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Digitalization of Agriculture in The Context of Ensuring Food Security

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Abstract

The article reviews theoretical approaches to the study of the issue of digital transformation of food systems, identifies innovative trends associated with increase in demand for food, in the context of decrease in resources, increase in urbanization and change in the value orientations of population. World trends in the development of digital technologies in the field of agricultural production in the modern world economy were studied. Analysis of the size and structure of global investments in the business models of consumer technologies was made: "from market to plate" (downstream) and industrial technologies "from farm to market" (upstream).
The impact of digital technologies on the production of agricultural products and food in the world was assessed using indicators of agricultural development, and the level of the economy innovativeness determined through the global innovation index. It was concluded that global food security will be ensured by those countries that provide food not only for their citizens, but also for other countries.

Keywords: Global Investments, Agricultural Technologies, Digital Technologies, Consumer Technologies (Downstream), Industrial Technologies (Upstream)

Introduction

In modern conditions, the global challenges caused by population growth, depletion of natural resources, climate change, and increasing urbanization of the world's population requires a radical change in the methods of production, processing, trade and consumption of food based on the digitalization of agri-food systems. Papers of foreign scientists are devoted to the digitalization in agricultural industry: Pfohl H., Yahsi B., Kurnaz T., Qin J., Liu Y., Grosvenor R, who performed research on the conceptual structure of digitalization, as well as papers of Russian scientists: D.M. Zozulia, T.A. Panteleeva who review the issues of determining the essence of digital economy, its specific features.

Despite numerous studies in the field of digital economy, the question arises, whether the digital technologies can make a revolution in the agriculture in order to increase food production without prejudice to the depleting natural resources and the environment? Obviously, the digital technologies may become a "liaison" uniting many concerned parties on a common platform through which developed countries can help countries with the highest rates of poverty and hunger through innovation, investment, and promotion of entrepreneurship. The purpose of our study is to find an answer to the questions, which countries can take leading positions in the context of the formation of innovative trends and ensuring food security in the global food market, in which areas will the digitalization be performed and what is its role?

Materials and Methods

The study was performed using the following methods and techniques of scientific knowledge: analysis, synthesis, deduction and induction, analytical comparisons.

Research Results and Discussion

Currently, modern world food systems are entering a fundamentally new stage of technological development, the merger of online and offline areas, introduction of digital technologies. Digitalization as a scientific category is quite new; it appeared in the second half of the 20th century; first of all, it is associated with the intensive development of information and communication technologies. If the initial stage of digitalization was characterized by the expansion of Internet access, the large-scale digital transformation being implemented in modern conditions is associated with integration of a spectrum of digital services, products and systems, that is, the formation of a "cyber-physical" world.

Most modern studies note that digitalization is based on the concept of Alvin Toffler, which considers the emergence of a new type of society from the point of view of technological determinacy. It is the new electronic and communication technologies that serve as an indicator of structural changes in modern society for him. The most detailed development of Toffler's concept is presented in the second book of his trilogy. It's called The Third Wave. Toffler suggests his own term characterizing post-industrial society – "the third wave". "The first wave" and "the second wave" he associates, respectively, with the agrarian and industrial society.

Perhaps the most developed concept of digitalization is offered by M. Castells in his three-volume edition "The Information Age". Like Toffler, Castells divides the history of mankind into three civilizations: agrarian, industrial, informational. But Castells determines different distinctive characteristics of these types of society. If for the agrarian

civilization the main feature is the quantitative growth of labour efforts and the extraction of resources, for the industrial era – the introduction of new energy sources, for the information age it is the technology of knowledge generation and information processing.

On the rise of recent scientific research, the concept of the "fourth industrial revolution" appeared, which was first introduced in Germany in 2011 and involved the implementation of the processes of development, production and delivery of products by transferring data in real time between all participants of the business processes, implying maximum transparency and awareness. The digital economy and Industry 4.0 are of current interest among scientists and practitioners, and the description of these concepts is the subject of the papers of famous scientists abroad and in Russia.

Following the industrial revolution, the agrarian revolution called "Agriculture 4.0" came and involved the use of "smart" solutions, bio- and nanotechnologies, progressive methods of processing and interpreting digital data. However, the digitalization of agriculture is not only the use of robots, aircrafts, precision agriculture technology, "smart" farm, but also the transformation of the process of creating agricultural products.

The appearing now transformations are so rapid and large-scale that in the next decade they will radically change the appearance and conditions for the world agro-industrial complex development, the role of which, even now, has ceased to be limited to a simple function of food production. Digital globalization changes all spheres of human activity, governs the appearance of world trends in social development. In this regard, it is necessary to pay attention to the nature of global challenges, since they induce innovative trends that go far beyond the agro-industrial complex. Global challenges are caused by the following factors:

1. Resource factors. They are caused by growing demand for the food associated with the reducing resources and slowing labour productivity. The world produces enough food, but the access to it varies. By 2050, according to the forecast of the Food and Agriculture Organization, population will make up 10 billion persons against 7.7 billion persons in 2019, and as a result – possible increase in income and an increase in global food demand will increase up to 50%.

Due to a number of factors – a decrease in the agro-climatic potential, degradation and depletion of natural resources due to agrochemical pollution, threat of the spread of infectious diseases – the ensuring of high rates of food production may be difficult. In the future, for 10-20 years, development of the world agro-industrial complex will be characterized by a shortage of resources for ensuring growing needs, production should depend on the technologies of agricultural yield enhancement and the productivity of agricultural animals.

2. Social factors are associated with the growth of urbanization and digitalization of population, a change in value orientation. According to the UN, by 2030 up to 60% of the world's population will live in cities, by 2050 – up to 68%, for comparison in 2020 this figure is 56.2%.

The predominance of rural population will remain only in African countries. Urban population is characterized by a higher level of education, awareness of nutrition and food choices. Accordingly, urbanization will affect the structure of the diet, consumer behaviour, production and distribution of food products, and introduction of digital technologies to optimize the supply chain. Social factors form the following trends, an increase in demand for ecologically-safe, processed foods, as well as healthful, ready-made meals, and an increase in online commerce.

3. Technological factors provide for the use of new models and complex solutions in the agricultural production associated with the introduction of "smart farms" technology, closed and partially closed farms that use alternative resources. For example, urban farms that makes it possible to get high-value products anywhere in the world, regardless of natural factors.

Changes associated with the development of digital technologies are so large-scale that they can change our way of life, respectively, the delayed reaction of certain countries in the application of new technologies in the agro-industrial complex will increase technological dependence on leading countries and threaten to reduce global food security.

But in order to reap the benefits of digital transformation in the agricultural sector, it is important to understand how new technologies can contribute to the processes that fundamentally change the entire structure and way of operation of the existing agri-food systems in the world. It is important to analyse the trends in the development of digital technologies in agriculture, to identify the main business models.

The intensification of technological transformation processes in the agro-industrial complex is also evidenced by the growth of private investment in digital startups (Table 1).

According to the official data of AgFunder, their value for 2014-2020 has reached 105.3 billion US dollars, a rapid

growth was observed in 2020 in comparison with 2019 by 52%.

Table 1: Investments in agricultural technologies in the world

Indicators	Years							Rate of change, %	
	2014	2015	2016	2017	2018	2019	2020	2019 vs 2018	2020 vs 2019
Total investments in agricultural technologies, billion US dollars, including:	5.7	8.8	8.6	11.5	20.8	19.8	30.1	95.2	152.0
consumer technology ("from market to plate")	2.8	5.8	5.1	6.5	13.2	12.0	14.3	90.9	119.2
industrial technologies ("from farm to market")	2.9	3.0	3.4	4.8	7.5	7.6	15.8	101.3	207.9
Number of transactions, total, thousands of transactions, including:	1.1	1.4	1.6	1.8	2.2	1.9	3.1	86.4	163.2
consumer technology ("from market to plate")	0.5	0.7	0.8	0.8	1.1	1.1	1.1	100.0	100.0
industrial technologies ("from farm to market")	0.5	0.7	0.8	0.9	1.1	0.8	2.0	72.7	250.0

The structure of private investments in agricultural technologies consists of two business models: consumer technologies "from market to plate" (downstream) and industrial technologies "from farm to market" (upstream).

The consumer technology segment accounts for 14.3 billion US dollars in 2020, an increase by 19.2% compared to 2019. In the structure of investments, the tendency "from market to plate" takes 56.6%, in monetary terms – 59.7 billion US dollars on a cumulative total for 2014-2020.

Development of the stated segment by anticipatory actions is associated with such social factors as: increasing urbanization and digitalization. In terms of the number of transactions, however, it is inferior to the segment of industrial technologies – for 2014-2020 it accounts for up to 46.56% in the total structure, cumulatively.

Industrial technologies "from farm to market" include a range of solutions in the field of agrobiotechnology, technology of processing and logistics of agricultural products. Total scope of investments for the analysed period is only 45 billion US dollars, the average value of transaction in this segment is 47% higher (cumulatively) than in the consumer technology segment, which is due to the investment in innovation and scientific and technical development.

The structure of global expenditures in agricultural technology in 2020 is given in Table 2.

Table 2: The structure of global expenditures in agricultural technology in 2020

Indicators	Investments, (billion US dollars)	Number of transactions	Average value of transaction (billion US dollars)
1. From market to plate (downstream)	12.24	813	15.1
services for the delivery of ready-made food from restaurants	2.1	72	29.2
services for the delivery of products from online stores	5.1	202	25.2
technologies of restaurant and retail (in store)	2.4	294	8.2
services for the delivery of semi-finished products and ingredients	0.574	120	4.8
home and kitchen technologies	0.15	59	2.5
cloud retail technologies	1.9	66	28.8
2. From farm to market (upstream)	13.62	1387	9.8

Agrobiotechnologies	1.6	179	8.9
Technologies of processing and logistics	5.3	338	15.7
Farm management technologies	0.879	188	4.7
E-commerce platforms for the agro-industrial complex	1.1	89	12.4
Bioenergy and biomaterials	0.772	131	5.9
New farming systems	1.3	99	13.1
Innovative food supplies	2.3	260	8.8
Robots and equipment	0.375	103	3.6

In 2020, the leading positions are taken by the technologies of processing and transport logistics – these are solutions in the field of ensuring safety and transparency of production and distribution, preservation, packaging and storage, with an investment scope of 5.3 billion US dollars, the number of transactions 338 and average value of 15.7 million US dollars. The second place is taken by services for the delivery of food from online stores with an investment scope of 5.1 billion US dollars, with an average transaction value of 25.2 million US dollars.

Results of the investor sentiment analysis makes it possible for us to conclude that the most attention is concentrated in the "from farm to market" segment, while the segment "from market to plate" is highly overvalued in terms of delivery of ready-made food from restaurants and online stores. In a study performed by AgFunder [8] in 2020, the most investment-worthy are the following areas: agrobiotechnologies (58% of investors), technologies of processing and logistics, innovative food, smart farm management technologies.

The identified trends create fundamentally new opportunities for increasing the competitiveness of the agro-industrial complex and ensuring food security in the period of digital transformation for individual countries. Which countries of the world have the potential to ensure global food security in the context of digitalization of food systems? To answer this key question, it is necessary to identify countries that are able to provide food not only to the population of their country, but also to other states. Leading exporters and importers of the agricultural products in the world are given in Table 3. It should be noted that data provided do not include indicators of exports and imports of highly processed food products.

Table 3: Leading exporters and importers of the agricultural products in the world

	Scope, billion US dollars	**Share in world export/import, %**				**Annual growth rate, %**			
	2019	**2000**	**2005**	**2010**	**2019**	**2010-2019**	**2017**	**2018**	**2019**
Export									
EU	639	38.9	41.9	37.4	35.9	3	8	6	-2
USA	165	13.0	9.8	10.5	9.3	2	3	1	-4
Brazil	89	2.8	4.1	5.1	5.0	3	14	6	-5
China	82	3.0	3.4	3.8	4.6	5	4	6	-1
Canada	65	6.3	4.9	3.8	3.7	2	6	4	-6
Thailand	43	2.2	2.1	2.6	2.4	2	18	2	-3
Indonesia	42	1.4	1.7	2.7	2.4	2	26	-7	-8
Argentina	40	2.2	2.3	2.6	2.2	1	-4	-3	15
India	37	1.1	1.2	1.7	2.1	6	17	0	-4
Mexico	36	1.7	1.5	1.4	2.0	8	12	6	3
Total	1230	72.5	82.8	71.6	69.6	-	-	-	-
Import									
EU	595	36.3	39.2	35.7	33.3	2	9	6	-4
China	199	3.3	5.0	7.8	11.2	7	17	8	2
USA	181	11.6	10.7	8.4	10.1	5	7	6	1
Japan	83	10.5	7.3	5.6	4.6	1	7	5	-
Great Britain	71	5.8	5.9	4.6	4.0	1	4	6	-3
Canada	41	2.6	2.4	2.3	2.3	3	4	3	1
The Republic of Korea	37	2.2	1.9	1.9	2.1	4	8	10	-3

The Russian Federation	31	1.3	1.9	2.6	1.7	-2	16	3	-
Mexico	28	1.9	1.8	1.7	1.6	2	6	5	-8
Hong Kong	28	N/A	N/A	N/A	N/A	3	2	4	-7
Total	1284	76.5	76.9	71.4	72.0	-	-	-	-

As it is seen from Table 3, a number of countries is actively using the advantages of international division of labour: the EU, USA, China, Canada are among both exporters and importers of agricultural products. The peculiarity of the presented countries of leaders in food production in the world market is that not all of them are agricultural countries. The main income of an agrarian country is agriculture, which determines specialization in the international division of labour. A significant part of the agrarian countries are underdeveloped or developing ones. Somalia is an ideal example, where the share of agriculture in the country's GDP is 65.5%, and 72.3% accounts for the employed in the industry.

It can be concluded that the rating of food importers and exporters differ both in the nature of international division of labour and in the type of economy (mainly industrial or agricultural). In addition, the status of agrarian country does not cover the satisfaction of the needs of population and ensuring food security. The reasons are the low level of development of agricultural countries, low productivity and an insufficient level of implementation of modern innovative technologies in the industry.
Prospects for the growth of agricultural production through the introduction of innovations are differentiated depending on the level of the country's innovative potential. In order to determine the impact of digital technologies on the production of agricultural products and food in the world we choose the indicators of agricultural development, and the level of the economy innovativeness determined through the global innovation index for 10 leading manufacturers.

Table 4. Indicators of agricultural development of the leading food producers in the world according to data for 2019

Manufacturing countries	Value of agricultural production in millions international dollars	Ratio of food exports and imports	Share of employment in agriculture	Share of agriculture in GDP	Rank in the Global Innovation Index
China	888,374	0.4	25.4	7.19	14
India	427,394	2.04	43.21	14.6	52
USA	364,293	0.9	1.34	0.92	3
Brazil	246,615	7.46	9.22	4.36	66
Indonesia	101,615	2.0	26.6	12.81	85
The Russian Federation	98,010	0.82	5.76	3.15	46
Argentina	77,353	9.3	0.06	6.10	73
Pakistan	72,691	1.05	36.7	22.86	105
Turkey	69,083	1.78	18.38	5.82	49
Mexico	64,063	1.3	12.61	3.39	61

Based on the presented data, the leading food manufacturers may be grouped into three areas.

The first group includes a country with highly efficient agricultural production – this is the United States, the digital transformation of agriculture is proceeding at a high pace and the country tops the rating of investors in the field of digital technologies in the industry. However, the United States cannot be classified as an agricultural country, the share of agriculture in GDP is 0.92%, employment in the industry is at 1.34%. As a result, further modernization of agriculture in countries is unlikely to have a significant impact on ensuring global food security.

The second group of countries is characterized by the developed agriculture and emerging food markets – China, the Russian Federation, Turkey, Brazil and Argentina. Prospects for the development of digitalization in these countries depend on the implementation of innovative potential. The leader in this group of countries is China, which is ranked 14th in the global innovation index, the lowest index has Argentina – 73rd rank, but at the same time it has the highest index of food export and import. It should be noted that China is focused on meeting domestic demand for food, therefore its contribution to world food trade may be assessed as insignificant.

The third group covers developing countries – Mexico, Pakistan, Indonesia, characterized by low labour productivity and insufficient innovation potential. Taking into account the low probability of an intensive increase in agricultural production in the nearest future, low innovation potential and the unlikely modernization and digitalization of

agriculture, it can be argued that food security is under threat in the stated countries.

Conclusion

Thus, digital transformation is not a panacea in the context of global food security, but it can be the foundation of food security within each country. In order to ensure national food security and competitiveness in the face of global challenges the countries should increase the level of implementation of innovative technologies, develop innovative infrastructure, invest in digital technologies, in training and retraining of personnel, and this, in turn, is possible through state policy in the field of stimulating innovative processes in agriculturethemselves may be of integrated nature, that is, they may be calculated on the basis of other, particular indicators.

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