The use of modern robotic systems in the agro-industrial complex

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Abstract. The article presents assessment of the role of digital technologies in the co-evolution of all elements of production systems, their comparison with traditional production technologies, the value of strengths and weaknesses of introducing digitalization into production processes of agricultural enterprises, the systematization of the experience of using robotic systems, the importance of disseminating information on the effective management of the digital transformation and the use of robots in the dairy industry. The authors estimate the effect of investments in digital technologies of agricultural enterprises. The classification of agricultural robots is carried out depending on the type of tasks performed. The results of the study of the world market of agricultural robots are presented and the dynamics of global investments in digital technologies of agricultural production is analyzed. The dependence of the result of using robotic systems on the scale of production is revealed. An assessment of the economic feasibility of switching to robotic systems for dairy production has been carried out. The structure and trends of the market of robotic milking systems in the Russian Federation are evaluated. Russian regions are grouped according to the number of operating robotic milking systems. The prospects for the further implementation of robotic systems in the production processes of agricultural enterprises and the role of state support in this process are assessed.

1. Introduction

The use of digital technologies in agriculture leads to the transformation of value chains and the co-evolution of all elements of production systems: social, biological, technical and technological ones in the process of their adaptation to external conditions of functioning [1-2].

According to the criterion of the volume of required capital investments, robotization is incomparably more difficult to implement in small farms, for example, in comparison with technologies of using the Internet of Things (Internet of Things, IoT), for which a smartphone and the installation of special software are often enough.

The consequences of digitalization are ambiguous. Digital transformation has some negative impact on the implementation of policies to support the diversification of agricultural production. Negative socio-demographic trends are noted as a result of employee displacement, especially "seasonal" workers. The need for low-skilled (and low-paid) work is decreasing. According to a study by auditing company Deloitte [3], digitalization stimulates the vertical integration of agricultural producers, which can lead to the creation of more favorable conditions for large companies and the formation of "digital inequality" in agricultural markets and their monopolization.
According to the report of the Committee on Agriculture and Agrarian Policy of the European Parliament [4], modern robotic systems for sowing and harvesting cannot yet compete with traditional technologies. At the same time, robotization has proven its effectiveness in the field of dairy production. The results of the work of 217 Canadian robotic dairy farms in 2014-2015 showed a reduction in personnel costs due to a significant share of employee displacement, a decrease in the duration of the production cycle, an increase in production and some improvement in quality indicators [5]. An analysis of the experience of the United States and European countries confirms that the transition to robotic dairy production contributes to a decrease in CO₂, an increase in energy efficiency, and economical consumption of water resources.

Researchers believe that one of the main advantages of robotic milking systems is the minimization of human intervention in the production process [6]. Reducing the labor intensity of the work performed as a result of introducing digital technologies has some positive effect on the quality of life of those employed in the agricultural sector. Research in Norway shows that robotization of dairy farms leads to positive changes for workers in the reallocation of time between work and family, increased job satisfaction, psychological comfort and reduced stress [7].

Comparison of traditional dairy production and robotic farms shows that the greatest effect is expected with a herd of 35-40 cows and more [8]. The return on investment in robotization occurs on average in 4-5 years from the moment of the first investment. At the same time, accelerated rates of return are possible due to the increase in production volumes and the dissemination of information on the effective management of the digital transformation process - the so-called "learning effect" of the practice of using robots in dairy production [9-10].

2. Materials and Methods

Initial data for a comparative analysis of trends in the development of traditional and robotic dairy industries include scientific publications on the topic, statistical databases of the Food and Agriculture Organization of the United Nations, open databases of statistics aggregators (KNOEMA, Statista, etc.). In the course of the study, the following methods were applied: dialectical cognition of socio-economic processes, system analysis, a formal-logical method, as well as methods of mathematical and statistical processing of the data obtained.

3. Results and Discussion

In terms of functionality, agricultural robots can be classified into two main types. The first one is focused on performing tasks based on data from sensors (treatment of plants with herbicides, monitoring the state of plants / animals, etc.). The second type of robots is capable of performing different types of work depending on the installed (and replaceable) devices and applications. Thus, a robot used in dairy production is capable of taking from 100 to 300 different readings of devices and sensors during the milking process (body temperature of an animal, disease symptoms, milk quality, etc.), which makes it possible to improve the system for monitoring and controlling the quality of production processes and products, track the condition of the animal.

In 2019, the world market for agricultural robots amounted to 445.3 billion rubles, and according to industry experts, the predicted value of the indicator by 2025 will be 1,503.8 billion rubles. At the same time, according to FAO data, in 2020 the largest share in investments in digital technologies for agricultural production in the world was occupied by investments in software for managing an agricultural organization, sensors, the Internet of Things (Figure 1).

According to statistical portal Statista.com, more than 127.2 thousand robots were shipped for agricultural production in the world in 2019, and by 2025 this figure, according to forecasts, will increase by 4.4 times and will amount to more than 561.2 thousand pieces. The limiting factor for the spread of robotization in the world is the high cost of purchasing, installing and maintaining equipment.
Figure 1. Investments in digital technologies for agricultural production in the world, 2020 (million rubles).

The robotization of production helps, first of all, to avoid heavy and monotonous work, and also allows to increase labor productivity not only in agriculture, but also in dairy farming. The widespread use of milking machines began in the mid-1990s with the launch of commercial production of affordable milking robots.

General global trends in the sale of robots for dairy production in the world are shown in Figure 2.

Figure 2. Sales of robots for dairy production in the world, pcs.

This trend is only growing, and according to analysts, sales of robotic systems for dairy farms in 2025 will reach 13,000 robots per year.

The most widespread robotic systems in dairy production are in the Netherlands (30 % of all dairy farms have switched to digital technologies), about 3 % of dairy industries are robotic in the United States. In 2016, the European countries leading in the introduction of robots in the newly created dairy production were Sweden and Finland where up to 90 % of new production facilities were created on the basis of modern technologies, as well as Germany with more than 50 % of all created enterprises. It is estimated that by 2025, approximately 50 % of dairy farms in northwest Europe will switch to robotic milking [11].

Studies have shown that compared to the productivity level of traditional European dairy farms (6,900 kg per year), fully robotic systems are capable of doubling the result - up to 12,000 kg per year with the same input production resources. However, it should be noted that the result of using robotic systems depends on the scale of production (and on a number of other factors). According to a study published by experts from the USDA in 2002, the use of robots in dairy production compared to
traditional technologies is effective when the size of the herd corresponds to the production capacity of robots (60, 110, 170 heads, etc.) [12].

According to the results of empirical research and simulation an assessment of the economic feasibility of switching to robotic systems for dairy production confirms the need for an objective analysis of the positive results of digitalization not only in financial terms, but also considering the social, technological, environmental and other strategic advantages of introducing innovations (Figure 3) [13,14,15].

The first robotic systems in dairy farming began to be used in the Russian Federation only in 2007. For the first time, milking robot VMS DeLaval was used. One of the priority areas of departmental project "Digital Agriculture" is direction "Smart Farm", which provides for the creation and implementation of appropriate domestic competitive technologies, the production of a complex of robotic machines for farms, the development of modern animal protection systems, introduction of a set of sensors to monitor the physiological state of an animal [16-17].

By the end of 2016, there were about 500 robotic milking systems operated in about 100 dairy farms in Russia [18].

European manufacturers were the leaders of the Russian market in terms of the number of delivered milking robots in 2016 (Figure 4) [19].

![Figure 3](image3.png)

**Figure 3.** Profit per cow (traditional vs. robotic dairy production, rubles per year/head).

![Figure 4](image4.png)

**Figure 4.** Market leaders in Russia by the number of delivered milking robots in 2016, %.
About 40% of this market was owned by Swedish company DeLaval VMS [20-21].

Robotic farms are scattered across the territory of the Russian Federation rather unevenly. There are leading regions, and there are no such farms at all in other regions. Figure 5 shows the subjects of the Russian Federation, where six or more robotic dairy farms exist and function.

![Figure 5. Russian regions leading in the number of robotic dairy farms, %.

Only one robotic dairy farm operates in 18 regions of the Russian Federation, two in five regions, three in four regions, four in three regions. In the rest of the constituent entities of the Russian Federation, not a single robotic dairy farm operates yet.

4. Conclusion
In the long term, agricultural robots will become autonomous and adaptive, depending on the operating conditions and the complexity of the work. The following factors will contribute to the achievement of the sustainable development goals:

- the transition of robots to new sources of electrical energy (including those located directly on the territory of production);
- reducing the negative impact of heavy agricultural machinery on the soil through the use of "modular" robots, which will be placed directly on the cultivated area and will be able to perform "point" impact only where it is necessary;
- reduction in the amount of resources required for production, including reduction in heavy (and monotonous) physical labor that does not require complex decisions;
- the optimal use of treatment (protection) means (herbicides, pesticides, insecticides, etc.), which will reduce the negative impact on soil and water resources.

The need to increase the productivity of agricultural production is due not only to economic, but also social factors, including the gradually emerging need to equalize the living standards of the rural and urban population, to reduce the labor intensity of agricultural work (which, among other things, will allow women to get additional jobs). However, the transition to digital technologies, which can contribute to productivity growth, is associated with long waiting periods for return on investment, risks at the implementation stage, and the complexity of adapting innovations to local operating conditions. The success of the implementation depends not only on the correspondence between the scale of production capacity and the potential of modern equipment and technologies. Even for large industries, the transition to robotic systems will require in addition to solid funding, the presence of a developed infrastructure of service companies, a certain level of technological development of other
participants in the supply chain, personnel qualifications, etc. Government support measures can remove some of the risks through mechanisms for co-financing digitalization projects, preferential subsidies for innovative industries, etc.

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