are implementing information and communication technologies in the agricultural sector.

The digital farming experience was reviewed in eight key areas:

1) Agricultural management (participation of public authorities and various departments in the development of agriculture using digital solutions in order to stimulate production, resource efficiency and economic growth).

2) Strategy and investment (implementation of targeted long-term programs for the development of

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sustainable digital agriculture supported by government subsidies and investments).

3) State electronic services and software products (availability of public services aimed at interaction between the state and agricultural organizations and farmers).

5) Network infrastructure and interoperability (provision of rural areas with broadband (3G and LTE), monitoring system, introduction of new data collection standards).

6) Consulting and exchange of experience (training of farmers and people involved in agriculture, holding round tables, forums, exchange of experience at regional and international platforms, in order to expand knowledge of the current trend in the development of digital agriculture).

7) Legal support (legislation regulating digital agriculture).

8) Labor potential (training digital literacy of farmers and people employed in agriculture, increasing the level of skills in working with digital technologies in agricultural production).

2 Results

When assessing the resource potential for the development of national digital agriculture, the International Telecommunication Union (ITU) and the Food and Agriculture Organization of the United Nations (FAO) used an empirical method, which included three stages of collecting, preparing and processing data on agriculture [6].

At the first stage, questionnaires were sent to the countries with a list of questions regarding the current state of the national level of digitalization of public services and the coverage of the territory with broadband Internet. Based on the analysis of the information received, proposals for programs and strategies aimed at the development of national digital agriculture were developed.

At the second stage, ITU experts systematized the data obtained at the first stage, as well as requested additional and clarifying information from the ITU, World Bank and UN databases. For each country, ITU experts created a profile that includes data on the infrastructure of information and communication technologies, a set of factor indicators for digital agriculture, as well as an overview of the state strategy for the development of digital agriculture, state programs supporting the digitalization of services.

At the third stage, experts reviewed the technical capabilities of digital agriculture, software in the field of agricultural production.

Table 1 shows the indicators of international indices of agriculture in Europe and Central Asia as of 2020 [6].

Despite the decline in the share of the agricultural sector in the national gross product, most countries attach great importance to the development of agriculture using information and communication technologies. As world practice shows, the creation of digital agriculture takes on average five years, with the active support of the public sector, as well as foreign investment [1].

The countries of Europe and Central Asia, the state policy of which is focused on the development of agriculture in a digital format, have determined the deadlines for the completion of the formation of their national systems of digital agriculture:

1) by 2021 in the countries of Albania, Azerbaijan, Montenegro, Kazakhstan, Bosnia and Herzegovina, Uzbekistan;

2) by 2022 in the countries of the Russian Federation, Belarus, North Macedonia;

3) by 2027 in Georgia.

Table 1. Indicators of digital agriculture indices in the studied countries

Country	World Economic Forum Executive Opinion Survey (max – 7)	Global Competitiveness Index indicator "Future orientation of government" (max – 7)	Rank in term Of Global Competitiveness Index
Azerbaijan	5.24	4.72	20
Tajikistan	4.46	4.46	27
Kazakhstan	4.65	4.13	39
Montenegro	4.14	3.95	50
Russian Federation	4.83	3.87	54
Albania	4.67	3.87	56
Armenia	4.42	3.84	61
Georgia	3.66	3.83	63
Turkey	3.38	3.82	64
Serbia	4.16	3.55	81
Kyrgyzstan	3.89	3.16	105
Moldova	4.43	2.99	114
Ukraine	4.43	2.98	115
North Macedonia	3.62	2.88	120
Bosnia and Herzegovina	3.82	2.13	137

It is assumed that by the specified dates, land identification systems will be formed, coverage of the territory of broadband infrastructure will be 100%, and agricultural systems will be integrated with the public sector [3].

Examining the issues of maintaining and shaping digital agriculture in Europe and Central Asia in terms of key positions, we see that their main tendency is to create a single information resource on the web portals of industry services. For example, in Azerbaijan, an electronic agricultural information system (EKTIS) has been developed with modules covering the business processes of agricultural producers, with the ability to conduct analytical reporting and modeling, and aimed at operational management [2]. This system is integrated with the information resources of state institutions and information interaction between state structures is carried out in real time. About 500 thousand farmers are already registered in this system. Since 2020, work has begun on the creation of a spatial data infrastructure for rural enterprises (RBIS) based on GIS. This system will

contribute to the expansion of information flows of the agricultural market and provide farmers with access to digital spatial data. In order to effectively conduct monitoring studies, a Pasture Management Application has been created within the framework of the European Space Agency project, focused on meeting the needs of the public and private sectors.

An integrated information environment has been developed in Armenia, uniting all electronic databases on an online platform. Such a web portal provides the ability to provide a number of government services in real time and provide access to registries. Within the framework of the Strategy for Sustainable Development of Agriculture (Vision 2029) until 2029, it is planned to develop a centralized electronic system in the agricultural sector, with the following modules: 1) register of farmers; 2) a system for counting and registering livestock; 3) a database of digitized maps of agricultural land and agrochemical research; 4) a database of technical and economic indicators and standards in the agricultural sector. The same principle of the set of modules is assumed by the digital agricultural system of Bosnia and Herzegovina.

Turkey is successfully implementing the Digital Agricultural Project, which has installed about 30 stations that provide farmers with monitoring data for moisture and soil quality, and display warnings about risks associated with weather and pests. The meteorological observation system is effectively applied. Data from the stations are processed every minute, and in critical situations, agrometeorological warnings are sent via SMS. Since 2020, with government support, the Intelligent Agricultural Platform has been introduced, on the basis of which agricultural data is analyzed and the potential of agricultural productivity is assessed. To support small farms, the two major mobile operators Vodafon and Tabit are offering discounted pricing plans. The development of mobile applications aimed at increasing the productivity of farms and optimizing yields is also being actively carried out.

In Belarus and Kazakhstan, information and communication technologies are focused on creating a single cloud platform that unites electronic trading platforms, a single digital system of state management of agriculture and logistics.

The digital agriculture of the Russian Federation is focused mainly on large agro-industrial complexes. The use of advanced technologies makes it possible to control the quantity of the product received, its quality, the processing, movement and other operations in a remote format based on a single information space in the field of the agro-industrial complex [4-5]. Within the framework of interdepartmental interaction, such a system allows accounting, monitoring and analyzing agricultural lands, as well as determining the economic and resource potential of lands. The capabilities of electronic services should be especially noted, which, through digital images from unmanned aerial vehicles and satellites, allow remotely detecting pests and diseases of agricultural crops, conducting an inventory of agricultural land, creating electronic maps of fields, and monitoring surveys of territories. Since 2020, digital farms “City-Farmer” are being created, in this format, remote management of agricultural production using artificial intelligence technologies is carried out, which makes it possible to increase efficiency, improve the quality of agricultural products and solve the problem of logistics in regions with difficult transport accessibility and difficult climatic conditions [7–10]. Agricultural digital resources are fully integrated into the Russian Digital Economy Program.

As part of the development of digital agriculture, Georgia has introduced the Bitcoin blockchain to conclude contracts for real estate registration, in order to reduce the time required for the procedure and reduce risks. With the support of the Food and Agriculture Organization of the United Nations, a market information system was introduced that monitors prices for agricultural products in real time. With the assistance of the European Union and the Food and Agriculture Organization, within the framework of the ENPARD program, models of agricultural cooperatives are being introduced, which receive information and financial assistance, and digital technologies are being trained for farmers.

In Kazakhstan, agriculture is completely moving to a digital format. Within the framework of the state program “Electronic Agriculture”, arable land is being digitized and maps of the agrochemical state of soils are being updated. In the future, it is planned to create digital farms in each district.

The active development of e-government, blockchain and artificial intelligence in the agricultural sector is observed in Uzbekistan. With the support of government programs, the fields are being digitized.

The transfer of agricultural machinery to a telemetric digital system is planned by the government of Turkmenistan. This will allow tracking the location of equipment, controlling fuel consumption, and efficiently distributing the operating time and load in a remote format.

In most countries, special attention is paid to the quality of resource potential, since the success of digitalization of agricultural production is impossible without digital literacy training for people employed in agriculture. The most successful practice is noted in Kazakhstan, where, within the framework of a pilot project, demonstration farms are operating at three test grounds of the Kaskelensky agropark, Shortandy at the Barayev Institute and the Kostanay region, where farmers are trained in digital farming methods.

Serbia has a digital demonstration farm “Krivaja DOO”, which reviews the latest agricultural equipment.

In Bosnia and Herzegovina, grants are provided to support young farmers, women entrepreneurs in agriculture, and subsidies are provided for training in new technologies introduced into agricultural production.

The educational system of Montenegro universities is focused on teaching digital skills, programming languages for students in agricultural areas.

In Georgia, within the framework of the ENPARD program, with the support of the European Union, a model of an agricultural cooperative is being developed,

which provides financial assistance, technical support and consulting, as well as training in digital technologies for farmers.

In Azerbaijan, the Ministry of Agriculture has created mobile groups of specialists who travel to regions of the country and hold meetings, round tables with farmers and people involved in agriculture to provide information and technical support in conducting digital agriculture.

To support the development of digital agriculture, agricultural lending systems operate in many countries, which, based on digital assessment, determine the financial potential of farmers, determine methods of operational optimization and market understanding. Such systems operate in Serbia and Turkey.

3 Conclusion

Studies have shown that information and communication technologies play an important role in the development of agricultural production in Europe and Central Asia influencing the social, economic and political sphere of society and the state as a whole. The introduction of such technologies makes it possible to improve the quality of products and services, and to increase the export of agricultural and food products.

Each country has its own digital agriculture system that meets the needs of that country and acts in the interests of national policies. As practice shows, the effectiveness of any national digital agriculture system is determined by the presence of:

1) modern infrastructure that ensures information security, cybersecurity and personal data protection:

2) electronic platforms for the provision of electronic services;

3) digitized information under the jurisdiction of government bodies;

4) full coverage of the territory with broadband communications of 3G, 4G and LTE formats;

5) information platforms, on the basis of which the interaction of services with persons employed in the agricultural sector is ensured;

6) informational and financial support for people employed in agriculture.

The general global trends in the development of digital agriculture include:

1) Transition to an integrated management and control system, on the basis of which modules with a specific set of data function, such as a register of farms, a livestock registration and identification system, a management and payment processing system, a land parcel identification system, as well as statistical data registers and a system of market prices.

2) The introduction of artificial intelligence that increases the productivity of agriculture. The capabilities of artificial intelligence allow, based on the analysis of the data obtained during remote monitoring, quickly responding to changes in the state of soils and crops,

3) Development of electronic marketing platforms, on the basis of which local agricultural products can be sold.

4) Creation of scientific centers, general education courses, the programs of which are focused on the study of new technologies of agricultural production.

International agreements and support from the Food and Agriculture Organization of the United Nations play a significant role in the development of national digital agriculture systems. Within the framework of such agreements, it is worth noting the support provided to Tajikistan in the implementation of a unified statistical data system on agricultural production, which is of strategic importance for agricultural policy planning. Assistance was also provided in the introduction of innovative technologies, in terms of digitalization, the creation of a database and a map of farms. In Turkey, an integrated web-based system TRIACS is supported, which includes modules for administration and control of payments of subsidies to farmers. Ukraine is supported in the development of digital technologies in grain and oil crops. The American Agency for International Development (USAID) for Uzbekistan has developed software that allows keeping records of plants and sending SMS-notifications in case of plant diseases.

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