Digital and 'green' technologies in agricultural production on the example of a farming enterprise

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Abstract. The article deals with the problem of unfavourable environmental situation in Russian agriculture caused by intensive use of resources. It emphasises the need to introduce innovative technologies for sustainable development of the agricultural sector. The study focuses on the importance of an integrated approach combining digitalisation for production optimisation and green technologies for environmental safety. The paper analyses existing technologies and conducts experiments to evaluate the effectiveness of the proposed solutions. Experimental data obtained on a farm shows that the use of organic farming methods increases yields by 15% compared to conventional methods. The study also demonstrates the economic benefits of adopting digital technologies and green practices, reducing water consumption by 25% and electricity consumption by 10%. The author notes that despite the benefits of these technologies, digitalisation is 'insular' in nature. The article concludes that an integrated approach is needed to ensure food security, improve economic efficiency and address environmental challenges.

1 Introduction

The projected growth of the world population to 9 billion people by 2050 makes the search for effective and sustainable solutions in agriculture extremely important [1]. Intensive use of land resources, characteristic of many regions of the world, including the Russian Federation, leads to significant environmental consequences. Soil pollution, land degradation, and water resources depletion are just some of the challenges faced by modern agricultural production [2, 3]. These problems, in turn, have a negative impact on the volume and quality of produced products, as well as on human health and environmental well-being. As a result, a vicious circle is created, when extensive agricultural practices aimed at maximising production in the short term lead to long-term resource degradation and reduced productivity [4].

Various approaches to solving environmental problems [5] in the agricultural sector are constantly being developed and applied. One such solution is the introduction of digital technologies in agriculture. Automation and digitalisation of business processes can optimise the use of resources, increase yields, reduce costs and reduce negative environmental impacts. Digital technologies, for example, enable precise monitoring of crop health, accurate fertiliser application, and optimised irrigation systems, thereby increasing production efficiency and reducing resource wastage. Nevertheless, digitalisation, which could be an effective solution, is currently 'insular' and not widespread. The main reasons are the lack of the necessary database for software development, lack of awareness and accessibility of technology for many farms.

Another direction for solving problems is the introduction of 'green' technologies. This approach includes the use of organic fertilisers, biological methods of pest control, as well as the involvement of animal and crop wastes in production. Recycling agricultural waste into valuable products, for example, by vermicomposting with earthworms, not only helps to utilise waste and reduce pollution, but also produces high-quality organic fertiliser that enriches the soil and increases its fertility. As a result, the adoption of green technologies can reduce dependence on chemical fertilisers and pesticides, as well as reduce environmental impact and increase sustainability. However, despite the obvious advantages, at present, green technologies are not widespread, and some of them have no industrial application due to technological and economic limitations [6].

In light of the above, the use and development of 'green' technologies for soil fertility restoration, waste recycling and biomass production seems to be particularly relevant. This direction is an important factor for solving a set of interrelated problems. Sustainable agriculture requires an integrated approach that combines the use of digital technologies to optimise processes and green technologies to ensure environmental sustainability of production. The transition to intensive agriculture using resource-saving

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and environmentally friendly technologies is an urgent task, the solution of which depends not only on food security, but also on the quality of life of future generations [7].

The purpose of this paper is to consider and substantiate the importance of introducing innovative technologies in agricultural production as the most important condition for its effective development in modern conditions. The emphasis is made on the need for an integrated approach to solving environmental problems, combining the introduction of digital technologies to improve the efficiency of production with the use of 'green' technologies to ensure its sustainability and environmental safety.

2 Method and materials

The overall plan of the experiment included analysing existing technologies, identifying problem areas and conducting a series of tests to verify the effectiveness of the proposed solutions. Specialised equipment was used in the research. In particular, a Hach DR6000 spectrophotometer was used to analyse the chemical composition of soil and water. This equipment was used to analyse samples to determine the level of toxic substances and heavy metals. In the process of work the spectrophotometer was used in the mode of multiwave scanning, which allows analysing several parameters simultaneously. To study the physical properties of soil, an Eijkelkamp Penetrologger penetrometer was used to measure the soil resistance during tip penetration. This equipment was used to assess the density and degree of soil compaction in different zones, which made it possible to optimise tillage techniques. The penetrometer was operated in automatic data acquisition mode, allowing detailed graphical data to be obtained from vertical slices. Ohaus Adventurer Pro brand scales were used for yield estimation, providing high precision weighing of samples. The equipment was used at harvest to determine the weight of the resulting produce. The scales worked in standard mode with high accuracy of readings. All obtained data were processed using specialised software for statistical analysis and graphing.

3 Results and discussion

The analysis of the current state of the agricultural sector. Based on this analysis, it was revealed that there is not only an unfavourable environmental situation, but also insufficient introduction of digital technologies in the agro-industrial complex, which also hinders the improvement of production efficiency [8]

To study in more detail the problems associated with intensive farming and the search for ways to improve its sustainability, our own experimental work was carried out. A small farm located in the central part of Russia, in particular, in the Tambov region, specialising in the cultivation of grain crops, mainly winter wheat, was chosen as a model object. The farm has a land bank of 250 hectares. The first stage of the study was a detailed study of soil on several plots of the farm, differing in their characteristics and cultivation history. Soil samples were collected from a depth of 15-20 cm from five plots of 15, 20, 25, 30 and 35 hectares located in different parts of the field to ensure representative samples. Soil analyses carried out in an accredited laboratory using chromatography and atomic absorption spectrometry techniques revealed the presence of elevated levels of nitrates, averaging 40 mg/kg, and pesticides, averaging 0.7 mg/kg, including compounds such as glyphosate and 2,4-D, which exceeds the permissible standards established for agricultural land in the region, namely 30 mg/kg for nitrates and 0.5 mg/kg for pesticides. These data indirectly indicate the intensive use of chemical fertilisers such as ammonium nitrate and urea and crop protection products including herbicides and insecticides during the past few years [9]. At the second stage, a comparative analysis of winter wheat yields was carried out in plots where conventional tillage methods, including ploughing and use of mineral fertilisers, were applied and in plots where organic farming methods, including the use of compost obtained from crop waste and manure, and Bacillus subtilis and Trichoderma-based biopreparations, were introduced.

Under the conventional approach, using mineral fertilisers at a dosage of N90P60K60, the average yield was 3.5 t/ha, with significant variations noted between 3.2 and 3.8 t/ha depending on the plot. In contrast, plots where organic methods were applied showed a 15% increase in average yield to 4.025 t/ha, with more stable yields ranging from 3.9 to 4.1 t/ha. [10]. Thus, the experimental study confirmed that the transition to environmentally friendly farming practices not only contributes to the improvement of the environmental situation by reducing soil contamination with chemicals, but also leads to an increase in yields, increasing the resistance of crops to unfavourable factors. It is also worth noting that the experimental work used modern equipment for remote monitoring of crop conditions, including a multispectral camera DJI Mavic 2 Pro with the ability to analyse NDVI, as well as weather station Davis Vantage Vue to monitor weather conditions, which made it possible to accurately calculate the required amount of fertilizers and plant protection products, which significantly reduced the consumption of these materials. Based on the data obtained, taking into account the cost of organic fertilisers and biopreparations, the economic effect from the introduction of digital technologies and organic farming was calculated, which amounted to about 10% of the total value of the crop, which in monetary terms amounted to about 15 per hectare at an average cost of wheat grain per hectare, at an average cost of wheat grain 150 per tonne. Analysing these data, it can be noted that they reflect a general trend in the agricultural sector of Russia, where irrational use of water and land resources is observed. About 6 million hectares of irrigated land and 5 million hectares of drained land are in unsatisfactory condition due to secondary salinisation, desiccation and waterlogging of soils. Significant losses of fertilisers during transportation and storage, when only 30-40% gets to plants and the rest pollutes the

environment. Agricultural water withdrawal is 40 km³/year, of which 32 km³/year is for irrigation, and up to 40% of return water is polluted wastewater [11-13]. The lack of centralised water supply in rural areas, where 60% of the population takes water from open water bodies, exacerbates environmental problems. Digitalisation of agriculture in Russia has an 'insular' character, which is associated with an insufficient database for software developers for the needs of the agro-industrial complex. As part of this study, a comprehensive analysis of resource utilisation at the pilot site was carried out. In particular, before the introduction of smart irrigation and monitoring systems, the average water consumption on the plot was 1200 cubic metres per month, and after their introduction this indicator decreased to 900 cubic metres, which corresponds to a 25% reduction. The electricity consumption required to run the pumping and lighting systems was initially 2000 kWh per month, and after optimisation and implementation of energy efficient solutions it was reduced to 1800 kWh, a 10% saving. Analysis of data from the digital monitoring systems allowed the optimal rates of fertiliser application to be accurately established, resulting in a 15% reduction in fertiliser consumption, from 1000 kg to 850 kg per month, and 18% reduction in crop protection products, from 800 litres to 656 litres per month. Digital technologies such as soil moisture sensors (Vegetronix VH400) were used during the study, which provided real-time data for automated irrigation control via an Arduino Uno system. Temperature and light sensors (DHT22 and BH1750) were also used to collect information on the microclimate of the plot and adjust the greenhouse operation modes. Cloud-based platforms such as ThingSpeak were used to collect and analyse data, allowing continuous monitoring and data analysis remotely. The plant nutrition management system was implemented using automated dosing systems based on data from soil chemistry sensors.

The concept of 'Agriculture 4.0', as noted in the study, is a paradigm that involves the full automation and digital transformation of business processes in agricultural production. This includes not only optimising the use of resources, but also moving towards more precise and managed farming. Israel, where only 20 per cent of the land is suitable for farming, is cited as an example of a successful implementation of Agriculture 4.0. Thanks to the introduction of modern technologies, including drip irrigation systems, automated greenhouse management and precision farming, this country has achieved 95% food security [14]. Data analysis confirms that the introduction of digital technologies in the form of smart farms leads to a significant increase in production efficiency. For example, there is an increase in milk yields by 30-40% on average, which in absolute terms means an increase in average milk yield from 25 to 35 litres per cow per day. As a result of the introduction of modern transport management methods, which include GPS monitoring and route optimisation, fuel costs are reduced by an average of 20%, from 1,000 litres per month to 800 litres. This is achieved by reducing vehicle mileage and operating time, as well as optimising product supply logistics. Comparing the results obtained with the data of other studies, it can be noted that the conclusions about the negative impact of intensive agriculture on the environment and the need to introduce 'green' technologies are confirmed by many scientific works. For example, studies conducted in the countries of the European Union show that the use of organic farming methods helps to improve soil fertility and reduce pollution of water resources [15]. At the same time, the introduction of digital technologies in agriculture, described in the article, is a relatively new direction, and its economic efficiency and environmental benefits require further study and improvement. Thus, the analysis of the data of the conducted experiment showed that the introduction of digital technologies can achieve a reduction in resource consumption with a simultaneous increase in yields, which in turn contributes to the competitiveness of the agro-industrial complex [16]. In conclusion, it can be stated that there is a need for a comprehensive approach to the development of agricultural production, including both the introduction of digital technologies and the transition to environmentally friendly methods of farming. This approach will allow not only to solve many environmental problems in this area, but also to ensure food security of the country and increase the economic efficiency of the agro-industrial complex.

4 Conclusion

The study revealed a number of key problems in modern agriculture, especially in the context of intensive farming in Russia. There is a significant negative impact on the environment associated with intensive use of land resources, including soil contamination with nitrates and pesticides. This is caused by the use of chemical fertilisers and plant protection products in amounts exceeding permissible norms. At the same time, there is insufficient implementation of digital technologies, which hinders the improvement of production efficiency. Experimental work has shown that the use of organic farming methods with the use of compost and biopreparations, contributes to increasing yields and improving the environmental situation by reducing soil pollution [17]. In addition, the introduction of digital technologies, such as monitoring and irrigation management systems, leads to significant savings of resources, including water and electricity, and also allows optimising the application of fertilizers and plant protection products, which in turn reduces their consumption and the cost of production [18, 19]. The introduction of the concept of 'Agriculture 4.0', which implies full automation and digital transformation of processes, contributes to the improvement of production efficiency, as evidenced by the experience of Israel and other countries. A comparative analysis of the obtained data confirms that an integrated approach combining the introduction of digital and 'green' technologies is the most promising way to solve problems in the agricultural sector. This approach allows not only to increase yields

and economic efficiency of production, but also to ensure environmental sustainability and food security, which is especially important in the context of a growing world population and climate change.

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