Received: 31.03.2025. Revised: 18.07.2025. Accepted: 29.08.2025.

EKONOMIKA APK

https://doi.org/10.32317/ekon.apk/4.2025.35

***Ekonomika APK*, 32(4), 35-45**

UDC 338.432:330.341.1:502.33

Models of innovative and investment development of farms in the context of ecological economics

Nataliia Chupryna*
Doctor of Economics, Professor
Ukrainian State University of Chemical Technology
49005, 8 Nauky Ave., Dnipro, Ukraine
https://orcid.org/0000-0002-4035-8934

Svitlana Loza
PhD in Economics, Associate Professor
Zaporizhia Polytechnic National University
69063, 64 Universitetska Str., Zaporizhia, Ukraine
https://orcid.org/0000-0002-2566-5020

Olga Nekrasova
Postgraduate Student
Zaporizhia Polytechnic National University
69063, 64 Universitetska Str., Zaporizhia, Ukraine
https://orcid.org/0009-0003-8277-5765

Yurii Kobenko
Postgraduate Student
Zaporizhia Polytechnic National University
69063, 64 Universitetska Str., Zaporizhia, Ukraine
https://orcid.org/0009-0006-8647-3520

Vladyslav Volianskyi
Postgraduate Student
Zaporizhia Polytechnic National University
69063, 64 Universitetska Str., Zaporizhia, Ukraine
https://orcid.org/0009-0008-1096-7289

► **Abstract.** This work was aimed at analysing modern approaches to the development of farms through the lens of innovation and investment, as well as examining the impact on sustainable development and the environmental aspects of the economy. The study explored the concept of sustainable development in the agricultural sector, particularly in the context of Ukraine, where there was significant potential for its implementation due to the presence of fertile land and favourable climatic conditions. It was found that capital investment in the agricultural sector decreased to UAH 12.6 billion in 2023, followed by a slight increase to UAH 15.2 billion in 2024. The research highlighted the need to move away from traditional agriculture based on chemical fertilisers and pesticides towards sustainable methods, such as organic farming, bioenergy, and precision agriculture, which allowed for resource optimisation and a reduction in negative environmental impact. In particular, spending on environmental protection in agriculture increased to UAH 1,007.3 million in 2023, indicating greater attention to the restoration of natural resources. It was revealed that the main barriers to the implementation of sustainable practices remained the low level of digitalisation, insufficient financial support, and institutional constraints. Based on the results obtained, several promising areas for development were identified, such as the expansion of the circular economy, the implementation of precision agriculture, and the stimulation of investment in renewable energy sources. The findings emphasised the need for active state support, the creation of a favourable investment environment, and the development of scientific research to ensure the sustainable development

► **Suggested Citation**: Chupryna, N., Loza, S., Nekrasova, O., Kobenko, Yu., & Volianskyi, V. (2025). Models of innovative and investment development of farms in the context of ecological economics. *Ekonomika APK*, 32(4), 35-45. doi: 10.32317/ekon.apk/4.2025.35.

*Corresponding author

of the agricultural sector. Strategies aimed at improving infrastructure, preserving natural resources, and increasing the efficiency of agricultural production could serve as the foundation for the creation of a resilient agricultural system capable of adapting to global challenges such as climate change and population growth

▸ **Keywords:** green technologies; precision agriculture; bioenergy; agricultural sector of Ukraine; state support

▸ Introduction

The development of the agricultural sector within the modern economy has been closely linked to the adoption of innovative approaches and the attraction of investment – key factors in ensuring its long-term sustainability and global competitiveness. This has necessitated a comprehensive reassessment of traditional farming methods in favour of innovative solutions capable of adapting the sector to evolving market and climate conditions. In this context, farms have become not only key producers of agricultural goods but also active participants in innovation and investment processes that account for economic, environmental, and social aspects of development. This approach has become particularly relevant in the face of global climate change, rapid land degradation, population growth, and the resulting increase in demand for environmentally friendly products.

One of the major challenges faced by farms in this process has been the insufficient funding for modern innovative technologies aimed at the efficient and rational use of natural resources. Combined with imperfect investment incentive mechanisms, limited access to financial instruments, and the weak integration of environmental principles into farm development strategies, this has hindered the adaptation to current market conditions. In particular, the absence of a systematic approach to innovation-driven investment development has created barriers to the adoption of modern technologies that not only increase efficiency but also minimise negative environmental impacts.

The theoretical framework for research in this area has been shaped by the concepts of sustainable development, ecological economics, and innovation management. The concept of sustainable development has focused on ensuring balanced economic growth, social well-being, and environmental preservation for future generations. Ecological economics has emphasised the integration of environmental protection measures into all areas of economic activity, including agriculture (Naumenkova *et al.*, 2024). Innovation management, in turn, has offered effective tools for the implementation of cutting-edge technologies that contribute to the optimisation of production processes and enhancement of the environmental safety.

In the context of researching innovation and investment development in farming, significant contributions have been made by various scholars, whose work has laid both the theoretical and practical foundations for analysing this topic. Notably, R.R. Danda (2023) highlighted the importance of technological innovations in enhancing the competitiveness of farms, emphasising that the integration of novel solutions into production reduces costs and optimises resource use. O. de Oca Munguia *et al.* (2021) stressed that innovation drives economic progress and that its application in agriculture transforms traditional land use methods into high-efficiency systems. V. Shcherbak & B. Shovkoplyas (2023) explored mechanisms for attracting investment into farms, focusing on the need to develop financial instruments accessible to small and medium-sized enterprises. The authors argued that effective financing stimulates both economic growth and the adoption of environmentally safe technologies. Meanwhile, J.F. Velasco-Muñoz *et al.* (2021) expanded on the principles of ecological economics, underscoring the importance of implementing circular economy practices in farming. The research stressed the need to shift from extensive to rational resource use. P. Yukhymenko *et al.* (2021) concentrated on the role of public policy in the development of farms, indicating that subsidies and tax incentives could be important drivers for investment in sustainable development. K. Pawlak & M. Kołodziejczak (2020) studied the role of institutions in ensuring a stable economic environment that supports farm development, emphasising the importance of conditions for long-term agricultural planning. M.M. Maja & S.F. Ayano (2021) pointed out that the economic development of agriculture is closely tied to demographic processes and that innovation in this sector can address food security challenges. H. Saleh *et al.* (2020) highlighted the importance of human capital in implementing innovations, noting that educational programmes and professional training for farmers are vital for the effective use of new technologies. R. Henry's (2020) study showed that agricultural intensification through innovation is an effective response to the rising demand for food products, particularly under conditions of limited natural resources. Finally, D. Pauschinger & F. Klauser (2022) emphasised that the adoption of digital technologies in farming, such as monitoring and data analysis systems, boosts productivity and reduces environmental pressure.

Thus, the research conducted by these authors demonstrates the diversity of approaches to the innovation and investment development of farms to ensure the sustainability, economic efficiency, and environmental responsibility. Despite the considerable academic interest in this area, several important aspects remain underexplored. Specifically, mechanisms for integrating environmental innovations into the business models of farms, with regard to regional specificities, have not been sufficiently studied. The relationship between the use of innovative technologies and the reduction of environmental pressure, as well as the role of public policy in encouraging the adoption of such technologies, also requires further investigation.

The aim of this study was to identify models for innovation and investment development in farms that ensure the effective implementation of environmentally oriented technologies and the creation of a resilient economic and ecological system in the context of current challenges. The objectives included analysing the current state of innovation and investment development in Ukrainian farms, identifying the factors influencing the investment attractiveness of environmental projects in agriculture, and developing recommendations for strengthening these efforts.

▸ Materials and methods

To study the sustainable development of Ukraine's agricultural sector in the context of ecological economics and innovation management, a comprehensive approach was used, incorporating several analytical methods. Statistical data obtained from the State Statistics Service of Ukraine (2023) served as the main source for analysing the economic situation in the agricultural sector. These data included indicators of production, capital investments, environmental protection expenditures, and other economic indicators that enabled the assessment of the state and trends in the development of the agricultural economy under sustainable development conditions. The study used statistical data from 2020 to 2023, as this period allowed for an evaluation of current sectoral development trends, while data for 2024 had not yet been published at the time of analysis. However, this does not apply to capital investments in agriculture, forestry and fisheries (State Statistics Service of Ukraine, n.d.). A comparative analysis method was applied to assess changes in the agricultural economy against the backdrop of climate change, the political situation, and external influences.

One of the main aspects of the work involved researching the implementation of innovative technologies in the agricultural sector, particularly precision farming, bioenergy, and organic agriculture. The research methodology also included exploring the potential for innovation integration into the production processes of agricultural enterprises. In particular, it analysed which technologies were the most promising for different regions of Ukraine under resource constraints and the need to preserve natural resources. This allowed for the assessment of which investment models were the most effective for the development of the agricultural sector and identified the barriers to large-scale innovation implementation. To analyse investment opportunities, methods for evaluating the investment attractiveness of agricultural enterprises were used, along with assessments of the economic efficiency of implementing "green" technologies.

Additionally, an analysis of government policy in the agricultural sector was conducted, focusing on the funding of scientific research, state programmes, and subsidies for farmers engaged in organic farming or using renewable energy sources. This analysis revealed key issues and opportunities for improving state support for sustainable development in the agricultural sector. The policy analysis method was used, involving the study of existing government initiatives and the effectiveness in the context of sustainable agricultural development. Another important stage of the study involved examining the environmental aspects of agricultural production. An ecological analysis method was used to assess the environmental impact of different forms of agricultural production. This included analysis of environmental protection expenditures, the use of biological and chemical pest control agents, and methods for preserving biodiversity on agricultural lands.

The effectiveness of sustainable practices in the agricultural sector was evaluated using a cross-country comparison method. Compared to other countries such as the Netherlands, Switzerland, Germany, Poland, and the USA, Ukraine's potential for developing organic farming, bioenergy projects, and precision agriculture was analysed. The selection of countries for comparison was based on the experience in implementing sustainable agricultural practices and the level of sectoral development. For this comparison, international reports and studies were used. This comparison helped identify weaknesses and prospects for developing innovation management in Ukraine's agricultural sector.

▸ Results

The concept of sustainable development has become one of the central ideas in modern economic, environmental, and social policy. Its primary aim is to ensure a balance between three key pillars: economic growth, environmental preservation, and social well-being. This concept holds that the planet's resources must be utilised in such a way that current needs are met without compromising the ability of future generations to meet the own needs (Ruggerio, 2021). The agricultural sector plays a vital role in realising the principles of sustainable development, as it is directly linked to the use of natural resources such as soil, water, biodiversity, and energy. Traditional farming methods, focused on maximising production, often lead to resource depletion, land degradation, and pollution of water and air. As a result, these approaches not only pose environmental threats but also undermine the long-term productivity of the agricultural sector itself (Harwood, 2020).

Sustainable agriculture involves a shift towards methods that prioritise environmental safety, social responsibility, and economic efficiency. For example, the implementation of precision farming technologies enables the efficient use of fertilisers and pesticides, thereby reducing the environmental impact (Tkachenko & Tykha, 2020). Organic farming is gaining popularity due to its ability to maintain soil fertility and support biodiversity. One of the key principles of sustainable development is the efficient use of resources. In the agricultural context, this means optimising water use through drip irrigation systems and rehabilitating degraded lands using reclamation technologies (Stephens *et al.*, 2020). In addition, growing attention is being paid to the use of renewable energy sources such as biogas plants, solar panels, and wind turbines, which can be integrated into farming operations.

Sustainable development also encompasses social aspects. The agricultural sector should provide decent working conditions, support employment in rural areas, and strengthen local communities. This is crucial not only for social stability, but also for preserving the cultural and economic potential of rural regions. The concept of sustainable development offers a pathway toward creating a resilient agricultural system that ensures food security, conserves natural resources, and contributes to socio-economic development (Rexhepi *et al.*, 2024). In the long term, this is the only viable approach to preserving the viability of the agricultural sector and ensuring its adaptation to global challenges such as climate change, population growth, and resource scarcity.

Ecological economics is a fundamental component of sustainable development, combining economic, social, and environmental aspects to create a resilient system of production and consumption. In the context of farming, ecological economics plays a critical role, as this sector is heavily reliant on natural resources and significantly impacts ecosystems. The primary goal of ecological economics is to integrate environmental principles into economic activities to strike a balance between production needs and ecological constraints (Prokopowicz, 2020). Farms guided by ecological economic principles emphasise the rational use of natural resources. This involves moving away from extensive agriculture, characterised by land exhaustion and excessive chemical use, towards integrated systems that consider resource renewability. For instance, organic farming methods reduce reliance on synthetic fertilisers and pesticides, helping to preserve soil fertility and reduce water and air pollution (Shuvar *et al.*, 2022).

Ecological economics also promotes the implementation of circular models on farms, which focus on minimising waste and reusing resources. Practices such as composting organic waste or using biogas systems to process agricultural residues allow farms to significantly reduce the environmental footprint and lower energy costs (Andreitsev *et al.*, 2024). Another important aspect is the economic valuation of natural resources. Ecological economics offers methods to account for the value of ecosystem services such as air purification, water cycle regulation, and biodiversity maintenance (Xia & Ruan, 2020). This approach helps farms recognise the real value of natural capital, encouraging more responsible environmental stewardship. Beyond technological solutions, ecological economics places emphasis on social factors. Sustainable farms create jobs, reduce rural outmigration, and contribute to the development of local communities (Washington & Maloney, 2020). For example, using environmentally friendly approaches can increase demand for high-value-added products such as organic goods or locally produced items, which in turn strengthens rural economies.

The relevance of ecological economics to farming also lies in its capacity to help adapt to climate change (Brych *et al.*, 2023). Measures such as reducing greenhouse gas emissions through low-carbon technologies or establishing agroforestry systems that limit soil erosion exemplify this adaptation. These initiatives help farms become more resilient to climate risks such as droughts, floods, and extreme temperatures (Tkachenko & Voronin, 2024). Government policy plays a vital role in the implementation of ecological economics principles. Incentivising farmers through financial tools – such as subsidies for green technologies or tax benefits for reducing environmental impacts – serves as a strong motivator for adopting sustainable models. Educational programmes that raise farmers' awareness about the benefits of eco-friendly solutions and the long-term impact on farm productivity are equally important.

Innovation management is a powerful tool enabling farms to enhance production efficiency, respond to market challenges, and ensure sustainable development. At its core, innovation management involves adopting new technologies, management practices, and organisational solutions aimed at optimising resource use, reducing costs, and boosting competitiveness. In agriculture, innovation management plays a pivotal role in securing productivity (Gama & Magistretti, 2023). One example is the use of precision agriculture technologies. Tools such as GPS navigation, soil moisture sensors, drones for crop monitoring, and data analysis software allow farms to plan production processes more accurately. This significantly reduces spending on fertilisers, water, and pesticides, while also minimising environmental impact (Sharma *et al.*, 2020).

Another key area of innovation management is digitalisation. The integration of modern information technologies, such as cloud platforms, mobile farm management apps, and automated data collection systems, allows farmers to control every stage of production more effectively. For example, software can analyse data on weather conditions, soil status, and crop needs, providing real-time recommendations (Abbasi *et al.*, 2022). Innovation management also includes the introduction of biotechnologies, which enhance the quality and productivity of crops. The use of biological pest control agents or genetically modified drought- and disease-resistant varieties ensures high yields even under unfavourable climatic conditions.

Furthermore, building energy resilience is a key aspect of innovation management. Renewable energy sources such as solar panels, wind turbines, and biogas plants are becoming increasingly popular on farms. These technologies help reduce reliance on traditional energy sources, lower greenhouse gas emissions, and cut energy costs. Innovation management also contributes to optimising logistics and product distribution. With tools like e-commerce platforms, direct-to-consumer sales channels, and digital marketing, farms can expand the market reach, reduce dependence on intermediaries, increase profitability, and establish direct connections with end consumers.

Human capital development is a crucial component of innovation management. Training farmers in modern technologies, expanding the knowledge of sustainable practices, and strengthening innovation competencies enable faster adoption of advanced solutions. Educational programmes, training sessions, partnerships with research institutions, and the exchange of best practices lay the foundation for the effective use of innovative tools (Khoshmaram *et al.*, 2020). Farms in Ukraine play an important role in ensuring food security, boosting export potential, and supporting the country's economic stability. However, the current state of innovation and investment development in the sector is uneven, influenced by both external and internal factors. On the one hand, Ukraine possesses significant natural potential for agricultural development, including fertile soils and a favourable climate. On the other hand, a range of economic, technological, and institutional barriers hinders the full-scale adoption of innovations and investment attraction. Table 1 presents the economic accounts of the agricultural sector.

Table 1. Economic accounts of agriculture in Ukraine for 2018-2023, UAH billion

No.	Types/groups of products/activities	2020	2021	2022	2023
1	Cereal crops	309.7	538.9	334.1	320
2	Industrial crops	209.9	393.1	294.3	310.5
3	Fodder crops	10.4	13.9	11.7	12.2
4	Vegetable crops	49.2	59.7	83.2	91

Table 1, Continued

No.	Types/groups of products/activities	2020	2021	2022	2023
5	Potato	60.9	61.2	54.2	55.5
6	Fruits, berries, grapes	26.8	28.8	24.1	26
7	Other crop products	3.5	4.6	9.5	10.3
8	Crop production output as a whole	670.4	1,100.2	811.1	825.5
9	Livestock (raising of farm animals)	110.4	127.9	136.6	140
10	Livestock products	93.6	109.7	107	108.3
11	Livestock production in general	203.9	237.6	243.6	248.3
12	Agricultural product output	874.4	1,337.8	1,054.7	1,073.8
13	Agricultural services output	13.5	21.6	14.9	15.5
14	Agricultural production output	887.8	1,359.4	1,069.6	1,089.3
15	Output of non-agricultural integral secondary activities	5	7.1	4.4	4.6
16	Agricultural output	892.9	1,366.5	1,073.9	1,093.9
17	Intermediate consumption	511.5	789.6	637	645
18	Gross value added	381.4	576.8	437	448.9

Source: based on State Statistics Service of Ukraine (2023)

The year 2021 marked a peak in agricultural production, driven by favourable weather conditions and increased exports of grain and industrial crops. However, in 2022, production declined due to the negative impact of the war, which led to a reduction in cultivated land areas, logistical difficulties, and limited access to financing. In 2023, the sector showed signs of partial recovery. Although output of grain and industrial crops slightly decreased compared to 2021, there was an increase in the production of vegetables and potatoes, indicating the adaptation of farms to the new conditions. Despite these changes, the gross value added by agriculture has remained at pre-war levels, underscoring the importance of innovation-driven investment to improve production efficiency. Recovery of the sector requires the implementation of modern technologies, enhancement of infrastructure, and attraction of investment – especially into environmentally oriented projects. The low level of investment in science and innovation presents a significant barrier to the adoption of modern technologies that could enhance production efficiency, ensure environmental sustainability, and help farms adapt to climate change. Insufficient funding makes it impossible to develop large-scale innovative projects, which require considerable resources and long-term research. The development of Ukraine's agricultural sector demands a fundamental reassessment of approaches to financing scientific research. The key task is not only to increase expenditure but also to ensure its effective allocation. This can be achieved through the attraction of private capital, partnerships with international organisations, and the integration of innovation into the sector's strategic development programmes. To ensure the sustainable development of the agricultural sector, it is essential to invest in the modernisation of technical infrastructure, the introduction of innovative technologies, and the improvement of production efficiency. Table 2 presents capital investments in agriculture, forestry, and fisheries.

Table 2. Capital investments in agriculture, forestry, and fisheries for 2020-2024, UAH million

Year	2020	2021	2022	2023	2024 (January-September)
Volume of capital investments	36,442.1	49,127.4	32,604	31,641.9	31,821.7
Investments in tangible assets	35,756.7	48,198.6	32,099.7	30,644.3	30,896.9
Of them					
Residential buildings	64.8	99.2	65.6	159.5	38.8
Non-residential buildings	6,735.8	7,485	4,937.9	4,609.8	4,112.3
Engineering structures	1,656.9	2,655.1	1,793.6	2,054.9	1,349.8
Machinery, equipment, and inventory	18,188	24,978.2	15,751.8	12,554	15,156.9
Vehicles	4,868	7,598	5,074.5	5,798.7	5,827.5
Earth	126.7	149.7	68	81.5	1,131.4
Long-term biological assets of crop and livestock production	3,765.4	4,698.5	4,022	4,860.2	2,879.2
Other tangible assets	351.1	534.9	386.3	525.6	401
Investments in intangible assets	685.4	928.8	504.3	997.7	924.9
Of them					
Software and databases	33.9	85.2	53.8	80.2	71.5

Source: based on State Statistics Service of Ukraine (n.d.)

The bulk of investment continues to be directed towards tangible assets, particularly machinery, equipment, and tools. However, the share has also decreased: in 2023, investment stood at UAH 12.6 billion, with a modest increase to UAH 15.2 billion in 2024. Investment in non-residential buildings and engineering structures remains low, indicating a slowdown in infrastructure expansion. The reduction in investments in long-term biological assets to UAH 2.8 billion in 2024 reflects high risks in livestock and crop production. Meanwhile, investments in intangible assets, such as software, remain negligible, signalling insufficient digitalisation within the sector. Overall, to revitalise and develop the agricultural sector, it is essential to stimulate investment in innovation, infrastructure, and digital technologies, which would enhance the competitiveness of farming enterprises and the resilience to challenges.

One of the most significant issues remains the insufficient level of financing for farms. Small and medium-sized farming businesses often face limited access to credit due to high interest rates, low financial capacity, and limited state support. Many farms, in particular, are unable to invest in modern technologies that are fundamental to innovative development. The state of innovation implementation also depends on the level of technical equipment available to farmers. Despite the availability of modern technologies – such as drones, precision farming systems, and automated management platforms – the adoption remains limited. The main reasons for this include the high cost of equipment, a lack of awareness among farmers regarding the benefits of new technologies, and a shortage of technical support at the local level.

At the regional level, there is a marked disparity in the development of farming enterprises. In the southern and central regions, where large agricultural holdings are concentrated, innovative solutions are adopted more actively. In contrast, in the western and northern regions, where small and medium-sized farms dominate, innovation and investment activity is significantly weaker. This disparity is driven not only by differences in financial capacity but also by unequal access to modern knowledge, technologies, and infrastructure. While government support is aimed at stimulating farm development, it remains insufficient. Funding programmes, such as compensation for the cost of agricultural machinery or support for organic production, do exist, but the coverage is limited. Moreover, complex procedures for obtaining subsidies and grants hinder farmers' access to these resources.

A noteworthy aspect of the current situation is the growing interest in environmentally-oriented production. Ukrainian farmers are gradually beginning to recognise the advantages of organic farming, renewable energy sources, and environmental protection practices. However, the implementation requires substantial investment and training, posing yet another challenge for small and medium-sized enterprises. Regarding the investment climate, foreign investors have shown interest in cooperating with Ukrainian farms, particularly in organic production and the use of renewable energy. However, the unstable economic situation, war, and regulatory constraints create risks that deter investment. Table 3 presents environmental protection expenditures in agriculture.

Table 3. Environmental protection expenditures in agriculture, forestry, and fisheries for 2021-2023, million UAH

Year	2020	2021	2022	2023
Current expenses	373.4	479.4	412.4	1,007.3
Air protection and climate change issues	–	12.7	11.9	29.1
Waste water treatment	–	11	7.5	14.1
Waste management	–	19.2	16.2	15.1
Protection and rehabilitation of soil, groundwater, and surface water	–	11.1	12.8	680.7
Other measures	–	425.3	363.9	268.3

Source: based on State Statistics Service of Ukraine (n.d.)

Expenditures on environmental protection in agriculture, forestry, and fisheries demonstrate important dynamics, reflecting certain shifts in environmental policy priorities. In 2020, total spending amounted to UAH 373.4 million. By 2023, this had risen significantly to UAH 1,007.3 million, likely due to the implementation of large-scale natural resource rehabilitation programmes. The most substantial increase was observed in expenditures on the protection and rehabilitation of soils and both groundwater and surface water: from UAH 12.8 million in 2022 to UAH 680.7 million in 2023. This indicates a growing recognition of land degradation as a critical issue for the agricultural sector. At the same time, expenditures on air protection, wastewater treatment, and waste management remain relatively low, suggesting insufficient attention to these areas.

Amid global challenges related to natural resource degradation, climate change, and growing demand for environmentally friendly products, the development of farming in Ukraine requires innovative and investment-driven approaches. In the context of ecological economics, which aims to balance economic growth with environmental preservation, farmers must adapt the production processes, adopt advanced technologies, and actively attract investment. This will ensure the sector's sustainability, minimise environmental risks, and enhance competitiveness. A key area for improving innovation-investment models is the adoption of circular economy principles. This involves resource reuse and minimisation of waste. For instance, organic livestock waste can be converted into biogas or compost, providing farms with energy independence and improving soil quality. A successful example of such practices can be found in Europe, particularly in the Netherlands, where farmers widely utilise biogas facilities (Westhoek & Boezeman, 2024). As of 2025, this direction is still developing in Ukraine, but the government should encourage farmers through grants, tax incentives, or subsidies to implement such solutions.

Another crucial element is the development of precision agriculture. The use of drones, sensors, and satellite technologies enables farmers to collect data on field conditions, soil moisture, and plant disease levels. This allows for precise application of fertilisers and pesticides, reducing costs and minimising environmental impact. For example, farmers in the USA actively use automatic tractor control systems, which not only save fuel but also improve productivity (The self-driving tractor…, 2025). In Ukraine, as of 2025, such technologies are increasingly being adopted, but the technologies remain largely accessible only to large farms due to the high cost.

Organic farming also represents a promising direction. Ukraine has significant potential in this area thanks to fertile soils and favourable climatic conditions. However, to expand the area under organic cultivation, government support is needed in the form of certification programmes, grants, and assistance in accessing international markets. Switzerland is a leader in organic farming due to its well-designed government policy and broad support for farmers (Organisation for Economic Co-operation and Development, 2023). In Ukraine, as of 2025, there are successful examples of organic production, but it has yet to become widespread.

Environmentally focused infrastructure investments are also of great importance. For example, implementing drip irrigation systems can significantly reduce water use and increase crop yields. This is especially relevant for southern regions of Ukraine, which suffer from water shortages. Other investments could include building modern logistics centres for produce storage, helping reduce harvest losses and maintain quality. Bioenergy is another strategic area for development. Farmers can install solar panels, wind turbines, or biogas plants to supply farms with alternative energy. In Germany, for example, farmers widely use biogas systems, allowing the farmers to sell surplus energy to the national grid, creating an additional income source (Park & Grundmann, 2025). In Ukraine, as of 2025, this area is still emerging but holds significant potential for scaling up.

State involvement is crucial to support innovative and investment-driven development. It should create a favourable investment climate through a stable legal framework, tax incentives for green projects, and access to concessional financing. Furthermore, public-private partnerships should be promoted to attract foreign investment and cutting-edge technologies. For instance, Poland has successfully established agritech hubs like the Poznań Science and Technology Park, which bring together research institutions, agricultural companies, and start-ups to drive innovation in agriculture. Creating similar hubs in Ukraine could accelerate agrotechnology development and boost the sector's competitiveness.

In conclusion, improving innovation-investment development models for farms within the framework of ecological economics is an integral part of sustainable agricultural development in Ukraine. The integration of modern technologies, development of the circular economy, bioenergy, and organic farming, as well as support from the state and international partners, will ensure farm sustainability, improve efficiency, and minimise environmental impact. These models will contribute not only to economic growth but also to building an environmentally responsible agricultural sector, laying the foundation for Ukraine's future development.

▸ Discussion

The study of sustainable development in Ukraine's agricultural sector within the context of ecological economics and innovative management has shown that, despite considerable potential, this sector faces a number of challenges that require resolution at both policy and practical levels. Barriers to the implementation of innovations, environmentally friendly technologies, and sustainable practices were identified, encompassing both economic and social aspects. This underscores the need for a comprehensive approach to ensure sustainable agricultural development. Analysis of results indicates that infrastructure for large-scale implementation of precision farming in Ukraine is insufficiently developed. GPS navigation technologies, drones, and data analysis for resource optimisation are already actively used in some regions of Ukraine, but the prevalence is still not widespread enough to mark a mass shift to these innovations (Remeshevska *et al.*, 2021; Horbal & Makarova, 2023). This is due both to the high initial costs of adopting such technologies and the lack of adequate qualifications among farmers. Similar problems are observed in other developing countries, but in Ukraine, these problems are more pronounced due to economic instability and uncertainty in agricultural policy. In the work, K. Takahashi *et al.* (2020) examined the impact of modern agricultural technologies on farming efficiency, particularly the use of drones, GPS navigation, automated control systems, and other innovative solutions that form the basis of precision farming. The authors noted that such technologies significantly reduce production costs and increase yields through precise monitoring of soil and crop conditions, allowing timely responses to changing environments. Y. Hu *et al.* (2022) also highlighted that economic benefits increase with the adoption of innovative technologies, but successful implementation requires substantial financial support for agricultural enterprises. Current findings align with the authors' conclusions about the importance of precision farming technologies. However, the current study focuses more on the environmental aspects and identified implementation barriers, which are less emphasised in the cited works.

Analysis of state policy in the agricultural sector revealed a significant issue – the low effectiveness of government programmes supporting sustainable agricultural development. Although programmes for supporting organic farming, bioenergy development, and environmentally friendly technologies exist, these technologies often suffer from limited funding and poor implementation at the local level (Romankiewicz *et al.*, 2023). This suggests a need to revise national agricultural policy and increase investment in sustainable farming development. Similar conclusions were drawn in studies from other countries, where government support proved critical for implementing innovative agricultural technologies. J. Streimikis & T. Baležentis (2020) analysed the effectiveness of sustainable development support programmes in the agricultural sector, noting that many fail to achieve the goals due to political instability and insufficient funding. The authors proposed optimising existing programmes and increasing financial support for ecological initiatives. These results align with current findings on the ineffectiveness of state programmes and the importance of boosting investment in sustainable agricultural development. While the authors stressed the need for policy reforms, the current study emphasised economic and social barriers.

T. Havemann *et al.* (2022) explored the potential for attracting private investment in sustainable agriculture and assessed the role of state support programmes. The authors argued that attracting investors effectively is only possible under stable economic conditions and with a favourable investment climate. The conclusions align with current findings regarding the importance of state funding for sustainable development of the agricultural sector. However, the present study focuses more on specific economic and social barriers impeding sustainable practices, while the authors place greater emphasis on state mechanisms and the role of the private sector.

Regarding environmental aspects, the research confirms the importance of transitioning to organic farming and preserving biodiversity. In this context, programmes supporting environmentally friendly production and rural enterprises that operate according to sustainable standards play a significant role (Rudavska *et al.*, 2023). However, the study showed that only a small proportion of agricultural enterprises in Ukraine are currently ready to transition to organic farming, primarily due to the high costs of certification and production process organisation. H. Aghasafari *et al.* (2020) focused on the state of organic farming, noting that although it holds great potential, development is hampered by high certification costs and an uncertain organic product market. Z. Ferdous *et al.* (2021) also noted that only some farmers can afford to switch to organic farming due to limited financial capacity, creating barriers to widespread adoption despite long-term ecological and economic benefits. The authors' findings align with current results, particularly concerning the importance of organic farming development and the obstacles to its widespread adoption. While the authors concentrated more on the technical aspects, the current study focuses on how these barriers affect sustainable development.

Another important issue is the lack of proper infrastructure for developing bioenergy in the agricultural sector. Bioenergy projects have considerable potential in Ukraine, given the country's rich resources for bioenergy production (Borysiak *et al.*, 2022). However, there are currently no effective mechanisms for advancing this field. International experience shows that agricultural bioenergy can be effective only through close cooperation between government institutions, the private sector, and research organisations. A. Bharti *et al.* (2021) explored the potential of bioenergy in agriculture, highlighting the use of biomass for energy production as a way to reduce reliance on traditional energy sources and lower energy costs in farming. However, A. Abdullah *et al.* (2021) stressed that the lack of infrastructure and investment creates serious barriers to the development of bioenergy technologies, limiting the wide-scale adoption in agriculture. The authors' findings reflect aspects of the current study, particularly the importance of developing bioenergy. Nevertheless, the present research places more emphasis on environmental aspects rather than the economic and infrastructural challenges. M. Qaim (2020) examined the influence of international organisations and foreign investment on the development of sustainable agriculture. The author noted that international programmes and funds play a crucial role in financing ecological initiatives, but the effectiveness is limited by the country's political and economic situation. While the author emphasises the role of international investors, the current study focuses more on domestic economic barriers and policy. The author draws attention to external factors that could help implement sustainable practices.

The analysis also confirmed that developing sustainable agriculture in Ukraine requires significant enhancement of educational programmes for farmers and infrastructure to support innovations. This includes creating advisory centres, access to modern agricultural technologies, and a more active role for local authorities in implementing national initiatives at the local level. E. Raji *et al.* (2024) studied challenges in sustainable agriculture development, particularly stressing the need for improved educational programmes for farmers and the development of relevant infrastructure to support innovative initiatives in the agricultural sector. The authors highlighted the importance of advisory centres to help small and medium-sized farmers navigate rapid changes in agriculture and adapt to new technological demands. The current findings confirm the importance of these aspects, as effective implementation of innovative technologies is impossible without proper training and infrastructure support at the local level. In conclusion, although Ukraine's agricultural sector has significant potential for sustainable development, achieving this requires substantial changes in state policy, financing, infrastructure, and education. The implementation of innovative and environmentally friendly technologies, support for organic farming, and bioenergy development can become the main drivers of sustainable growth in the country's agricultural sector.

▸ Conclusions

The research results showed that sustainable development in agriculture includes the implementation of innovative technologies such as precision farming, organic production, and the use of renewable energy sources. The use of organic farming methods contributes to the preservation of soil fertility and the maintenance of biodiversity. For example, in Ukraine in 2021, spending on environmental protection in the agricultural sector amounted to UAH 479.4 million, but due to crisis conditions related to the war, in 2022 this decreased to UAH 412.4 million. In 2023, this spending increased again, reaching UAH 1,007.3 million, indicating growing attention to the issue of environmental sustainability.

In 2023, the volume of capital investment in the agricultural sector amounted to UAH 12.6 billion, but even so, investment in infrastructure and digital technologies remains low, particularly in intangible assets such as software, which continue to be at a low level. This indicates limited digitalisation in agriculture, which is an important factor in increasing the efficiency and resilience of agricultural enterprises. Nevertheless, Ukrainian farmers are gradually beginning to adopt new environmental practices. Thus, in 2023, there was an increase in spending on soil and water resource protection, which indicates a growing interest in sustainable and environmentally safe farming methods. However, for further development, it is important to increase public funding for scientific research, encourage investment in innovative technologies, and modernise infrastructure.

Therefore, to ensure the sustainable development of Ukraine's agricultural sector, it is necessary to increase investment in innovation and infrastructure, as well as to support the implementation of new environmentally oriented technologies. The active role of the state in creating favourable conditions for investment, including through tax incentives and subsidies, as well as the development of public-private partnerships, is key to the successful transformation of the agricultural industry. A limitation of the study is the lack of available data due to the impact of the war on economic indicators and limited funding in the agricultural sector. Further research should focus on a deeper analysis of the effectiveness of sustainable technologies in agricultural production and the role of state support in the development of innovation.

▸ Acknowledgements
None.

▸ Funding
None.

▸ Conflict of Interest
None.

▸ References

[1] Abbasi, R., Martinez, P., & Ahmad, R. (2022). The digitization of agricultural industry – a systematic literature review on agriculture 4.0. *Smart Agricultural Technology*, 2, article number 100042. doi: 10.1016/j.atech.2022.100042.

[2] Abdullah, A., Ahmed, A., Akhter, P., Razzaq, A., Hussain, M., Hossain, N., Abu Bakar, M.S., Khurram, S., Majeed, K., & Park, Y.-K. (2021). Potential for sustainable utilisation of agricultural residues for bioenergy production in Pakistan: An overview. *Journal of Cleaner Production*, 287, article number 125047. doi: 10.1016/j.jclepro.2020.125047.

[3] Aghasafari, H., Karbasi, A., Mohammadi, H., & Calisti, R. (2020). Determination of the best strategies for development of organic farming: A SWOT – Fuzzy Analytic Network Process approach. *Journal of Cleaner Production*, 277, article number 124039. doi: 10.1016/j.jclepro.2020.124039.

[4] Andreitsev, V., Moroz, V., Shuvar, A., Pugachov, V., & Sliusarchuk, O. (2024). Exploring opportunities for renewable energy adoption in business operations: Enhancing emission reduction and climate resilience. *Multidisciplinary Reviews*, 7, article number e2024spe002. doi: 10.31893/multirev.2024spe002.

[5] Bharti, A., Paritosh, K., Mandla, V.R., Chawade, A., & Vivekanand, V. (2021). GIS application for the estimation of bioenergy potential from agriculture residues: An overview. *Energies*, 14(4), article number 898. doi: 10.3390/en14040898.

[6] Borysiak, O., Skowron, Ł., Brych, V., Manzhula, V., Dluhopolskyi, O., Sak-Skowron, M., & Wołowiec, T. (2022). Towards climate management of district heating enterprises' innovative resources. *Energies*, 15(21), article number 7841. doi: 10.3390/en15217841.

[7] Brych, V., Borysiak, O., Halysh, N., Liakhovych, G., Kupchak, V., & Vakun, O. (2023). Impact of international climate policy on the supply management of enterprises producing green energy. In B. Alareeni & A. Hamdan (Eds.), *Impact of artificial intelligence, and the fourth industrial revolution on business success* (Vol. 485, p. 649-661). Cham: Springer.. doi: 10.1007/978-3-031-08093-7_43.

[8] Danda, R.R. (2023). Innovations in agricultural machinery: Assessing the impact of advanced technologies on farm efficiency. *Journal of Artificial Intelligence and Big Data*, 3(1), 29-48. doi: 10.31586/jaibd.2022.1156.

[9] De Oca Munguia, O.M., Pannell, D.J., & Llewellyn, R. (2021). Understanding the adoption of innovations in agriculture: A review of selected conceptual models. *Agronomy*, 11(1), article number 139. doi: 10.3390/agronomy11010139.

[10] Ferdous, Z., Zulfiqar, F., Datta, A., Hasan, A.K., & Sarker, A. (2021). Potential and challenges of organic agriculture in Bangladesh: A review. *Journal of Crop Improvement*, 35(3), 403-426. doi: 10.1080/15427528.2020.1824951.

[11] Gama, F., & Magistretti, S. (2023). Artificial intelligence in innovation management: A review of innovation capabilities and a taxonomy of AI applications. *Journal of Product Innovation Management*, 42(1), 76-111. doi: 10.1111/jpim.12698.

[12] Harwood, R.R. (2020). A history of sustainable agriculture. In C.A. Edwards (Ed.), *Sustainable agricultural systems* (pp. 3-19). Boca Raton: CRC Press. doi: 10.1201/9781003070474.

[13] Havemann, T., Negra, C., & Werneck, F. (2022). Blended finance for agriculture: Exploring the constraints and possibilities of combining financial instruments for sustainable transitions. In G. Desa & X. Jia (Eds.), *Social innovation and sustainability transition* (pp. 347-358). Cham: Springer. doi: 10.1007/978-3-031-18560-1_23.

[14] Henry, R. (2020). Innovations in agriculture and food supply in response to the COVID-19 pandemic. *Molecular Plant*, 13(8), 1095-1097. doi: 10.1016/j.molp.2020.07.011.

[15] Horbal, N., & Makarova, Yu. (2023). Eco-innovations for sustainable development of Ukrainian enterprises. *Economics, Entrepreneurship, Management*, 10(1), 30-39. doi: 10.56318/eem2023.01.030.

[16] Hu, Y., Li, B., Zhang, Z., & Wang, J. (2022). Farm size and agricultural technology progress: Evidence from China. *Journal of Rural Studies*, 93, 417-429. doi: 10.1016/j.jrurstud.2019.01.009.

[17] Khoshmaram, M., Shiri, N., Shinnar, R.S., & Savari, M. (2020). Environmental support and entrepreneurial behavior among Iranian farmers: The mediating roles of social and human capital. *Journal of Small Business Management*, 58(5), 1064-1088. doi: 10.1111/jsbm.12501.

[18] Maja, M.M., & Ayano, S.F. (2021). The impact of population growth on natural resources and farmers' capacity to adapt to climate change in low-income countries. *Earth Systems and Environment*, 5, 271-283. doi: 10.1007/s41748-021-00209-6.

[19] Naumenkova, S., Tishchenko, I., Mishchenko, V., & Mishchenko, S. (2024). Rethinking energy poverty alleviation through energy efficiency: Evidence from Ukraine. *Environmental Economics*, 15(2), 198-214. doi: 10.21511/ee.15(2).2024.14.

[20] Organisation for Economic Co-operation and Development. (2023). *Agricultural policy monitoring and evaluation 2023*. Retrieved from https://www.oecd.org/en/publications/agricultural-policy-monitoring-and-evaluation-2023_b14de474-en/full-report/switzerland_98a7ae6f.html.

[21] Park, H., & Grundmann, P. (2025). Institutional work after hype: The case of biogas in Germany. *Energy Research & Social Science*, 119, article number 103820. doi: 10.1016/j.erss.2024.103820.

[22] Pauschinger, D., & Klauser, F.R. (2022). The introduction of digital technologies into agriculture: Space, materiality and the public-private interacting forms of authority and expertise. *Journal of Rural Studies*, 91, 217-227. doi: 10.1016/j.jrurstud.2021.06.015.
[23] Pawlak, K., & Kołodziejczak, M. (2020). The role of agriculture in ensuring food security in developing countries: Considerations in the context of the problem of sustainable food production. *Sustainability*, 12(13), article number 5488. doi: 10.3390/su12135488.
[24] Prokopowicz, D. (2020). Implementation of the principles of sustainable economy development as a key element of the pro-ecological transformation of the economy towards green economy and circular economy. *International Journal of New Economics and Social Sciences*, 11(1), 417-480. doi: 10.5604/01.3001.0014.3558.
[25] Qaim, M. (2020). Role of new plant breeding technologies for food security and sustainable agricultural development. *Applied Economic Perspectives and Policy*, 42(2), 129-150. doi: 10.1002/aepp.13044.
[26] Raji, E., Ijomah, T.I., & Eyieyien, O.G. (2024). Improving agricultural practices and productivity through extension services and innovative training programs. *International Journal of Applied Research in Social Sciences*, 6(7), 1297-1309. doi: 10.51594/ijarss.v6i7.1267.
[27] Remeshevska, I., Trokhymenko, G., Gurets, N., Stepova, O., Trus, I., & Akhmedova, V. (2021). Study of the ways and methods of searching water leaks in water supply networks of the settlements of Ukraine. *Ecological Engineering & Environmental Technology*, 22(4), 14-21. doi: 10.12912/27197050/137874.
[28] Romankiewicz, B., Reguła, M., Różański, R., Potempska, M., Gaze, B., Knutel, B., Wojtko, P., Drozdovych, I., & Kawa, K. (2023). Analysis of energy consumption of the process of composting dairy sludge in hyperbaric conditions. *Rynek Energii*, 2023(6), 89-97.
[29] Rudavska, N., Konyk, H., Tymchyshyn, O., Dorota, H., & Shuvar, A. (2023). Productivity of winter wheat depending on sowing dates and fertilisation. *Scientific Horizons*, 26(10), 107-115. doi: 10.48077/scihor10.2023.107.
[30] Ruggerio, C.A. (2021). Sustainability and sustainable development: A review of principles and definitions. *Science of the Total Environment*, 786, article number 147481. doi: 10.1016/j.scitotenv.2021.147481.
[31] Saleh, H., Surya, B., Annisa Ahmad, D.N., & Manda, D. (2020). The role of natural and human resources on economic growth and regional development: With discussion of open innovation dynamics. *Journal of Open Innovation: Technology, Market, and Complexity*, 6(4), article number 103. doi: 10.3390/joitmc6040103.
[32] Sharma, A., Jain, A., Gupta, P., & Chowdary, V. (2020). Machine learning applications for precision agriculture: A comprehensive review. *IEEE Access*, 9, 4843-4873. doi: 10.1109/ACCESS.2020.3048415.
[33] Shcherbak, V., & Shovkoplyas, B. (2023). Financing entrepreneurship development in farm holdings. *Entrepreneurship and Trade*, 39, 248-253. doi: 10.32782/2522-1256-2023-39-31.
[34] Shuvar, I., Korpita, H., Shuvar, A., Shuvar, B., Balkovskyi, V., Kosylovych, H., & Dudar, I. (2022). Relationship of potato yield and factors of influence on the background of herbological protection. *Open Agriculture*, 7(1), 920-925. doi: 10.1515/opag-2022-0153.
[35] State Statistics Service of Ukraine. (2023). *Economic accounts of agriculture*. Retrieved from https://stat.gov.ua/en/datasets/economic-accounts-agriculture.
[36] State Statistics Service of Ukraine. (n.d.). *Agriculture, forestry and fisheries*. Retrieved from https://www.ukrstat.gov.ua/operativ/menu/menu_u/cg.htm.
[37] Stephens, E.C., Martin, G., Van Wijk, M., Timsina, J., & Snow, V. (2020). Impacts of COVID-19 on agricultural and food systems worldwide and on progress to the sustainable development goals. *Agricultural Systems*, 183, article number 102873. doi: 10.1016/j.agsy.2020.102873.
[38] Streimikis, J., & Baležentis, T. (2020). Agricultural sustainability assessment framework integrating sustainable development goals and interlinked priorities of environmental, climate and agriculture policies. *Sustainable Development*, 28(6), 1702-1712. doi: 10.1002/sd.2118.
[39] Takahashi, K., Muraoka, R., & Otsuka, K. (2020). Technology adoption, impact, and extension in developing countries' agriculture: A review of the recent literature. *Agricultural Economics*, 51(1), 31-45. doi: 10.1111/agec.12539.
[40] The self-driving tractor: Understanding autonomous tractors in agriculture. (2025). *Monarch*. Retrieved from https://www.monarchtractor.com/blog/understanding-autonomous-tractors-in-agriculture.
[41] Tkachenko, A., & Tykha, N. (2020). Introducing innovation is an important task today. *Scientific Bulletin of Poltava University of Economics and Trade. Series "Economic Sciences"*, 1, 17-25. doi: 10.37734/2409-6873-2020-1-2.
[42] Tkachenko, A., & Voronin, D. (2024). Innovation potential of startups: Evaluation criteria and diagnostics. *Economic Analysis*, 34(2), 301-316. doi: 10.35774/econa2024.02.301.
[43] Velasco-Muñoz, J.F., Mendoza, J.M.F., Aznar-Sánchez, J.A., & Gallego-Schmid, A. (2021). Circular economy implementation in the agricultural sector: Definition, strategies and indicators. *Resources, Conservation and Recycling*, 170, article number 105618. doi: 10.1016/j.resconrec.2021.105618.
[44] Washington, H., & Maloney, M. (2020). The need for ecological ethics in a new ecological economics. *Ecological Economics*, 169, article number 106478. doi: 10.1016/j.ecolecon.2019.106478.
[45] Westhoek, H., & Boezeman, D. (2024). *No deal on farming: Lessons from the Netherlands*. Retrieved from https://www.iddri.org/en/publications-and-events/blog-post/no-deal-farming-lessons-netherlands.
[46] Xia, X., & Ruan, J. (2020). Analyzing barriers for developing a sustainable circular economy in agriculture in China Using Grey-DEMATEL approach. *Sustainability*, 12(16), article number 6358. doi: 10.3390/su12166358.

[47] Yukhymenko, P., Sokolska, T., Arbuzova, T., Paska, I., Zharikova, O., Khakhula, L., & Zhytnyk, T. (2021). Formation of the model of state support for Ukrainian agrarian sector in the market economy: Change of the approach. *Economic Annals-XXI*, 187(1-2), 75-81. doi: 10.21003/ea.V187-07.

Моделі інноваційно-інвестиційного розвитку фермерських господарств у контексті екологічної економіки

Наталія Чуприна
Доктор економічних наук, професор
Український державний хіміко-технологічний університет
49005, просп. Науки, 8, м. Дніпро, Україна
https://orcid.org/0000-0002-4035-8934
Світлана Лоза
Кандидат економічних наук, доцент
Національний університет «Запорізька політехніка»
69063, вул. Університетська, 64, м. Запоріжжя, Україна
https://orcid.org/0000-0002-2566-5020
Ольга Некрасова
Аспірант
Національний університет «Запорізька політехніка»
69063, вул. Університетська, 64, м. Запоріжжя, Україна
https://orcid.org/0009-0003-8277-5765
Юрій Кобенко
Аспірант
Національний університет «Запорізька політехніка»
69063, вул. Університетська, 64, м. Запоріжжя, Україна
https://orcid.org/0009-0006-8647-3520
Владислав Волянський
Аспірант
Національний університет «Запорізька політехніка»
69063, вул. Університетська, 64, м. Запоріжжя, Україна
https://orcid.org/0009-0008-1096-7289

▸ **Анотація.** Дана робота була направлена на аналіз сучасних підходів до розвитку фермерських господарств через призму інновацій та інвестицій, а також вивчення їхнього впливу на сталий розвиток та екологічні аспекти економіки. У роботі досліджувалась концепція сталого розвитку в аграрному секторі, зокрема в контексті України, де є значний потенціал для її впровадження через наявність родючих земель і сприятливих кліматичних умов. Було встановлено, що капітальні інвестиції в агросектор скоротилися у 2023 році до 12,6 млрд грн, з подальшим незначним зростанням до 15,2 млрд грн у 2024 році. Дослідження підкреслило необхідність переходу від традиційного сільського господарства, що базується на хімічних добривах та пестицидах, до сталих методів, таких як органічне землеробство, біоенергетика та точне землеробство, що дозволяє оптимізувати використання ресурсів та зменшити негативний екологічний вплив. Зокрема, витрати на екологічний захист у сільському господарстві у 2023 році зросли до 1007,3 млн грн, що вказує на підвищену увагу до відновлення природних ресурсів. Виявлено, що ключовими бар'єрами на шляху впровадження сталих практик залишаються низький рівень цифровізації, недостатність фінансової підтримки та інституційні обмеження. На основі отриманих результатів визначено перспективні напрямки розвитку, такі як поширення циркулярної економіки, впровадження точного землеробства та стимулювання інвестицій у відновлювані джерела енергії. Отримані дані підкреслили необхідність активної державної підтримки, створення сприятливого інвестиційного середовища та розвитку наукових досліджень для забезпечення сталого розвитку аграрного сектору. Стратегії, спрямовані на покращення інфраструктури, збереження природних ресурсів і підвищення ефективності аграрного виробництва, можуть стати основою для створення стійкої аграрної системи, що адаптується до глобальних викликів, таких як зміна клімату та зростання популяції

▸ **Ключові слова:** зелені технології; точне землеробство; біоенергетика; аграрний сектор України; державна підтримка