www.volsu.ru

DOI: https://doi.org/10.15688/ek.jvolsu.2023.2.5

UDC 338.43(470+571):004
LBC 65.9(2Poc)32-55

Submitted: 01.02.2023
Accepted: 02.03.2023

DIGITALIZATION OF THE RUSSIAN AGRO-INDUSTRIAL COMPLEX: MODERN TRENDS AND DEVELOPMENT PROBLEMS [1]

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Abstract. The study's relevance is determined by the fact that digital transformation of the agro-industrial complex will help to cope with the global and national challenges facing agro-industrial production in Russia. This paper will explore the factors influencing the digitalization of the agro-industrial complex. The study hypothesizes that the existing institutional environment and unavoidable risks of the digital gap present the main obstacles to the digital transformation of the Russian agro-industrial complex. The study employs the following research methods in the framework of the evolutionary approach: structural and functional, temporal and spatial, comparative and documentary analysis, along with statistical and graphical techniques. Special attention in the research methods was paid to drawing a comparison between the digital transformation of the agro-industrial complex in Russia and on a global scale. By using the proposed methods, analyzing trends and institutional backing for digital transformation in the agro-industrial complex is possible. Consequently, the factors and conditions that cause and lessen the digital divide in Russia's agricultural sector were determined. The scientific novelty of the study lies in the identification and analysis of digital gaps (industrial, intra-industrial, time-related, human resource, social, market, and transformational ones) that inhibit the digital transformation of the agro-industrial complex. In this research, the authors prove that bridging these digital gaps will expedite the agro-industrial complex's shift to Agriculture 4.0 in Russia.

Key words: agro-industrial complex, digital technologies, digitalization of the agricultural sector, government support, digital gap.

Citation. Mitrofanova I.V., Inshakova E.I., Dovbiy I.P. Digitalization of the Russian Agro-Industrial Complex: Modern Trends and Development Problems. *Vestnik Volgogradskogo gosudarstvennogo universiteta. Ekonomika* [Journal of Volgograd State University. Economics], 2023, vol. 25, no. 2, pp. 59-71. DOI: https://doi.org/10.15688/ek.jvolsu.2023.2.5

УДК 338.43(470+571):004
ББК 65.9(2Рос)32-55

Дата поступления статьи: 01.02.2023
Дата принятия статьи: 02.03.2023

ЦИФРОВИЗАЦИЯ АПК РОССИИ: СОВРЕМЕННЫЕ ТЕНДЕНЦИИ И ПРОБЛЕМЫ РАЗВИТИЯ [1]

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Аннотация. Актуальность исследования определяется тем, что поиск проблем развития цифровой трансформации агропромышленного комплекса позволит справиться с глобальными и национальными вызовами, стоящими перед агропромышленным производством в России. Цель статьи – выявить тенденции, определяющие цифровизацию агропромышленного комплекса страны, который подвержен влиянию факторов, формирующихся на глобальном и национальном уровнях. В работе выдвинута гипотеза о том, что существующая институциональная среда и неизбежные риски цифрового разрыва представляют собой основные препятствия для цифровой трансформации отечественного агропромышленного комплекса. В рамках эволюционного подхода в статье использованы следующие методы исследования: структурно-функциональный, пространственно-временной, сравнительного и документального анализа, а также статистический и графический методы. Особое внимание в методологии исследования уделено проведению сравнительного изучения цифровой трансформации агропромышленного комплекса в России и в мире. Использование предложенной методологии позволило выявить тенденции и проанализировать институциональное обеспечение цифровой трансформации агропромышленного комплекса; а также определить условия и факторы, определяющие формирование и нивелирование цифрового разрыва в АПК России. Научная новизна исследования заключается в выявлении и анализе цифровых разрывов (производственных, внутрипроизводственных, временных, кадровых, социальных, рыночных, трансформационных), которые тормозят цифровую трансформацию АПК. Авторы обосновывают, что преодоление этих цифровых разрывов ускорит переход агропромышленного комплекса России на формат «Сельское хозяйство 4.0».

Ключевые слова: агропромышленный комплекс, цифровые технологии, цифровизация сельскохозяйственного сектора, государственная поддержка, цифровой разрыв.

Цитирование. Митрофанова И. В., Иншакова Е. И., Довбий И. П. Цифровизация АПК России: современные тенденции и проблемы развития // Вестник Волгоградского государственного университета. Экономика. – 2023. – Т. 25, № 2. – С. 59–71. – (На англ. яз.). – DOI: https://doi.org/10.15688/ek.jvolsu.2023.2.5

Introduction

Achieving the goals and objectives of sustainability requires enhancing the efficiency of the agro-industrial complex, which can receive a new impetus for development from digitalization. The digital transformation of the agro-industrial complex is one of the global challenges for world economic development in the 21st century [Future of Food ... , 2019], contributing to the achievement of a world free of hunger, which is the critical UN sustainable development goal. Digital transformation, which allows receiving information about the situation in real time to make prompt decisions [Rose et al., 2018], has a global character, going beyond the level of individual farms and producers.

The agro-industrial complex of Russia as a supra-industry imminently plays a crucial role in a new type of economic formation, anticipating future climate change. In response to global trends, the Russian authorities are developing strategic measures to enhance the digital transformation of the agro-industrial and fishery complex for the period until 2030. The adoption by the Russian Government of several strategic documents related to food security and digitalization of the agro-industrial sector results from the growing understanding that digital transformation will help to cope with the global and national challenges facing agro-industrial production in the country. The Ministry of Agriculture of the Russian Federation is allocating 50 billion roubles for these purposes [Do 2030 goda ... , 2021]. For example, the digitalization of grain production will allow the country to increase yields by 40% and reduce costs by 23% [Prognoz nauchno-tekhnologicheskogo razvitiya ... , 2017].

The digital trends embraced mainly by large agro-industrial enterprises in the agricultural sector of the Russian Federation include artificial intelligence technologies, Big Data, the Internet of

Things, smart factories, virtualization, service modes, new business models, etc. The advantages of modern digital technologies are that they:

– meet the needs in the formation of optimal soil-agro-technical and organizational-territorial conditions [Gostev et al., 2020], providing expanded reproduction of the agro-industrial complex following the requirements of the environmental protection policy and soil fertility conservation;

– act as the essential production factor that contributes to 'the maintenance, expansion, and upgrade of economic and production performance of the most important structures of the agro-industrial complex components' [Fedotova et al., 2021];

– promote intersectoral cooperation, which includes finding solutions to problems that previously were out of the scope of their competence [Arvanitis et al., 2020];

– have a heavy impact on the entire value chains in the industrial sectors of the economy [Xu et al., 2018; Pfeiffer, 2017];

– become more accessible to agricultural producers and enhance the investment attractiveness of the industry: in 2020, global investments in agri-food technologies amounted to 22.3 billion US dollars, including venture capital that increased to 5.0 billion dollars [Agrifood Tech Investment Review 2020].

In numerous studies that focus on the digitalization features of the agro-industrial complex in Russia, researchers substantiate the necessity and expediency of its digital transformation [Astakhova et al., 2018; Izmailov et al., 2019]. They discuss the potential of public-private partnerships that rely on co-financing [Lovchikova et al., 2019]; reveal its regional specifics [Skvortsov et al., 2018; Shafikov, 2018]. They also point out the need to adapt business processes and management in this sector because the benefits from digital applications in the agro-industrial complex exceed those expected from automating such industries as construction, insurance, and trade. Also, researchers mention exceeded wear limits, obsolescence of fixed assets, and a low degree of digital transformation in the agricultural sector as causes of the unbalanced structure of the national economy. From a historical perspective, the processes of automation, electrification, and informatization existed before the digitalization of the agro-industrial complex in Russia [Ognivtsev, 2019; Mitrofanova et al., 2019b].

Legal and institutional support is one of the main conditions that enable digital transformation: firstly, since outdated legal practices continue to be implemented, it is vital to eliminate gaps related to the use of information and digital technologies in the agricultural sector in the legal regulation [Kolotkina, 2020; The Russian Agricultural Sector ... , 2020]; secondly, legal mechanisms for the implementation of national strategic initiatives that meet the challenges arising from the digital transformation of the agro-industrial complex should be developed [Fomin, 2019].

In this context, the target conflict, generated by the need to increase productivity that often results in environmental pollution, for example, soil erosion, requires special attention [Digitalization of Agricultural Production ... , 2018]. It should be said that specific indicators of anthropogenic impact per capita and unit of gross national product (GNP) in Russia are among the highest in the world, and about 15.0% of the whole territory of the country suffers from severe environmental damage [Akmarov et al., 2019].

At the turn of the 2020s, the digital divide between agricultural producers in Russia and farmers in developed countries in terms of the level of information technology implementation was due to several reasons:

– the path dependence paradox and the conservatism in land relations [Prognoz nauchno-tekhnologicheskogo razvitiya ... , 2017];

– low expertise and qualifications in modern technologies [Akmarov et al., 2019];

– restrictions that arise from agro-climatic factors and adherence to outdated agronomic methods; sluggishness and low development of legal culture; low adaptation to sustainable development rules; lack of standardization for food trade; and other reasons [Kolotkina, 2020; The Russian Agricultural Sector ... , 2020].

Carried out in the context of global development trends, the digitalization of the Russian agro-industrial complex displays national specificity, which requires research. It is vital to identify factors that define the digital transformation of the industry. It is also essential to address the digital gaps that act as the main

obstacles to the development and digitalization of the agro-industrial complex [Digitalization of Agricultural Production ... , 2018; Agricultural Markets, 2020].

Methods

The research employs the methodology of the evolutionary approach using structural and functional, temporal and spatial, comparative and documentary analysis, along with statistical and graphical techniques. The database for the research uses information materials retrieved from the official sites of the Government of the Russian Federation, the Ministry of Agriculture of the Russian Federation, the Federal State Statistics Service, and analytical reports delivered by specialized foreign and national organizations and institutions. The paper utilizes the results of the studies on the topic obtained by the scholars in Russia and abroad, as well as the results of the previous studies conducted by the contributors.

Results and discussion

Ranked 23rd in the Global Food Security Index [Global Food Security Index 2021 ...] with 10% of the arable and 40.0% black earth lands in the world, Russia is an agro-industrial country and a leading player in the global agro-food market (19th place), exporting products to more than 150 countries [Savin et al., 2018]. According to official statistics, between 2011 and 2020, the output of agricultural products increased by 80.6%, and its exports grew by 154.2%. Since the early 2000s, Russia has become the world's largest grain exporter. According to estimates, in the 2030s and 2040s, the country will increase exports to about 35–40 million tons of grain per year; however, grain yields in Russia are still three or four times lower than in the USA and Germany [The Future of Agriculture ... , 2022]; the rate of energy-to-labor ratio is comparatively low; and the depreciation of fixed assets comprises 40.5% [Stepen' iznosa osnovnykh fondov, 2021].

Along with the low level of digitalization, the loss of agricultural products reaches up to 40.0% throughout the entire production cycle [Ministry of Agriculture ... , 2018]. The dependence on imports of agricultural machinery (42.0% of the domestic market [Itogi 2020 goda ... , 2020]), materials, and components aggravates the situation.

The institutional nature of the digitalization of the agro-industrial complex is due to the influence of formal and informal institutions on its efficiency and sustainable reproduction [Inshakov, 2003]. Traditional institutions in the agro-industrial complex include market self-regulation of supply and demand; corporate regulation of the entire value chain; state regulation of legislative, executive, and control mechanisms; and state support for the industry.

Although an analysis of the market and corporate self-regulation in the Russian agricultural sector requires a separate study, the general description of the state of these institutions is as follows:

– an unfavorable institutional environment is singled out as the main reason hindering the digitalization of the Russian economy and the development of digital technologies by the business [Mitrofanova et al., 2019a; Alpidovskaya et al., 2020; Mitrofanova et al., 2020];

– the complexity of state management in the agricultural sector due to the heterogeneity and geographical dispersion of economic entities [Kurdyumov et al., 2020];

– the presence of digital gaps that have developed in the economy [Agricultural Markets ... , 2020; Ministry of Agriculture ... , 2018].

However, significant progress in state regulation of the agricultural sector in Russia has been made in the last few years. Over the past five years, several strategic and program documents and norms have been adopted, that stipulate, first, rules and regulations for introducing modern technologies in the agro-industrial business, including digital ones; second, a list of subjects, a procedurally and normatively regulated list of actions and powers for the digitalization of the agro-industrial complex: the National Security Strategy, the Doctrine of Food Security, the Strategy for the Sustainable Development of Rural Territories, the Strategy for the Development of Agro-Industrial and Fisheries Complexes, the Strategy of the Information Society Development, the State Program for the Development of Agriculture and the Regulation of Markets for Agricultural Products, Raw Materials and Food, the State Program "Digital Economy", the Federal

Scientific and Technical Program for the Development of Agriculture for the period of 2017–2025, the National Action Plan for the First Stage of Adaptation to Climate Change for the period up to 2022, etc.

Although the authorities have created several formal institutions for the digital transformation of the agro-industrial complex in Russia, their effectiveness is not sufficient. The study of other (formal and informal) institutions is beyond the scope of this study.

The digitalization of the agricultural sector is under the influence of long-term trends and faces challenges that are typical for the global agro-industrial complex but have national specifics (Table 1).

The advent of the agro-industrial complex's digital transformation dates back to the 1990s, when the authorities created the Unified State Register of Soil Resources of Russia (USRSR) and first digitized the soil map of Russia, which is annually updated.

Table 1. **Trends in agro-industrial complex development arising from digital transformation**

Long-term trends and challenges	Global scale		National scale (specificity of digital transformation in Russia)
	Challenge	Effect	
Economic and structural	a gap between growing demand and inadequate food supply	rise in food prices	limited economic availability of food; limited access of small agricultural producers to marketing channels; lack of production capacity to cover domestic demand for agricultural products
	the development of technologies and the introduction of business models for the agro-industrial complex are changing the traditional way of life	bankruptcy of companies and the reduction of employment; degradation of arable land and infrastructure	the growing role of TNCs; growing exports, but at the expense of added value; customization and personalization of agro-industrial products and services
			a large share of subsidiaries and small farms in the structure of the agro-industrial complex deprived of access to state-of-art means of mechanization, automation, chemicalization and digitalization. The result is low productivity, high unit costs, strong dependence on the human factor
	subsidizing agricultural production in developed countries makes the agro-industrial complex of developing countries uncompetitive	increasing dependence on imports of equipment, technologies, raw materials and products	high debt load at the current loan rates that absorb the current profit; limited access to financial resources, including long-term loans; lack of funding for the modernization of fixed assets
Social	growing popularity of a healthy lifestyle; demand for healthy and organic food	growing demand for organic products in the world	household spending on food comprises up to 50 percent of the income; the structure of consumption is dominated by cheap low-quality products; low level of availability of "healthy" foodstuff for the general population
	increasing stratification in the size of income;	unequal access to high-quality healthy products;	inequality of incomes between urban and rural populations; poor standard of living in the countryside
	reduction in employment, unemployment; the outflow of the population, especially young people; aging farmers	deterioration of the situation of the rural population, degradation of developed space	high unemployment rate and growing depopulation of rural areas;
	urbanization and population concentration in metropolitan areas and large cities	the problem of uninterrupted food supply	the lack of attractive jobs

End of table 1

Long-term trends and challenges	Global scale		National scale (specificity of digital transformation in Russia)
	Challenge	Effect	
Ecological and Natural-resource	global climate change	reduction of the agro-climatic potential of the planet	emergence of epitophies and epizootics as a result of climate change
	loss of soil fertility, depletion of water sources	undermining the sustainable development of rural areas	lack of attention to soil resources, that results in their withdrawal from agricultural circulation; rich raw material base for the production of environment-friendly products; growing scarcity of fresh water
	reduction in varietal and natural diversity	missing opportunities for long-term diversification	weak protection of intellectual property in breeding and biotechnologies; high dependence on imports of genetic resources
	decrease in the bioproductivity of the world ocean	development of aquaculture of low-value fish species	threats coming from illegal fishing in Russian waters
Political and Institutional	conservative view of the agro-industrial complex	slow development of technologies and markets	low support and lack of end-to-end planning on behalf of the state
	food security requirements at national levels	increased international trade barriers	induced by politics barriers to Russian agricultural export
	threats of bioterrorism and acts of covert biological warfare	increased costs of phytosanitary and veterinary control	the threat of uncontrolled spread of GMOs
	food or fuel dilemma	increased risks in the biofuel industry	high administrative barriers and transaction costs; long chains of intermediaries (wholesale and retail) contribute to the redistribution of up to 90% of the margin in favor of chains and banks
Values-based	high conservatism in land relations	obstacles for new owners to enter the agricultural market	low prestige of professions in the agro-industrial complex
	innovations in agriculture are considered as a threat to traditional life values	rejection of cloning and genetic engineering technologies, new methods of animal husbandry	low innovative culture; low level of funding and resource support for scientific research in the field of agro-industrial complex and food industry; local innovative developments have a weak adaptive and integrative capacity for various types of farms
Techno-logical	development of intersectoral platform technologies in the agro-industrial complex, total computerization	transition to a circular economy, resource-efficient production processes	inadequate application of competitive technological reserves developed in various industries in the agro-industrial complex; low geographical scope of IT infrastructure and communications; crisis in fundamental agricultural science
	outdated technological paradigm, the necessity of transition to a new one	reduced yields and productivity, large-scale losses in value chains	huge losses due to poor logistics, backlog in agricultural technologies; lack of facilities for deep processing of agricultural products; lack of dealer and service centers for the sale and maintenance of agricultural machinery

Note. Compiled by the authors based on: [Altukhov et al., 2019; Ognivtsev, 2019; Prognoz nauchno-tekhnologicheskogo razvitiya ... , 2017; Status of Digital Agriculture, 2020].

In 2014, the System for Monitoring and Forecasting Food Security of the Russian Federation (SMPB) was established, which generates information from the Federal State Statistics Service of the Russian Federation, the Federal Customs Service of Russia, and reports from municipal and regional governments. The Ministry of Agriculture of the Russian Federation used online services to analyze data and generate forecast balances and summary information on the state of food reserves and the dynamics of prices for food and agricultural products.

In 2016, the State Information System for Ensuring Food Security was designed to automate information processing and improve the quality of responses to challenges and threats.

In 2018, the authorities launched the Unified Federal Information System on Agricultural Lands to increase the efficiency of agricultural land and maintain its fertility.

By 2021, the Ministry of Agriculture of the Russian Federation had developed a complex of information systems that performed accounting and registration of agricultural machinery (self-propelled machines and tractors) [Perechen' informatsionnykh system ... , 2022]; monitoring and forecasting food security; provision of electronic public services; maintenance of registers, provision of regulatory and reference information; planning and control of state program execution; collection and processing of accounting and specialized reports on subsidizing the agro-industrial complex; state data support for agriculture; provision of information on the location, condition and use of land; monitoring and assessing risks of the state, and scientific and technical support for the development of agriculture.

The digitalization of the Russian agro-industrial complex is moving towards the development of algorithms for the presentation of agronomic data in various formats that are understandable to end-users. To date, digitalization has achieved the following important results:

– digital bases providing decision support: digitization of maps and satellite data; formation of databases (meteorological, geobotanical, epidemiological, etc.) accessible via API, etc.;

– digitalization of production processes based on robotics, artificial intelligence (AI), and smart technology ("agricultural equipment with AI and analytics, satellites and drones, irrigation systems and greenhouses", "Farming-as-a-Service" (FaaS), precision farming);

– Big Data, cloud services, and analytical platforms that provide structuring of unstructured agricultural data, forecasting climate risks, crop yields, etc. across all production chains in the agro-industrial complex;

– digitalization of sales (transparency of product movement along value chains based on blockchain, electronic exchanges of agricultural products);

– remote sensing of territories from satellites, GPS-based navigation, automated decision support systems, etc.

Thus, the digitalization of the agro-industrial complex in Russia is in full swing and will significantly transform value chains. However, agriculture clearly manifests digital gaps (sectoral, social, time, transformational, market, human resource, etc.), which must be eliminated, since digital technology dividends are not automatic and not everyone can benefit equally.

Sectoral gaps arise because industries embrace technologies with pronounced industry specifics. The finance, healthcare, and energy complexes display the highest level of digitalization, whereas the real sector of the economy, including the agro-industrial complex, shows the lowest level of digital transformation (See Table 2).

Intra-industry gaps arise due to the high proportion of small businesses that produce about 42.0% of agricultural products. Russia has a bipolar economy in agriculture. On the one hand, there are highly profitable farms and large agro-industrial complexes that have the financial resources to access digital technologies and platforms (PJSC Rusagro (AGRO); PJSC Cherkizovo Group (GCHE); PJSC PhosAgro (PHOR); PJSC Akron (AKRN). On the other hand, there are farms operating on the verge of break-even and small peasant (farm) enterprises using outdated technologies. The lag is due to underdeveloped infrastructure, conservatism and a lack of digital competencies, weak economic potential, and saving on the purchase of modern technologies reduces the ability to connect to telemetry platforms and manage the Internet of Things. In addition, the Russian agro-industrial complex has a large proportion of a shadow segment (about 80.0% of small forms of business) that is not ready and does not want to disavow

and integrate into the digital space of the national economy.

The digital gap between urban and rural areas leads to social gaps, which is the consequence of the insufficient development of rural digital infrastructure. Only 74.3% of agricultural enterprises in Russia have broadband access to the Internet; the Internet use at public access points in rural areas is 16.6%, and in urban areas it is 36.1% [Abdrakhmanova et al., 2021].

In rural areas, only 23.8% of the population aged 15–74 uses the Internet for purchasing goods and services, whereas in urban areas, this category of Internet users comprises almost 40.0%. The proportion of the population in rural areas that receives state and municipal services in electronic form is 67.0%, whereas in urban areas, this figure is 80.7%. The reasons for this digital gap are as follows: lack of interest (20.8%); insufficient skills (10.4%); high cost (7.0%); lack of technical capabilities (4.3%). Despite recent efforts to improve digital literacy, the digital gap between urban and rural areas, especially those farther out into the country, seems to persist for a long time [Tsifrovaya transformatsiya ... , 2019].

Time digital gaps, the span between the creation and implementation of digital technologies, arise for several reasons: the high cost of foreign equipment and technologies induced by the high volatility of the national currency; import dependence on the technologies and equipment for the production of higher value-added commodities, which in some sectors reaches over 80.0%; the lack of information technology; and the absence of global projections of prices for agricultural products. In addition, the rapid development of technologies reduces their life cycle critically. Lack of knowledge about innovations and a weak or almost complete lack of interaction between farmers, research institutions, and developers also result in low demand for digitalization [Kurdyumov et al., 2020]. Among other reasons for the slow acceptance of digital technologies are the imperfection of informal institutions, adherence to old forms and methods of management at the micro-level, intangible internal resistance and rejection of digital technologies, alertness to transformations, distrust of artificial intelligence, and fear of cyber attacks.

Transformational gaps reflect the growing imbalance between the accumulation of digital information, on the one hand, and its storage, processing, and use, on the other. For instance, one of the most important trends in modern agriculture is precision agriculture, which is the core element of resource conservation based on "managing crop productivity concidering the intra-field variability of plant habitats" [Badenko et al., 2020, p. 21]. The solutions to these problems are associated with the use of high-precision positioning systems based on satellite systems, permanent communication channels, and the formation of a unique information base. Farmers are likely to regard participation in the analysis and processing of the data as a daunting task. The information should be as precise as possible to make prompt and effective decisions. Market gaps are caused by supply and demand for various digital technologies in agriculture (See Table 3).

Table 2. **Industry demand for digital technologies in the Russian Federation (percentage)**

Sectors and branches of the economy	Digital technologies							
	Technologies of virtual and augmented reality	AI Technologies	Quantum Technologies	Innovative production technologies	Robotics and Sensors	Distributed Ledger Technology	Wireless Technologies	Digital technologies wide
Health Care	33.1	23.2	21.7	5.0	25.5	15.1	7.5	18.7
Industry	4.2	8.0	2.4	14.5	16.1	5.3	10.8	8.8
Agriculture	4.2	5.3	2.4	13.0	15.3	2.6	1.7	6.4
Construction	31.6	2.7	2.8	22.5	7.5	14.8	5.8	12.5
Fuel-Energy complex	19.3	10.4	26.7	25.5	9.6	14.6	37.5	20.5
Transport and Logistics	6.3	12.5	14.2	8.4	23.6	14.8	22.5	14.6
Finance	1.3	38.0	29.8	11.0	2.4	32.8	14.2	18.5

Note. Compiled by the authors based on: [Abdrakhmanova et al., 2020; Abdrakhmanova et al., 2021].

In the agro-industrial complex, digital transformation is associated with high costs, and its pace is determined by the socio-economic situation in the industry.

Human resource gaps represent the whole range of problems accumulated in the agro-industrial complex. In 2019, agriculture accounted for 2.2% of professionals using ICT intensively and only 0.3% of ICT professionals. At the same time, in industries not related to information and communications, these figures are, respectively, 42.0% and 5.4% in the financial and insurance sectors; 30.0 percent and 6.1 percent in research and technical professions; 22.2% and 1.7% in public administration, military security, and social security. The population with basic and advanced digital skills in rural areas comprises 22.0%; in urban areas, it is 65.0. The use of the Internet at workplaces in rural areas by the population aged 15–74 comprises 37.0%; in urban areas, it is 49.0% [Abdrakhmanova et al., 2020].

Human resource gaps are characterized not only by the insufficiency of research and developments in agricultural technologies but also by the low digital competence of the management staff of economic entities in the agro-industrial complex. There is a significant shortage of specialists in the labor market in the sector with qualifications in digital agricultural technologies. With about 113 thousand people employed in the IT agro-industrial complex, the personnel deficit is about 90 thousand people.

Conclusion

The research revealed that the digital transformation of the agro-industrial complex in Russia shows features of two dialectically related global trends. On the one hand, the Russian agricultural sector faces long-term challenges that have emerged in the world and national economies; on the other hand, the agro-industrial complex exerts influence on the development of the domestic economy on the whole. Further development of the agro-industrial complex of Russia will follow the path of the new model formation, the so-called Agriculture 4.0, marked by complete innovation and digitalization.

This model is bound to ensure the saving of natural and economic resources and the preservation of the environment when producing high-quality environment-friendly products.

The digitalization of the agro-industrial complex in the Russian Federation coincides with global trends but displays national specifics. This situation is primarily due to the insufficient

Table 3. **The level of acceptance of digital technologies in agriculture**

The factors that form demand for digital technologies	Technologies of virtual and augmented reality	Neuroscience and Artificial Intelligence technologies	Quantum Technologies	Innovative production technologies	Robotics and sensors	Distributed ledger technology	Wireless technology
The need to increase productivity							
Shortage of qualified staff							
Low efficiency of agricultural equipment							
The need to reduce expenses for agricultural entities							
The need to enhance quality and eco-friendliness of products							
Reduction in yield due to agroclimatic risks							

Note. Compiled by the authors based on: [Tsifrovye tekhnologii v rossiyskoy ekonomike, 2021]. Colour intensity indicates the significance of the factor.

development of market institutions and multiple digital gaps (industrial, intra-industrial, time-related, human resource, social, market, and transformational). Bridging these gaps is viewed as a necessary condition for accelerating the transition of the Russian agro-industrial complex to Agriculture 4.0.

For Russia, the transition to Agriculture 4.0 involves building a holistic model of agriculture on the scale of the national economy in alliance with infrastructure and related processing industries based on a single digital platform for managing the agro-industrial complex. This model should ensure transparency, information accessibility, efficiency and quality of decision-making in management, reliability of results, collection and systematization of reports, etc. The authors consider that prospective research projects should focus on the problems of institutional support for the digitalization of the agro-industrial complex and measures aimed at bridging digital gaps.

NOTE

[1] The publication was prepared as part of the implementation of the State Assignment of the Southern Scientific Centre of the Russian Academy of Sciences, project "Strategic vectors of development of the socio-economic complex of the south of Russia taking into account regional resilience (economic and demographic aspects)", state registration No. 122020100349-6.

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