DIGITIZATION OF THE ECONOMY OF THE AGRICULTURAL COMPLEX: PROBLEMS AND PROSPECTS

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Abstract. *According to the results of the scientific study, it was found that the digitalization of the agro-industrial economy can be implemented according to the following models: «pure producer», business model «from the field to the counter», «agro-industrial ecosystem». The main directions of digital transformation in the sphere of agro-industrial complexes are: precision farming, smart farms, smart greenhouse systems (complexes), the program of technological cooperation between agro-industrial complexes and IT-sphere «Industrial FoodNet». The fundamental problems and barriers to the digitalization of the agro-industrial economy are: misunderstanding of the importance of this activity on the part of many agricultural producers; lack of incentives and benefits for agro-industrial organizations and IT companies involved in cross-industry cooperation and import substitution; poor awareness of advanced automated innovation machine technologies and technical means based on the use of digital solutions and artificial intelligence; negative impacts of the reduction of international exchanges and the application of sanctions to Russian manufacturers. In order to determine the prospects for digitalization of the Russian agro-industrial complex, the author prepared scenarios based on the Foresight «4 Worlds» method, each of which describes the likely trajectory of the industry development, taking into account the dominant internal and external factors and prerequisites.*
Keywords: *digitalization, agro-industrial complex, agrotech, venture investments, im-port substitution, sanctions, inter-firm cooperation, ESG-policy.*

Introduction. Stable development of the agro-industrial complex in Russia is the main task that is directly related to ensuring food security and increasing the country's independence from imported food supplies, agricultural technology and technological solutions, and the digitalization of the agro-industrial complex economy is today one of the most promising solutions for the development of an intensive management model Agriculture. To achieve such an ambitious task, all industry participants (including government regulators) require a large-scale rethinking of the approach to managing business processes in agriculture and a readiness to implement the latest digital technologies to ensure productivity and rational use of natural, climatic and biological resources.

The relevance of the topic of scientific publication is greatly enhanced by the negative effects arising from the imposed international sanctions, which led to a break in the established chains of technology and agricultural technology transfer and exchange of best agribusiness practices and are currently motivating company management and government industry regulators to accelerate import substitution of a number of critical products and technological positions on which the internal biological and veterinary safety of the industry depends (for example, chemical

plant protection products, vitamins and feed, technologies for remote monitoring of soil and crops, and so on).

2. Materials and methods. The purpose of this scientific research is to analyze digitalization in the agro-industrial complex of the Russian Federation and determine the prospects for its development, as well as to quantify the penetration of digital technologies into the industry and its readiness for transformation to the requirements of the new technological paradigm of Industry 4.0. Object of research is the economy of the agro complex, subject is the processes of digitalization in agribusiness. When preparing theoretical section of scientific research, devoted to determining the main directions of digitalization of the agricultural economics, general scientific methods were used (observation, measurement, comparison, method of logical reasoning, analysis and synthesis). Specific scientific methods (statistical analysis, expert estimates, graphic method) were used to quantify the innovation activity and digital maturity of agro complex. The sources of statistical information and analytical materials were statistical collections, publications, business portals «Agroinvestor», «RBC», «AgFunder».

3.Results. The following models of digitalization of agribusiness are distinguished:

1. A pure producer - agricultural sector is focusing its efforts on developing its own production with the introduction of advanced technologies that improve product quality and labor productivity, while complying with international phytosanitary regulations. In this model, the emphasis is placed specifically on the primary production of agricultural products, as well as active investment in the purchase (selection) of the best samples of biological assets (seed and breeding gene pool), while issues of further processing of products are addressed indirectly, which carries risks of return on investment and overall efficiency agribusiness activities, because the added value of the product can sharply decrease at the processing stage [1]. The model is most applicable for the Russian agro-industrial complex in terms of the largest producers of basic agricultural products in the field of crop production (for example, growing grain, industrial crops) and livestock farming (meat and dairy).

2. The business model “from field to counter” is a more complex and “advanced” level of implementation of digital transformation in the industry and represents an entire value chain from the production of a basic product to its delivery to the circulation or catering industry. Within the framework of this model, digitalization is aimed at creating a holistic space for the exchange of information between the manufacturer of agricultural products and representatives of the distribution sector (catering) to create uniform technological requirements for products, logistics maps and just-in-time delivery schedules [2]. A feature of the use of digital technologies in this model is the active creation of a communication infrastructure, conducting marketing research on consumer behavior, and manufacturer branding; Separately, it should be noted the significant costs for the creation of new product storage facilities, R&D projects in the field of crop preservation and maintaining its commercial characteristics.

3. “Agro-industrial ecosystem” is the most complex and progressive level of digital transformation of agribusiness, the ultimate goal of which is to create a mechanism for data exchange between all participants in the value chain with the ability to personalize the characteristics of the final product to individual client requests [3]. The practical implementation of such a model is the creation of an industrial FoodNet platform in Russia, on which in real time its participants can track the movement of agricultural products, analyze its characteristics and life cycle, form a portfolio of orders, a delivery and payment schedule [4].

In Russia, the main document regulating the directions of digital transformation of the agro complex economy is the departmental project of the Ministry of Agriculture “Digital Agriculture”, according to which the goals of digitalization of the agro complex are:

– reducing import dependence in terms of seeds, breeding stock of agricultural animals, plant protection products and veterinary drugs through the development of domestic breeding technologies and genetic engineering;

– development of inter-company cooperation between agribusinesses and IT companies in the field of digital agricultural technologies;

– intensification of the use of farmland through the use of predictive analytics tools and remote monitoring of soil conditions;

– ensuring an increase in the quality of marketability and safety of primary products and the safety of livestock through the use of smart control systems for physical and chemical parameters in storage facilities (farms);

– leveling of export risks in terms of certification and phyto- and veterinary-sanitary control;

– increasing the efficiency and transparency of the processes of state financing of the agrol complex and public procurement management [5].

Based on the stated goals of the project, the author examined the main directions of digital transformation in the agricultural sector:

1. Precision agriculture.

For the purpose of managing the processes of fertilizing, plowing, and sowing, the GLONAS system is installed and used in agricultural machinery [6]. Also, with the participation of industrial drones, it is planned to carry out physical and chemical monitoring of the condition of the soil, its moisture content, analyze the condition of crops, harvesting, and compile digital yield maps.

Requirements for implementation: equipping agricultural machinery with a special software complex of machine vision and unmanned transport control; integration and interaction of rolling stock through the IoT network, formation of data transmission infrastructure.

Assessment of the impact on the development of agro complex: increasing the efficiency of use of farmland (especially arable land) due to their higher involvement in crop rotation; optimization of the application of fertilizers and chemical plant protection products through a preliminary assessment of soil condition and crops.

Assessment of the current state of development: certain elements of precision agriculture (monitoring the state of the soil by industrial drones, the development of elements of unmanned control of agricultural machinery) is being implemented in the following constituent entities of Russia: Volgograd region (257 farms), Krasnodar region (250 farms), Voronezh region (211 farms) [7].

2. Smart farms.

A fully or partially autonomous robotic infrastructure object in which livestock business processes are implemented with minimal participation of personnel (livestock breeder, operator, veterinarian), and which works based on the use of artificial intelligence in ERP format (Enterprise, Resources, Processes).

The goal of creating smart farms is to intensify the processes of production of products of animal origin with a simultaneous increase in their quality, safety of livestock and reduction of

operating costs for life cycle management, as well as the development of domestic selection [8]. The main indicators of efficiency are improving the quality of dairy products, reducing the incidence of animal diseases and increasing the profitability of livestock products.

Implementation of the direction includes:

1. Carrying out work on microchipping animals and installing sensors to monitor their physiological state with the subsequent formation of a database describing the life cycle of an individual.

2. Creation of a network of centers for intelligent control of technological processes of the farm (milking, feeding/watering, maintenance control, manure removal) with data centralization on the platform.

3. Development and implementation of automated innovative machine technologies and technical means of feeding, diet selection and monitoring of feed digestibility.

Thus, the introduction of the "Smart Farms" direction makes it possible to increase the efficiency of agricultural production in terms of dairy and meat farming with an increase in milk yield, average daily weight gain, and ripening speed.

Assessment of the current state of development: currently there is no holistic model of a smart farm, Russian agribusiness is implementing only certain areas: the Soyuz-Agro agricultural holding is developing unmanned agricultural equipment, Cherkizovo PJSC is developing computer vision systems for managing the life cycle of poultry [9].

3. Smart greenhouse systems (complexes)

As part of import substitution policy of fresh fruits and vegetables and increasing their availability to the population, it is planned to create automated greenhouse production with a continuous process of growing fruits and vegetables [10]. This direction is of priority importance for the development of agriculture in areas of risky farming (for example, the northern territories of the country) to ensure local production of products and reduce the costs of their delivery. A smart greenhouse is a complex infrastructure solution that is controlled using artificial intelligence technology that collects data from IoT sensors and autonomously regulates all physical and chemical parameters in the greenhouse.

The implementation of this direction is planned in the following formats: 1) on the basis of existing large agricultural holdings for self-sufficiency of workers with fresh vegetables and fruits; 2) local greenhouse complexes in remote regions where the supply of fresh vegetable/fruit products is difficult or possible only for a short time (for example, cities of the Far North); 3) private farm initiatives for growing niche agricultural products (for example, fresh herbs, exotic fruits, heat-loving vegetables).

Accordingly, the introduction of the "Smart Greenhouse Systems" direction ensures an increase in the state's self-sufficiency in fresh vegetables and fruits; increasing the localization of the production of vegetables and fruits while simultaneously reducing the costs of their transportation (relevant for remote areas and territories), reducing the influence of climatic factors (droughts, floods, damage to plants by diseases) [4; 9].

4. Program of technological cooperation between the agro-industrial complex and the IT sector "Industrial FoodNet" Description of the direction: integration of certain areas in the activities of agricultural organizations with the work of technology parks, design bureaus, and agricultural universities with the introduction of digital technologies will allow for increased production, increased labor productivity and improved quality of agricultural products.

Technological cooperation includes the following areas:

– research in the field of using innovative sources of raw materials for the production of food and feed, including the use of artificial synthesis of proteins and biomass of microorganisms;

– equipment and technologies for highly productive agribusiness (roboticization and automation of business processes; construction of city farms, digital twins, selection and genetic modeling);

– smart supply chains (production and delivery cycle tracking services; smart packaging and labeling; recycling and safe disposal);

– biologized agriculture (development of the practice of industrial reproduction of valuable and rare wild plants, restoration of plants listed in the Red Book; acceleration of terraforming of farmland) [11; 12].

Based on various domestic statistical data for the period 2017-2022, in Table 1 the authors analyzed indicators for assessing innovative activity and the level of penetration of digital technologies in the agro-industrial complex of the Russian Federation.

Table 1. Indicators of innovative activity and the level of penetration of digital technologies in the agro-industrial complex of the Russian Federation for the period 2017-2022

Indicators	2017	2018	2019	2020	2021	2022
1. Share of the contribution of the agro-industrial complex to GDP, %	3,9	3,5	3,7	4,0	4,7	5,3
2. Level of innovation activity in the agro-industrial complex by area:						
2.1 Crop production	7,5	7,4	8,2	9,1	8,6	8,8
2.2 Livestock	2,8	3,9	4,7	5,2	6,5	7,3
2.3 Growing seedlings and greenhouse business	2,0	2,1	14,3	16,9	18,3	17,7
3. Investments in agrotech (including start-up projects), million US dollars Including:	150,7	159,4	220,3	239,4	271,6	>300
3.1 Investments in industrial technologies “from farm to fork”	81,4	73,5	107,9	107,7	105,9	>130
3.2 Investments in consumer technologies “from counter to plate”	69,3	85,9	112,4	131,7	165,7	>180
4. Number of joint innovative projects in the field of agriculture, total, units Including:	49	56	70	93	154	< 97
4.1 With IT companies	17	36	42	50	97	28
5. Intensity of costs for technological innovations in the total volume of shipped products, %	1,4	1,6	1,8	1,5	1,7	1.6
6. Level of digital maturity of subjects in the agro-industrial complex, as a percentage of the total	1,3	1,6	2,7	3,5	4,2	5,1

Note. Source: compiled by the author based on data from the Ministry of Agriculture

As follows from the calculations given in the table, the agricultural sector in the analyzed period increased its contribution to the formation of the country's GDP from 3.9% to 5.3%, however, it is important to understand that this is an absolute, quantitative assessment of the product produced, with growth in the last two years is associated both with favorable climatic conditions conducive to a good harvest, and with the introduction of international sanctions against Russia, including a food embargo on a number of items, and this, in turn, led to the saturation of the domestic food market. When considering relative indicators, the picture is not so rosy: the level of innovation activity in the agro-industrial complex on average does not exceed 8.4% and 5.1%, respectively, for crop production and livestock production, i.e. there is an extensive model of farming. At the same time, despite the two-fold increase in investments in agritech (including startup projects) from 2017 to 2022, the emphasis on the development of consumer technologies of the group "from counter to plate" is noticeable, i.e. formation of added value in the last stages of the product life cycle.

The aggravation of the problem of international technological sanctions had a negative impact on the dynamics of joint innovative projects in the field of agriculture: with a seemingly positive increase in the number of projects from 49 to more than 97 units, while joint projects (including R&D projects) with IT -companies in 2022 almost returned to the 2017 level, which is due to the following reasons: 1) the freezing of numerous initiatives with foreign companies; 2) relocation of Russian IT companies engaged in the field of agricultural technology (as a rule, these are micro and small businesses engaged in niche products and services); 3) a sharp deterioration in the image of the Russian venture market and the difficulty of obtaining international funding for Russian teams.

On the part of agribusinesses themselves, interest in the development of digital technologies remains weakly expressed, largely targeted and even reactive: thus, the intensity of costs for technological innovation in the total volume of shipped products in the analyzed period did not exceed 1.8% (the record value was in 2019) , while the level of digital maturity of subjects in the agro-industrial complex increased noticeably during the analyzed period: from 1.3% to 5.1%, which, however, is not explained by the growth of investments in digital technologies, but by the efforts of the state regulator represented by the Ministry of Agriculture, in particular the launch of such information -analytical platforms such as the Central Information and Analytical System of Agriculture, the Unified Federal Information System of Agricultural Lands, the "Effective Hectare" project for the development of pilot projects in the field of agrotech and technological innovation.

4.Discussion. In accordance with the logic of the study, the authors carried out a clear identification and structuring of problems and barriers limiting the processes of digitalization of the economy of the agro-industrial complex:

– the prevalence of state participation in the implementation of programs and projects for digital reform of the agro-industrial complex – according to Rosstat, in 2021/2022. the share of state budget funds in financing venture projects in the field of agricultural technology was more than 60%, in terms of the acquisition of new technologies - more than 37%. This picture indicates a certain "monopolization of interests" in the industry and a dirigiste policy on the part of the industry regulator, which de facto determines the vectors of digitalization of the industry, often leaving very little room for choice on the part of the subjects themselves, as well as creating barriers to entry for micro-projects implemented by startups -teams for private small farms;

– lack of a systematic set of incentives and benefits for agribusinesses and IT companies wishing to implement intercompany cooperation projects – as of early 2023, the Tax and Land Code of the Russian Federation does not provide for any significant incentives and benefits for companies actively implementing projects for digital reform of business processes. In addition, the formation of a national register of accredited IT organizations greatly complicates the organizational issues of implementing cooperation;

– low popularity of ESG policy ideas and the underdevelopment of the concept of "green" and circular economy, coupled with active government financial support for the agro-industrial complex, expressed in the difficulty of creating responsible environmental management and waste-free production – an indirect factor hindering the digital reform of the agro-industrial complex is the commitment of industry management to an extensive management policy and underdeveloped measures of influence on the part of society, financial institutions and public organizations in the field of ecology. In this state of affairs, agribusiness management simply does not have external incentives to introduce resource-saving technologies or develop a culture of responsible farming;

– the negative effects of international technological sanctions and the subsequent policy of import substitution – despite the fact that the countries of the collective West have not officially introduced sanctions in the field of food and related technologies and products, the real state of affairs carries a number of significant risks, in particular : extremely high dependence of the Russian agro-industrial complex on the import of feed additives, vitamins and vaccines aimed at realizing the genetic potential of animal breeds (the share of imports ranges from 95 to 100%, including 70–80% from supplies from the EU and the USA); degradation of the genetic fund of biological assets bred in livestock farming with insufficient experience in genetic modeling and domestic selection; impossibility of direct supplies of complex equipment and agricultural machinery, equipment and service [12; 13].

In the final part of the scientific publication, the authors prepared scenarios describing the prospects for digitalization of the agricultural sector using the "4 Worlds" Foresight method (Table 2).

Table 2. Scenarios for the prospects for digitalization of the agro-industrial complex according to the "4 Worlds" Foresight method

Scenario	Scenario Description
1. Red world "international agro-industrial isolation"	*Prerequisites (driver factors):* continued escalation of international technological sanctions against Russia in connection with the ongoing SVO in Ukraine; intensified attempts by Western political elites to manipulate the country's food security; initiation of using the risks of epizootics and the emergence of epidemic diseases as a tool of pressure on the interests of the Russian Federation. Expected scenario: the growing international scientific and technological isolation of the country leads to a further "rollback" in the development of the industry, and the beginning of its new development trajectory based on previously accumulated experience, existing samples of equipment and service solutions, as well as large-scale industrial espionage and the legalization of parallel imports.

2. Yellow world "bar-ter relations"	*Prerequisites (driver factors):* exhaustion of sources of financing for import substitution projects; low efficiency of the parallel import mechanism; ongoing relocation of personnel and IT companies. Expected scenario: management understands the impossibility of achieving import substitution goals in the short term and moves to a barter format of interaction with Western countries: targeted import of critical technologies, seed material and animal gene pool in exchange for energy resources. A possible "branch" of the scenario is the expansion of the Russian Federation into the agro-industrial complex of the countries of North and South Africa to obtain through them the required technologies and equipment within the framework of international humanitarian and technical assistance projects.
3. Green world "food truce"	*Prerequisites (driver factors):* Russia's withdrawal from the grain deal, degradation of the biosystem and the impossibility of exploiting valuable land in the Black Sea basin, growing food shortages and prices on the world market. Expected scenario: the countries of the collective West, realizing the futility and dangers of further isolation of Russia, are moving to the format of a "humanitarian corridor" and ensuring the supply of the industry with the necessary equipment and technologies, ensuring the transfer of samples of biological material in exchange for maintaining price stability in the world food market and preventing threats food shortage. The outcome of the scenario is that Russia will acquire the status of a new world leader in the field of food exports and primary processing of agricultural products.
4. Blue world "global restructuring"	*Prerequisites (driver factors):* aggravation of natural and climatic threats in Russia and the world; the final exhaustion of the potential of the extensive agricultural model; a significant decrease in the fertility of arable land. Expected scenario: the state regulator of the industry makes a decision on the large-scale implementation of ESG principles in the agricultural sector, work is underway to introduce a system of criteria for assessing the environmental friendliness of agribusiness and its compliance with the principles of "green" and "circular" economy. Financial institutions and government funds are introducing new requirements for issuing loans and other forms of financial support for the agricultural sector, taking into account ESG criteria, and the integration of research centers with representatives of agribusiness and the venture industry is developing. The result of the scenario is the formation of a national model of the green economy of the agro-industrial complex, based on the use of digital technologies to monitor the industry's impact on natural and climatic parameters and the most waste-free production.

Note. Source: compiled by the authors; [4; 12; 14; 15].

Each of the described scenarios is a probable version of the development of events, however, the authors suggest that other options for the development of digitalization of the agro-industrial complex of the Russian Federation are possible, since this may be associated with both external and internal economic and political factors.

5 Conclusion. This analysis allowed the authors to identify existing problems in the digitalization of the agro-industrial complex of the Russian Federation, as well as to suggest various options for its development in the medium term. The main initiator in the development of digital technologies in the country's agricultural sector remains the Ministry of Agriculture, which, despite the reduction in international exchanges, continues to actively promote the implementation of large-scale digital reforms. At the same time, the objective growth of external challenges and threats and stimulation from the Ministry of Agriculture in terms of import substitution indicates the strengthening of digital transformation processes in the industry, despite multiple attempts by the collective West to establish a regime of "technological and economic isolation."

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