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INNOVATIONS IN SUSTAINABLE AGRICULTURAL DEVELOPMENT: TRENDS, ISSUES, PERSPECTIVES

ІННОВАЦІЇ В СТАЛОМУ РОЗВИТКУ АГРАРНОГО ВИРОБНИЦТВА: ТЕНДЕНЦІЇ, ПРОБЛЕМИ, ПЕРСПЕКТИВИ

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The article is dedicated to exploring the role of innovations in sustainable agricultural development, along with an analysis of current trends, identifying issues, and discussing prospects in this field. Experience from developed countries worldwide confirms that effective development of the agricultural sector and its competitiveness in modern conditions are achieved through the activation of innovative activities. The authors emphasize the significance of innovative approaches for the sustainable development of the agricultural sector, which plays a crucial role in a country's economy and ensures food security. The article examines current trends in the innovative development of agricultural production, such as the adoption of advanced technologies and improvement of production processes. The challenges facing the agricultural sector are identified, including insufficient financial resources, limited access to innovative solutions and technologies, and difficulties in implementing innovations in production. Prospects for the development of the agricultural sector through innovative solutions are explored, with a particular focus on opportunities for increasing productivity, improving product quality, reducing environmental impact, and promoting sustainable agriculture.

Keywords: innovations, sustainable development, agricultural production, agricultural enterprises, innovative technologies.

Багаторічний досвід розвинених країн світу підтверджує, що ефективний розвиток аграрного сектора економіки та забезпечення його конкурентоспроможності в сучасних умовах досягаються завдяки активізації інноваційної діяльності. Стаття присвячена дослідженню ролі інновацій у сталому розвитку аграрного виробництва, а також аналізу поточних тенденцій, ідентифікації проблем та розгляду перспектив у даній сфері. Дослідження базується на сучасних положеннях економічної теорії та результатах наукових праць провідних вітчизняних та зарубіжних вчених, у сфері інноваційних трансформацій з урахуванням викликів, пов'язаних з глобальним сталим розвитком. Метою статті є виявлення тенденцій та можливостей для інноваційного розвитку аграрного

виробництва, а також ідентифікація факторів, що можуть уповільнювати або перешкоджати цьому процесу. Авторами акцентується увага на значущості інноваційних підходів для сталого розвитку аграрного сектору, який має важливе значення для економіки країни та забезпечення її продовольчої безпеки. У статті розглядаються переваги впровадження інноваційних технологій у господарську діяльність аграрних підприємств, серед яких підвищення продуктивності праці, зростання урожайності, оптимізація управління витратами, зниження відходів виробництва, мінімізація вуглецевого сліду тощо. Визначаються проблеми, що стоять перед аграрним сектором, зокрема висока вартість обслуговування нової техніки, обмеженість доступу до інноваційних рішень та технологій, а також складнощі впровадження нововведень у виробництво, пов'язані із недостатнім практичним досвідом та неспроможністю ефективно користуватися новою технікою та програмним забезпеченням, і, як наслідок, отримати вигоду від застосування інноваційних технологій. В статті досліджуються перспективи розвитку аграрного сектору за допомогою інноваційних рішень, зокрема зосереджуючись на можливостях збільшення продуктивності, покращенні якості продукції, зменшенні впливу на навколишнє природне середовище та розвитку сталої агрокультури. Обґрунтовано, що найближчою перспективою з метою відновлення української економіки, інфраструктури та промисловості, що постраждали від наслідків війни необхідним буде підвищення конкурентоспроможності шляхом впровадження інноваційних підходів. Це дозволить українським виробникам створити переваги на внутрішніх та міжнародних ринках, а також зайняти гідне місце серед розвинених країн світу.

Ключові слова: інновації, сталий розвиток, аграрне виробництво, сільськогосподарські підприємства, інноваційні технології.

Problem statement. The role of agricultural production, which supplies food products and raw materials for consumer goods, plays a crucial role in the economic development of any country. Experience from developed countries shows that dynamic and sustainable development of the agricultural sector, as well as the enhancement of its efficiency and competitiveness in modern conditions, are mainly achieved through the activation of innovative activities.

Innovations in agricultural production refer to a series of actions aimed at creating new or improved agricultural products, refining technologies, and organizing production based on the use of scientific research results, developments, or advanced production experience [7; 10].

The relevance of the problem lies in the fact that the implementation of innovations enables continuous modernization of the technological, technical, organizational, and economic foundation of agricultural production, leading to competitive product output. All of these factors contribute to the integration of the country into the global market.

In Ukraine, as well as in leading countries worldwide, a new stage of technological restructuring is ongoing, based on a knowledge-based economy. Mechanisms and institutional structures are being created for the dissemination and utilization of knowledge.

Food security is a critical concern for humanity, especially considering the scarcity of land and water resources, exacerbated by global climate changes and the need to conserve natural landscapes and support biodiversity. Therefore, the adoption of innovations must become a priority direction for the development of Ukrainian agriculture in the short and medium term.

Review of recent research and publications. In recent decades, nearly two-thirds of the increase in agricultural production worldwide is linked to the implementation of scientific and technical progress. The development of the modern agricultural sector is pursued in several directions simultaneously, focusing primarily on the adoption of new technologies in agriculture. The use of advanced methods contributes to the sustainability of agriculture through more rational and well-founded management decisions. Many domestic and foreign scientists have studied these issues, including Botta A., Cavallone P., Baglieri L., Colucci G., Tagliavini L., Quaglia G. [1], Le Gal P.-Y., Dugué P., Faure G., Novak S.M. [3], Mohd J. [5], Schut M., Kadihlon J.-J., Misiko M., Dror I. [6], Skudlarski J. [7], Borovyk L. [8], Verniuk N. [9], Kotvytska N. [11], Oliynyk O., Sidelnikova I. [12], Trishyn F.A., Nikoluk O.V. [13], Khakhula B. [14–15], and others.

However, certain aspects of further development of the agricultural sector based on innovation require further research.

Unresolved parts of the general problem. Despite numerous scientific works by both foreign and domestic researchers, the issue of ensuring innovative development in agricultural sector enterprises amid Ukraine's integration into the European space requires further scientific investigation. The goal is to create competitive advantages through the implementation of innovations, technologies, and information solutions.

Article objectives. The aim of this research is to identify trends and perspectives in the innovative development of agricultural production and to identify factors that hinder this development.

Presentation of the main research material. Many developed countries have achieved

success in various areas through significant progress in innovative development in both industry and agriculture.

Innovative development, commensurate with future scales and objectives of scientific and technical transformation in agricultural production, is feasible with the presence of a properly organized and efficiently functioning innovation system for agricultural production [4]. Its foundational element is the reproduction of agricultural innovations and the adoption of more advanced methods in agricultural practices, collectively shaping the innovative development of agriculture. This, in turn, entails a complex of interconnected measures aimed at creating favorable conditions for the progression of all stages of scientific and technical upgrading of production.

Ensuring the innovative development of agricultural production consists of two blocks (Figure).

Therefore, the innovation system can be characterized as a comprehensive set of interacting social institutions and organizations that transform scientific knowledge into new types of competitive products and services, aiming to ensure sustainable development and socio-economic growth.

The approach to agricultural management has undergone significant changes in the last

decades. The application of modern technologies in agriculture largely explains the success in cultivating agricultural crops and increasing their productivity according to the principles of sustainable agriculture.

New technologies in the agro-sector encompass a wide range of industries and technical tools aimed at increasing the productivity of agricultural enterprises. New agricultural technologies include agricultural machinery, robotics, computers, satellites, drones, mobile devices, software, the utilization of big data analytics, and artificial intelligence.

The implementation of "smart" farming methods benefits all participants in the agri-food chain. The adoption of cutting-edge technologies in agriculture for optimization and automation of agricultural operations and fieldwork results in significant time and resource savings. The main advantages of applying innovative technologies in agricultural production are:

- Reduced use of irrigation water, fertilizers, pesticides, and other resources, leading to cost savings and increased profits for agricultural producers.
- Decreased chemical runoff from fields and prevention of water body contamination, promoting environmental sustainability and enhancing the resilience of agricultural production.

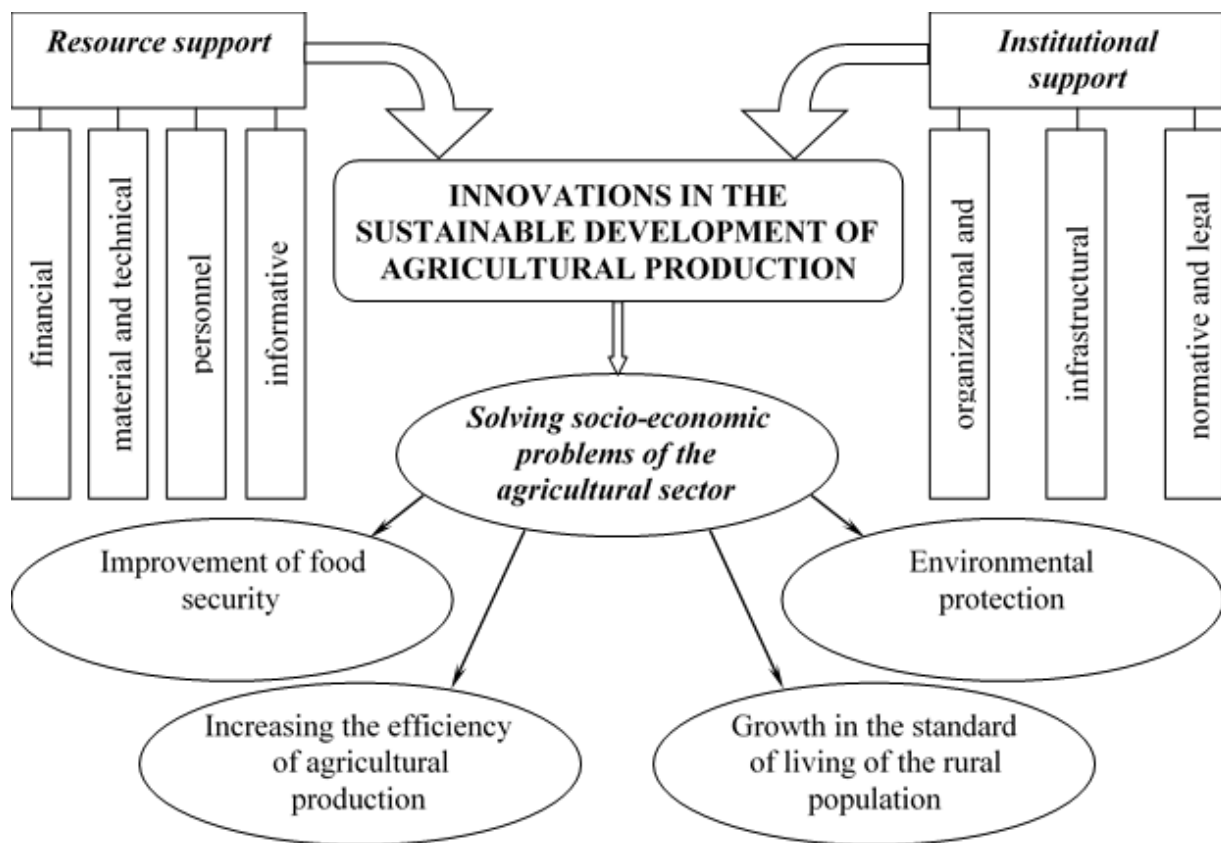


Figure. Ensuring Innovative Development in Agricultural Production

- Increased crop yields with reduced labor inputs.

- Streamlined interaction and coordination among stakeholders in the agricultural process through mobile devices, specialized programs, or web resources.

- Improved access to agricultural insurance, financial services, market, and technological data.

- Minimization of crop losses due to pest and disease infestations, natural disasters, and adverse weather conditions through continuous agricultural monitoring systems at affordable prices.

- Increased income for agricultural enterprises due to improved product quality and enhanced quality control.

- Timely identification of nutrient deficiencies in crops and provision of information to agricultural producers regarding the type and quantity of necessary fertilizers and other agrochemicals for crop cultivation and increased productivity.

- The ability to anticipate potential field problems through the visualization of production models and patterns obtained through the application of new data analysis methods based on up-to-date field information [1; 3; 5–6].

Assessing the overall yield of agricultural crops helps farmers to create more accurate budgets for the upcoming crop season and better prepare for unforeseen situations.

Technologies for the agro-sector have come a long way in development and are not limited to basic agricultural processes such as planting, cultivation, and harvesting.

In recent years, the agro-sector has achieved several significant advancements, from enhancing seed viability to improved planning and processing of agricultural products. New agricultural technologies also contribute to the optimization of product marketing and improved logistics decisions concerning its delivery to end consumers.

Rapid progress is also observed in the development and application of agricultural software and new technologies, which facilitate not only field operations but also the management of various components of the food supply chain. If previously it was necessary to personally go to the field for inspection, now it can be done remotely. Innovative technologies for remote sensing data processing are best suited for this purpose.

Despite the significant benefits of modern agriculture from the development of new technologies in terms of increased efficiency, reduced costs, and increased crop yields, there is a downside associated with large-scale extensive agriculture. The most significant drawback of new agricultural technologies is their detrimental

impact on the environment. The harmful effects of innovative agrarian technologies on ecosystems are caused by factors such as:

- Soil and water pollution due to the extensive use of pesticides.

- Reduction of biodiversity through the displacement of region-specific plant species caused by the cultivation of agricultural crops.

- Greenhouse gas emissions resulting from deforestation for the expansion of agricultural lands and the excessive use of new agricultural machinery.

The adverse impact of new technologies on the agricultural sector is not limited to environmental problems. The implementation of innovative technologies in agricultural production also poses certain challenges for agronomists and other field workers, such as:

- Farmers who lack the necessary education and practical experience may be unable to effectively use new machinery and software, and therefore, cannot benefit from the application of innovative agricultural technologies.

- The high cost of servicing new machinery.

- The application of chemical fertilizers and pesticides can be harmful to the health of farmers and other workers who work in the fields.

It is quite evident that we cannot completely abandon innovative agricultural technologies as they help meet the growing population's food needs. However, the negative consequences of new agro technologies can be mitigated by using and improving precision agriculture methods that do not harm the environment.

Since innovative technologies in agriculture can reduce or even minimize the negative impact of traditional farming methods, they help address a wide range of environmental issues. Thus, proponents of intensive farming can achieve a double benefit: increase their competitiveness and contribute to the well-being of our planet's population in the long term.

In the era of information discoveries, innovative technologies find increasing applications in the agricultural sector. Agricultural enterprises use modern technologies to optimize field management, and this is just one example of how innovations promote progress in agriculture.

The application of innovative technologies in agriculture and appropriate software can reduce the volumes of fertilizers, pesticides, and other agro-production means used. Another advantage of implementing innovations is that new agricultural technologies help reduce greenhouse gas emissions and other harmful substances that pollute the environment. This achievement

is possible through the streamlining of agricultural production processes and the elimination of unnecessary stages.

Genetic engineering is another innovative technology in agriculture, through which breeders in different countries develop seeds better adapted to specific local climate and soil conditions. Additionally, crop yields can be further enhanced through precision application of fertilizers.

Furthermore, new methods of mechanizing agricultural processes enhance the productivity and efficiency of agribusiness at all stages of agricultural production, including sowing, harvesting, and marketing agricultural products.

Currently, in Ukraine, due to military actions, unfavorable conditions have arisen for effectively implementing innovative activities both in general and in specific industries. Therefore, the task of forming a mechanism for regulating innovative development through the implementation of certain economic policies and improvement of the state system for stimulating innovative development remains relevant. The strategic objectives lie in enhancing the competitiveness of the domestic economy based on innovation, which will enable the formation of advantages for domestic producers in the competition with com-

petitors in domestic and international markets and will help Ukraine take a worthy place among developed countries worldwide.

Conclusions. In modern conditions, innovative technologies play a significant role in the development of the country's socio-economic system and in addressing global problems and challenges that arise. Large national corporations already possess substantial financial and resource potential for transitioning to innovative production methods. Information technologies and digital solutions have transformed traditional economic sectors, influencing consumption and creating new methods of analysis, forecasting, and management. Innovative technologies affect all economic entities, including those in the agricultural sector.

Global transformation has led to the emergence of new market trends focused on the interests of the end consumer. The agricultural sector cannot avoid innovative changes in its production. Enterprises competing in national and global markets must adopt advanced world technologies to ensure their competitiveness. Further research should focus on analyzing the possibilities of digital transformation in agriculture and studying the advantages and challenges associated with this development direction.

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