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Agricultural sector circular economy development: Agroecological approach

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► **Abstract.** This study aimed to investigate the feasibility of using agroecological concepts to establish a circular economy in the agricultural industry. The paper examined circular economy as a novel economic development paradigm that seeks to optimise resource utilisation and reduce waste, particularly in the agriculture industry. The main principle of the circular economy is resource conservation, which includes the rational use of land, water and energy, as well as the preservation of biodiversity and the improvement of soil fertility. An analysis was conducted on the economic advantages of adopting a circular economy in the agriculture industry, which include the reduction of production costs, enhancement of productivity, and generation of new employment opportunities. The study also addressed the importance of digitalisation, which can significantly increase the efficiency of agricultural production using modern digital technologies for monitoring soil conditions, managing water resources and optimising processes. This paper examined the effects of the war in Ukraine on the agricultural industry, specifically highlighting a substantial decrease in the output of key crops and livestock products. A comprehensive examination of the destruction of infrastructure, soil, and water contamination exposed severe environmental issues resulting from the attacks. The successful circular concepts implemented by European countries such as the Netherlands, Sweden, Denmark, and France can be applied

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to the post-war revival of the Ukrainian agriculture industry. The study also addressed the experience of the Ukrainian company Kernel, which successfully implements circular practices such as recycling of production waste, use of biomass and introduction of precision farming, which reduces environmental impact and increases production efficiency. Based on the analysis, recommendations for the post-war reconstruction of Ukraine's agricultural sector were proposed, including the identification of priority regions for recovery, stimulation of innovation and modern technologies, support for small and medium-sized farms, development of irrigation systems, environmental restoration and protection, international cooperation and support, and education and training

▸ **Keywords:** environmental pollution; resource conservation; post-war reconstruction; war waste; sustainable development; climate change; greenhouse gas emissions

▸ Introduction

The circular economy is a novel economic development paradigm that seeks to reduce waste and optimise resource utilisation. The fundamental concepts of this approach involve the recovery, recycling, and reutilization of resources in manufacturing operations. Within the agricultural sector, the circular economy presents novel prospects to enhance the sustainability of agricultural industry and mitigate the adverse environmental effects. The significance of establishing a circular economy in the agricultural industry is motivated by multiple causes. The agricultural sector is a significant consumer of natural resources, including water, land, and energy. Traditional approaches to agriculture often lead to soil depletion, water pollution and ecosystem degradation. The increasing global population and the phenomenon of climate change necessitate the development of novel strategies to guarantee food security and adjust to emerging environmental contexts. Within this particular framework, the circular economy has the potential to effectively mitigate the environmental impact and enhance the productivity of the agricultural industry.

The challenge of implementing a circular economy in the agricultural sector is the need to change traditional production practices and introduce new technologies and methods of resource management (Gavkalova *et al.*, 2024). The main challenges include the need for financial investment, changing the mindset and behaviour of farmers, and the need to develop an effective regulatory framework. In addition, there is a need to develop infrastructure for the processing and reuse of agricultural waste, as well as to create markets for circular economy products. Addressing these challenges requires cooperation between government agencies, the private sector and academia to ensure a comprehensive approach to transforming the agricultural sector.

The agroecological approach encompasses the incorporation of biological processes into agricultural production, the application of organic fertilisers, crop rotation, intercropping, and other techniques that promote the sustainable management of agricultural systems (Shahini *et al.*, 2022). Implementing this strategy decreases reliance on finite resources and decreases the release of greenhouse gases, which is crucial in the context of addressing climate change. Apart from the environmental advantages, the implementation of the circular economy in the agricultural industry can yield substantial economic benefits. The introduction of resource-efficient technologies and processes can reduce production costs, increase competitiveness and create new jobs in the waste processing and management sector (Dykha *et al.*, 2024).

Upon analysing the current research, it is feasible to pinpoint some notable studies that have made a substantial impact on the advancement of the circular economy in the agricultural industry and the agroecological approach. S. Kara *et al.* (2022) emphasised the importance of introducing closed production cycles in agriculture. The authors emphasised that such cycles can significantly reduce waste and increase resource efficiency. D. Breus & O. Yevtushenko (2023) assessed the impact of agroecological methods on soil fertility and biodiversity. They contended that the application of organic fertilisers and intercropping resulted in a decrease in soil erosion and an enhancement of soil structure. O. Shubravska *et al.* (2019) investigated the environmental benefits of the agroecological approach. The researchers concluded that including biological processes in production helps to decrease greenhouse gas emissions and preserve water resources. J.A. Aznar-Sánchez *et al.* (2019) investigated methods of increasing resource efficiency in agriculture. They highlighted the importance of organic waste processing for biogas and compost production. M. Duque-Acevedo *et al.* (2020) analysed the legal and regulatory frameworks needed to support the circular economy in the agricultural sector. They underscored the significance of public policy in fostering innovation and investment in this field. A.M. Dumont *et al.* (2021) studied the social aspects of implementing agroecological practices. They noted that such practices can contribute to the development of local communities and increase the social responsibility of farmers. S. Sehnem *et al.* (2019) explored the possibilities of creating new markets for circular economy products. The authors concluded that consumers increasingly prefer environmentally friendly products, which opens new prospects for farmers. An analysis of the role of technology in the implementation of the circular economy was conducted by A. Berxolli *et al.* (2023). They underscored the need to advance novel techniques for garbage recycling and the utilisation of sustainable energy sources. Furthermore, the influence of agroecological techniques on the sustainability of food systems was also examined by A. Wezel *et al.* (2020). The authors emphasised that the incorporation of these methods can greatly mitigate the adverse effects of agricultural output on the environment.

O. Dovgal & N. Potryvaieva (2024) discuss the pressing issue of increasing the efficiency of the agricultural sector of Ukraine through the introduction of circular economy principles. The study addressed the case of Myronivsky Hliboproduct, which demonstrates the benefits and challenges of this approach. Considerable focus was given to

the examination of waste in biogas operations, which not only mitigates CO2 emissions but also enhances the efficiency of resource utilisation within the organisation. Furthermore, the report detailed the challenges encountered by the company following the comprehensive Russian incursion in 2022 and the actions implemented to ensure long-term growth. V. Shebanin *et al.* (2023) studied the implementation of sustainable development at the regional level, which is critical in modern conditions. The authors emphasised the need to coordinate natural resources, investments, and scientific and technological orientation to meet the future needs of humanity. The study explored the notion of circular economy as a crucial factor for the sustainable growth of businesses and regions since it guarantees the more effective utilisation of resources and enhances environmental safety.

Despite significant progress in the study of circular economy and agroecological practices, several topics require further research. The issue of integrating new technologies into circular processes in the agricultural sector in the context of their economic feasibility and practical implementation, has not been sufficiently considered. Many studies focus on theoretical aspects and general principles, while specific examples of technology implementation and their effectiveness remain insufficiently covered.

The objective of the study was to evaluate the feasibility of adopting a circular economy in the agricultural industry using an agroecological methodology. The study aimed to examine contemporary technologies that enable the adoption of the circular economy in the agricultural industry and their influence on economic productivity. Also, to evaluate the social challenges of farmers' adjustment to agroecological practices and their consequences on local communities. In addition, to evaluate the efficacy of current government policies and programs in promoting the circular economy, and to provide suggestions for enhancing their effectiveness.

▸Materials and methods

Data from the Area, gross harvest and crop yields (n.d.), Livestock production, number of livestock and feed supply (n.d.) were used to analyse the current state of the Ukrainian agricultural sector and assess the impact of the war on crop and livestock production. The data covers the period from 2014 to 2023, which was used for regression and trend analysis to identify long-term trends and changes in production. A regression analysis was conducted to evaluate the correlation between hostilities and the yield of key crops such as wheat, corn, barley, sunflower, and soybeans, as well as livestock products including meat, milk, eggs, and wool. The study employed a comparative analysis to evaluate the structural changes in the agricultural sector. This research revealed alterations in the composition of the harvest and their consequences on several categories of agricultural goods.

The assessment of the environmental and economic consequences of the war in Ukraine was based on reports by international organisations, including the World Bank, which analysed damage and direct losses in the agricultural sector (Neyter *et al.*, 2024). To assess the environmental impacts, a trend analysis of data from the State Ecological Inspectorate of Ukraine on the level of soil and water pollution because of military operations, including pollution with heavy metals, pesticide residues and other pollutants, was conducted in the study (The weekly infographic..., 2023). The effectiveness of circular practices was assessed based on the criteria of economic profitability, including reduced costs and increased revenues, and environmental impact, including reduced CO_2, CH_4 and N_2O emissions.

Specific technologies that were already successfully applied in different European countries were analysed in detail. Closed water systems in the Netherlands, precision agriculture in Sweden, waste-to-energy in Denmark and France, and reforestation projects in Germany and Switzerland were studied. A comparative analysis was employed to tailor these techniques to the specific circumstances of the Ukrainian agricultural industry, enhancing the environmental condition, boosting production, and promoting sustainable growth. Specifically, the implementation of closed water systems, precision agriculture, cutting-edge waste management technology, and reforestation initiatives can greatly enhance the environmental conditions in Ukraine.

This study examined the adoption of circular practices in the Ukrainian agricultural firm Kernel using data obtained from the company's corporate filings. A comparative analysis was conducted of the methods of recycling production waste, using biomass for energy production and precision agriculture. The effectiveness of these methods was assessed based on economic feasibility, including an analysis of the company's profitability and competitiveness, as well as environmental criteria, such as reducing the company's environmental footprint by reducing CO_2, CH_4 and N_2O emissions (Kernel annual report, 2023). Therefore, the study integrated regression, trend, and comparative analysis to evaluate the influence of the war on the agricultural industry. It also included an examination of the economic and environmental viability of adopting circular practices derived from both international and national experiences.

▸ Results

The circular economy is a novel economic development paradigm that prioritises the optimisation of resource utilisation and reduced waste generation. This notion holds considerable significance in the agricultural sector, given that agriculture is among the most resource-intensive businesses and has a substantial environmental footprint. The fundamental concept of the circular economy is to establish self-contained cycles in which trash generated by one operation is transformed into a valuable resource for another. This reduces the consumption of primary resources and reduces pollution. In the agricultural sector, circular processes can include recycling organic waste into compost or biogas, using perennial crops, integrating intercropping, and applying biological plant protection methods (Haque *et al.*, 2023). Resource conservation is a fundamental concept at the core of the circular economy in the agricultural industry. This entails not only the equitable utilisation of land, water, and energy but also the preservation of biodiversity and the enhancement of soil fertility. The substitution of chemical fertilisers with organic fertilisers, together with the implementation of crop

rotation and intercropping, can enhance soil structure and mitigate erosion.

The agroecological approach, which is an integral part of the circular economy, involves the integration of biological processes into agricultural production. This includes the use of natural mechanisms to control pests, and the use of cover crops to preserve soil moisture and improve soil fertility. Agroecological methods reduce the use of synthetic chemicals and pesticides, which in turn helps to reduce environmental pollution and improve product quality. The economic benefits of implementing a circular economy in the agricultural sector are also significant (Reynaud *et al.*, 2019). The use of resource-efficient technologies can reduce production costs, increase productivity, and create new jobs in waste processing and management. For instance, the production of biogas from organic waste can be an additional source of income for farmers, as well as reduce dependence on fossil fuels.

The adoption of digitalisation plays a significant role in the execution of the circular economy within the agricultural industry. Modern digital technologies can be employed to monitor soil conditions, manage water resources and optimise processes that can significantly increase the efficiency of agricultural production. Innovations such as sensors, drones, and precision farming systems help to reduce resource waste and increase productivity (Boz & Martin-Ryals, 2023).

The agricultural sector in Ukraine accounts for roughly 10% of the country's gross domestic product and employs a significant portion of the population, particularly in rural regions. Characterised by highly fertile soils, especially black soil which accounts for 30% of the global supply, Ukraine possesses significant potential for cultivating key commodities such as wheat, sunflower, maize, barley and soybeans. Another important aspect is the export of grains and oilseeds, which significantly contributes to the country's trade balance. This phenomenon gives rise to the substantial productivity of prominent agricultural commodities including wheat, corn, barley, sunflower, and soybeans. Furthermore, Ukraine holds a prominent position as a global exporter of grains and oilseeds, exerting a substantial influence on its trade balance. Production growth in the agricultural industry from 2012 to 2020 was driven by the implementation of advanced technologies and innovations, which enhanced production efficiency and the competitiveness of products in global markets. However, the war negatively impacted the sector, through the destruction of infrastructure, landmines and environmental pollution, which reduced yields and export potential (Fig. 1).

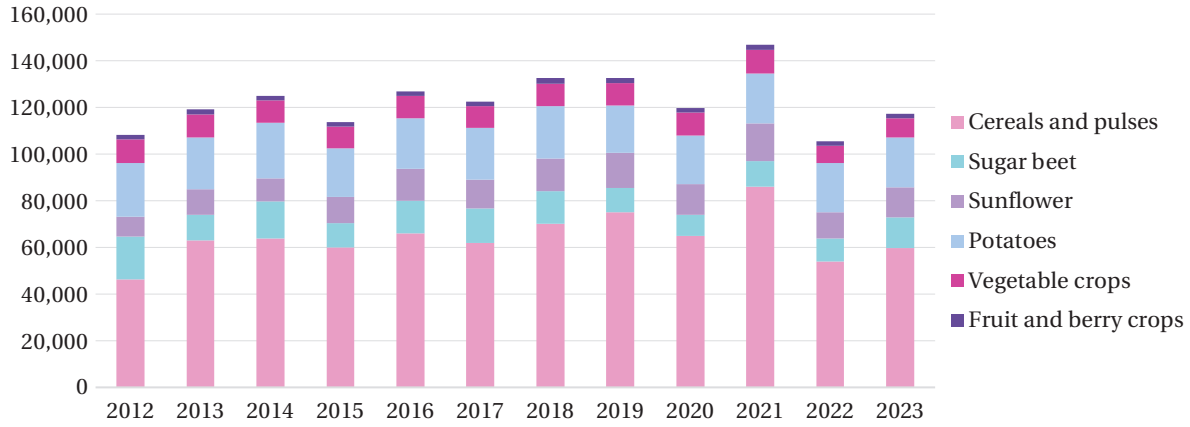

Figure 1. Gross agricultural production in Ukraine from 2012 to 2023, measured in thousand tonnes
Source: compiled by the authors based on the data from Area, gross harvest and crop yields (n.d.)

The war in Ukraine has inflicted extensive harm on the agricultural industry, resulting in a substantial decrease in the yield of key commodity crops. Despite a partial rebound in 2023, the production quantities still fall short of the levels seen before the war. This highlights the necessity for sustained assistance and reconstruction of agriculture in response to persistent difficulties. Presented in Table 1 are the production volumes of livestock products.

Table 1. Estimated output of primary livestock products in Ukraine from 2012 to 2023

Year	Meat (in slaughter weight), thousand tonnes	Milk, thousand tonnes	Eggs, million	Wool, t
2012	2,209.6	11,377.6	19,110.5	3,724
2013	2,389.4	11,488.2	19,614.8	3,520
2014	2,359.6	11,132.8	19,587.3	2,602
2015	2,322.6	10,615.4	16,782.9	2,270
2016	2,323.6	10,381.5	15,100.4	2,072
2017	2,318.2	10,280.5	15,505.8	1,967
2018	2,354.9	10,064	16,132	1,908
2019	2,492.4	9,663.2	16,677.5	1,734
2020	2,477.5	9,263.6	16,167.2	1,573

Table 1, Continued

Year	Meat (in slaughter weight), thousand tonnes	Milk, thousand tonnes	Eggs, million	Wool, t
2021	2,438.3	8,713.9	14,071.3	1,497
2022	2,206.7	7,767.7	11,921.8	1,237
2023	2,239.5	7,430.4	11,379.4	1,187

Source: compiled by the authors based on the data from Livestock production, number of livestock and feed supply (n.d.)

Table 1 presents the production metrics of the primary animal products in Ukraine, illustrating notable fluctuations in output levels between 2012 and 2023. There has been a downward trend in milk, eggs and wool production, especially since 2015. Meat production remains more stable, although it has also experienced some fluctuations. The significant decline in production in 2022 and 2023 is due to the negative impact of the war, which highlights the need to take measures to support and restore livestock production in the country.

The war in Ukraine has caused severe damage to infrastructure, and soil and water pollution, which has had a significant negative impact on the agricultural sector. An analysis of damage and direct losses conducted by the World Bank and its partners shows that different sectors of the economy suffered the greatest losses: housing (17% of total damage), transport (15%), energy (10%), industry and trade (14%), and agriculture (12%) (Neyter *et al.*, 2024). However, losses in agriculture are underestimated and hidden.

Data from the State Ecological Inspectorate of Ukraine indicate that aggressive Russian actions caused significant environmental and agronomic problems (The weekly infographic..., 2023). 594.5 thousand m^2 of soil were contaminated with harmful substances, which impairs their fertility and makes them unsuitable for agricultural use. A large part of the land (17.8 million m^2) was covered with the remains of destroyed objects and ammunition, making it difficult to cultivate and use these areas for agricultural purposes (Neyter *et al.*, 2024). The shelling resulted in the burning of 721.8 thousand tonnes of oil products, which significantly polluted the air and soil. This pollution affects water and soil quality, making it difficult to grow crops. In addition, more than 38 thousand tonnes of emissions from the combustion of Russian equipment were released into the atmosphere, which also harms the environmental situation. More than 352 thousand tonnes of waste were generated, polluting both air and land. Fires caused by missiles and shells destroyed 66.8 thousand hectares of forests, which not only worsened the environmental situation but also contributed to soil erosion and loss of natural resources. At the same time, the mining of territories has become another serious problem. The clearance of these territories, which cover an area of approximately 200 thousand km^2, requires significant resources and time, which delays the restoration of agricultural land.

In summary, the war in Ukraine has severely damaged the agricultural sector through direct destruction of infrastructure, soil and water contamination, as well as long-term problems related to landmines and environmental pollution. Urgent measures are needed to restore the agricultural sector, including the clean-up of contaminated areas, restoration of infrastructure and maintenance of environmental safety. The post-war reconstruction of the Ukrainian agricultural sector requires the integration of innovative practices that will effectively restore agriculture, reduce the negative impact of the war, and ensure sustainable development. The implementation of a circular economy by European countries might be a significant benchmark and a valuable source of practice for Ukraine.

European countries such as the Netherlands and Sweden demonstrate efficient ways of using resources in the agricultural sector. The Netherlands is a global leader in the implementation of closed-water cycles in agriculture. Water recycling systems are used in greenhouses where different crops are grown. These systems collect, purify and reuse water, which significantly reduces its consumption and costs. For example, in Dutch greenhouses, up to 90% of water can be reused, reducing water consumption by 50-70% compared to traditional methods (Gonzalez-Martinez *et al.*, 2021). For Ukraine, where the war has severely damaged infrastructure and resources, the introduction of such technologies can significantly reduce water consumption and improve water quality. In reconstructed areas where irrigation systems have been destroyed, the use of closed water cycles will allow for efficient use of available resources, reduce water pollution, and increase crop productivity.

Swedish agriculture actively employs precision farming technologies to maximise the utilisation of fertilisers and herbicides. Precision agriculture includes the utilisation of sensors, satellite imaging, and drones to closely observe and assess the state of soil and plants. This allows farmers to accurately determine the fertiliser and pesticide requirements of each area of the field, which reduces their consumption and improves soil fertility. For instance, in Sweden, precision farming has reduced fertiliser costs by 20-30% and increased yields by 10-15% (Dietmann & Stålhammar, 2020). For Ukraine, where the use of chemical fertilisers and pesticides may be limited due to infrastructure damage and pollution, these technologies could be a solution to improve soil fertility and increase yields. Precision farming will additionally mitigate the adverse effects on the environment and afford a more sustainable methodology for agricultural output.

The recycling and waste management practices used in Denmark and France can be adapted to restore areas affected by war. Denmark is a leader in the use of organic waste for biogas production. Cooperative biogas plants have been set up in many rural areas to process organic waste from farms, the food industry and households. France is actively implementing urban biogas plants that process organic waste from large cities such as Paris. These plants produce biogas that is used to power public transport or heat homes. In Ukraine, where agricultural

waste disposal and soil contamination are serious problems, using waste to produce biogas or compost can help improve soil fertility and reduce dependence on external resources. Organic waste processing technologies can create valuable fertilisers and reduce the negative impact of waste accumulation. European countries are actively implementing agroecology practices to improve the ecological balance. Agroforestry is a method of integrating woody plants into agricultural systems. In France, this approach is widely used to combat soil erosion and improve soil structure. In agroforestry systems, trees are planted along fields to help stabilise soils, reduce erosion and increase fertility. Woody plants also provide a natural defence against wind erosion and help retain soil moisture (Hotelier-Rous *et al.*, 2020). For Ukraine, where large areas have been affected by the war and where soil erosion is a pressing issue, the introduction of agroforestry could be an important step in recovery. Planting trees and shrubs at field boundaries and in the aisles will reduce erosion, improve soil structure and increase soil fertility. It will contribute to the restoration of biodiversity and the creation of new ecological niches for local flora and fauna.

In Germany and Switzerland, projects are being implemented to restore forests that have been destroyed or degraded. These projects include re-planting trees, restoring natural forest ecosystems and maintaining vegetation diversity. One of the key projects in Germany is the Waldklimafonds (Forest Climate Fund), which was established by the government to restore and adapt forests to climate change. As part of this initiative, extensive replanting of trees, specifically chosen native species that are more well-suited to the new climatic circumstances, has been conducted. The reforestation of thousands of hectares of forest nationwide has effectively mitigated CO_2 emissions and generated employment opportunities within the forestry industry. In Switzerland, one of the most significant projects was the Lothar Project, launched after the 1999 Lothar storm, which destroyed large areas of forest. The project restored more than 25 thousand hectares of forest, making them more resilient to future storms and extreme weather conditions. The economic benefits of this project have been significant: the conservation and restoration of forest resources have become an important factor for the Swiss woodworking industry and support for local tourism. Furthermore, green infrastructure, including green corridors and ecological networks, significantly contributes to the enhancement of air quality and the mitigation of pollution. For Ukraine, where the war has caused significant damage to natural ecosystems, restoring forests and green infrastructure will be critical to improving the environmental situation. In the UK and the Netherlands, green surfaces are being created to absorb pollutants and provide natural air purification. Green infrastructure, such as urban parks, green roofs and walls, helps to reduce the concentration of pollutants in the air and improve the overall environmental situation. For Ukraine, the implementation of such initiatives can help restore damaged areas and improve air quality.

Local initiatives in Italy and other European countries demonstrate the importance of developing local economies through the implementation of circular practices. In Italy in the Tuscany region, agricultural waste recycling projects are being implemented that provide numerous economic benefits. One of these projects is the establishment of composting stations where organic waste is converted into high-quality compost for soil fertilisation. This not only reduces the amount of waste that needs to be disposed of but also reduces the need for chemical fertilisers. As a result, fertiliser costs are reduced, soil fertility is improved, and the risk of environmental pollution is reduced. The cost of agricultural production is also reduced due to greater efficiency in the use of natural resources. Another example of a successful initiative in Italy involves the use of olive oil residues. These residues are processed into biomass, which serves as an alternative fuel for heating greenhouses. This reduces the consumption of traditional energy resources such as gas or electricity, which in turn reduces energy costs. In addition to decreasing greenhouse gas emissions, the use of biomass also enhances the resilience of greenhouses to climate change (Cristiano, 2021). Such practices have also been noted in Germany, where agricultural cooperatives share machinery and waste management, reducing costs and environmental impact. In Ukraine, where the war has severely damaged infrastructure and the economy, these innovative approaches could be an important factor in the recovery of the agricultural sector. Supporting local producers and agribusinesses that use the latest tillage and waste management techniques can help reduce costs and increase efficiency. For example, the creation of local clusters and cooperatives will help farmers pool resources to share machinery and equipment, which will reduce costs and provide access to new technologies. The experience of European countries in rehabilitating infrastructure can serve as a useful guide for Ukraine. Therefore, it is crucial to allocate resources towards the restoration of agricultural infrastructure, encompassing trash collection and recycling systems, irrigation systems, and energy solutions that adhere to the concepts of a circular economy. This will not only help restore production capacity but also ensure its sustainability and efficiency in the long term.

Kernel is a prominent agricultural enterprise in Ukraine that aggressively adopts circular economy principles to enhance production efficiency and minimise environmental footprint. The company uses an integrated approach to resource management, focusing on waste recycling, biomass utilisation and precision farming. A fundamental activity of the organisation is the recycling of production waste. Kernel transforms waste from sunflower processing, such as husks and oilcakes, into useful products for livestock. Instead of disposing of this waste as garbage, the company collects it, processes it and turns it into high-quality animal feed. This process involves drying, grinding and mixing the waste with other ingredients to achieve optimum feed quality. Through this practice, Kernel reduces the amount of waste going to landfills and reduces the cost of purchasing feed. The company also actively uses biomass as a renewable energy source. Production waste, such as sunflower husks, is processed into biomass, which is used to produce biofuels and heat. This process involves pelletising and burning biomass in specialised boilers, which generates energy for the company's production needs. The utilisation of biomass diminishes reliance on fossil fuels and contributes to the mitigation

of greenhouse gas emissions, therefore yielding a favourable environmental outcome. In addition, it allows the company to reduce energy costs, as part of its energy needs are covered by internal resources. Kernel is also implementing precision farming technologies to improve resource efficiency and reduce its environmental impact. The use of Global Positioning System technologies, drones and specialised software tools can be used to accurately determine the needs of crops for fertilisers, water and other resources. Data monitoring and analysis systems help farmers make informed decisions about tillage and fertilisation. This includes the use of sensors, satellite imagery and soil analysis. Thanks to precision agriculture, the company reduces the cost of fertilisers and chemicals while increasing yields and product quality. It also helps to preserve soil and reduce the negative impact on the environment. Table 2 shows the main indicators of the company's gas emissions.

Table 2. Kernel's key emissions indicators from 2021 to 2023, thousand tonnes of CO_2

Emission	2021	2022	2023
By type			
CO_2	291.7	521.5	416.9
CH_4	22	22.8	23.4
N_2O	712.2	719.9	615.2
By business segment			
Oilseeds processing	19	9.1	6.6
Infrastructure and trade	58.4	81.3	62.2
Agriculture	941.1	1,172.7	986.2
Fuel consumption	135.5	103.2	124.8
Fertiliser application	697.3	708.6	602.4
Changes in soil carbon reserves	83.9	335.4	232.8
Bovine methane from enteric fermentation	24.4	25.5	26.2
Other	7.4	1.2	0.7
Biogenic (burning sunflower husks)	349.5	348.9	509.8
Total	1,025.9	1,264.2	1,055.6

Source: compiled by the authors based on Kernel Annual Report (2023)

CO_2 emissions increased significantly from 291.7 thousand tonnes in 2021 to 521.5 thousand tonnes in 2022 but decreased to 416.9 thousand tonnes in 2023. CH_4 and N_2O emissions also increased in 2022 but then decreased in 2023. By business segment, oilseeds processing and agriculture showed a decrease in emissions, while infrastructure and trade fluctuated. Total emissions increased from 1,025.9 thousand tonnes in 2021 to 1,264.2 thousand tonnes in 2022 but decreased to 1,055.6 thousand tonnes in 2023. These data show that Kernel is working to reduce its environmental impact by implementing efficient technologies and practices, although some aspects require further optimisation, including an increase in biogenic emissions in 2023.

Kernel's circular economy practices significantly reduced the amount of waste and the cost of its disposal. Recycling waste into feed and biomass improves the use of available resources, reducing energy and raw material costs. The use of precision farming increases productivity and reduces the need for chemicals. Minimising the volume of waste deposited in landfills and decreasing the reliance on fossil fuels has a beneficial effect on the environmental conditions in the surrounding area. Utilising biomass as an energy source and implementing precision agriculture techniques contribute to the mitigation of greenhouse gas emissions and the enhancement of soil health. Kernel's experience in implementing circular practices shows that agricultural companies can significantly increase their efficiency and sustainability by applying innovative approaches to resource management. The use of waste, biomass and precision farming can reduce costs, conserve natural resources and improve the environment. Such techniques can be used as a blueprint for other agricultural businesses aiming to attain sustainable development and protect the environment.

Developing a circular economy in the agriculture sector is becoming a crucial undertaking in Ukraine, considering the context of sustainable development and post-war rebound. With this objective in mind, the government is enacting several laws and programs designed to bolster environmental efforts and promote the effective utilisation of resources in agriculture. One crucial endeavour is the National Trash Management Strategy, which seeks to minimise trash and enhance recycling. The objective of the policy is to establish infrastructure for the gathering and treatment of agricultural waste while encouraging the use of organic fertilisers and composting.

Another important role is played by the State Programme for Support of Organic Production, which is aimed at developing organic farming. The programme provides financial support to farmers who adopt organic production methods, including the use of natural fertilisers and biological pest control methods. This reduces the use of chemicals and improves soil quality. The state bioenergy development programme advocates for the utilisation of biomass in energy generation. This includes the promotion of biogas generation from agricultural waste and the optimisation of biomass utilisation for

heat generation. The implementation of such measures serves to diminish reliance on fossil fuels and mitigate the release of greenhouse gas emissions. An important component of the circular economy support is the Small and Medium-Sized Farmer Support Programme, which aims to stimulate cooperation between farmers and develop local markets. The initiative offers financial assistance for the implementation of ecologically sustainable technologies and methods in agriculture, including precision farming, agroforestry, and water resources management. Also worth mentioning is the National Climate Change Action Plan, which includes measures to adapt agriculture to climate change. This involves the development of sustainable agricultural systems, including the use of resistant plant varieties, optimisation of water use and the introduction of agroforestry.

In general, Ukrainian government policies and programmes aim to create conditions for sustainable development of the agricultural sector by implementing circular practices, reducing environmental impact and increasing resource efficiency. These measures are important steps towards restoring ecosystems and improving the economic situation of the agricultural sector in the post-war recovery. For the post-war reconstruction and recovery of the Ukrainian agricultural sector, a comprehensive strategy that addresses environmental, economic and social aspects needs to be developed. First, priority regions and sectors should be identified for recovery based on the degree of damage and potential for development. For example, the recovery of key agricultural regions such as Kherson, Zaporizhzhia and Kharkiv, which have suffered significant damage, will be a priority for recovery. The introduction of circular practices, such as the use of agricultural waste for biofuel and biogas production, will contribute to energy independence and reduce greenhouse gas emissions (Kapoor *et al.*, 2020). For instance, as the experience of different countries shows, processing sunflower residues into biofuels can significantly reduce the need for traditional fuels.

Composting organic waste and using it as fertiliser will improve soil fertility, which is particularly important for restoring degraded land. For instance, farmers can use crop residues to create compost, which will improve soil structure and increase yields. Encouraging innovation and modern technologies, including precision farming to optimise the use of fertiliser and water, will reduce costs and increase yields. Deploying drones for field monitoring and precise application of fertilisers would mitigate the excessive use of pesticides and minimise the adverse environmental effects. The implementation of irrigation infrastructure and efficient water management practices will alleviate water scarcity in dry regions. For instance, the introduction of drip irrigation in the southern regions of Ukraine will significantly reduce water consumption and increase the efficiency of its use, as is the case in the Netherlands. Supporting small and medium-sized farms through financial incentives such as subsidies, soft loans and grants will help restore production. The development of cooperatives and local markets will provide access to inputs and sales. For example, the creation of cooperatives for the joint purchase of equipment and inputs will help reduce costs for individual farmers.

Support for the transition to organic production methods, including training and advisership to farmers, will facilitate the certification of organic products and their subsequent export to international markets. For example, organising trainings for farmers on organic farming will increase their knowledge and adoption of environmentally friendly practices. Reconstruction of transport and logistics infrastructure will ensure efficient transportation of agricultural products. Restoration and modernisation of agricultural enterprises and production facilities will ensure production restoration. For instance, repairing and upgrading railway lines will provide faster delivery of products to various markets. Ecological restoration and protection, including measures to restore degraded land, reforestation and planting, and cleaning up contaminated soil and water resources, will improve the environment. Like restoration in Germany and Switzerland, planting forest strips around fields will help reduce soil erosion and improve the local climate. International cooperation and support, including financial assistance, technical support and exchange of experience, will facilitate the implementation of best practices and technologies. For instance, cooperation with European partners to exchange knowledge and experience in the field of agroecology will help to implement best practices in Ukraine. Environmental insurance is a critical element in the implementation of a circular economy in the agricultural sector, as it provides financial protection against risks associated with environmental damage and pollution (Shebanina *et al.*, 2023). In the context of recovery from war or natural disasters, environmental insurance helps to reduce financial risks for farmers and agribusinesses, which helps to stimulate investment in sustainable development and new environmental practices. This allows agricultural enterprises to implement innovative circular solutions with the confidence that in the event of environmental problems, they will receive the necessary support to quickly recover and continue their operations.

Training and education through the organisation of training programmes and the establishment of further education centres will ensure a skilled workforce. For instance, the creation of training centres for agronomists and technicians will improve the knowledge and skills of local workers. The development of medical, educational and social infrastructure in rural areas will ensure decent living and working conditions. The implementation of these suggestions will bolster the revival and advancement of the Ukrainian agricultural industry, guaranteeing its long-term viability, effectiveness, and ecological integrity during the post-war period of recovery.

▸ Discussion

In the context of post-war recovery, the study's findings validate the considerable potential for establishing a circular economy in Ukraine's agriculture sector. The concept of economic development, characterised by the optimisation of resource utilisation and reduction of waste, holds significant relevance for the agricultural industry, which is highly resource-intensive and environmentally detrimental. Implementing closed cycles, in which waste generated by one operation is repurposed as a resource for another, effectively decreases

the use of primary resources and mitigation of pollution. M.R. Mosquera-Losada *et al.* (2019) examined the influence of perennial crops on soil fertility within the context of a circular economy. The investigation was carried out on controlled trial fields utilising perennial crops like lucerne, clover and perennial grasses. The study conducted by J.F. Velasco-Muñoz *et al.* (2022) demonstrated that the implementation of these crops had a substantial impact on the mitigation of soil erosion and the enhancement of its organic composition. Following three years of utilising perennial crops, it was seen that the soil's organic matter content had a 15% rise, while erosion exhibited a 25% reduction. The findings of the research indicate the potential of crop rotation and an agroecological approach to improve soil fertility in Ukraine, which is important for the restoration of affected land.

O. Dovgal & N. Potryvaieva (2024) discuss the pressing issue of increasing the efficiency of the agricultural sector of Ukraine through the introduction of circular economy principles. The study addressed the case of Myronivsky Hliboproduct, which demonstrates the benefits and challenges of this approach. Considerable focus was given to the examination of waste in biogas operations, which not only mitigates CO_2 emissions but also enhances the efficiency of resource utilisation within the organisation. Furthermore, the report detailed the challenges encountered by the company following the comprehensive Russian incursion in 2022 and the actions implemented to ensure long-term growth. V. Shebanin *et al.* (2023) studied the implementation of sustainable development at the regional level, which is critical in modern conditions. The authors emphasised the need to coordinate natural resources, investments, and scientific and technological orientation to meet the future needs of humanity. The study explored the notion of circular economy as a crucial factor for the sustainable growth of businesses and regions since it guarantees the more effective utilisation of resources and enhances environmental safety.

F.C. Silva *et al.* (2019) focused on the impact of circular practices on the economic efficiency of farms. They conducted a detailed comparison of the costs and revenues of farmers who implement circular practices with those who follow traditional methods. Their study used data from different regions where farmers were implementing practices such as organic waste reuse, biomass processing and energy-efficient technologies. For Ukraine, these results demonstrate the potential for significant cost savings and increased income for farmers through the implementation of circular practices. This may be particularly relevant in the context of post-war recovery, where cost-effectiveness is critical to stabilising the agricultural sector.

The findings underscore the significance of resource conservation as a fundamental tenet of the circular economy. Substituting chemical fertilisers with organic fertilisers, implementing crop rotation, and incorporating perennial crops can enhance soil structure and mitigate erosion. These approaches have the potential to greatly enhance soil fertility and make a substantial contribution to the sustainable development of the agricultural industry (Biyashev *et al.*, 2024). I.P. Sharma *et al.* (2020) analysed the impact of intercropping on biodiversity conservation. They used a mixture of different crops in fields to increase the resilience of agroecosystems. Their results showed that the use of intercropping increases biodiversity and improves the resilience of agroecosystems to climate change. Intercropping contributes to the creation of more resilient agroecosystems. The results show that intercropping improves biodiversity and resilience to climate change. For Ukraine, the integration of intercropping can contribute to the creation of more resilient agroecosystems, which will help in climate change adaptation and biodiversity conservation in the affected regions.

The agroecological approach, which is an integral part of the circular economy, involves the integration of biological processes into agricultural production (Nunes & Sytnychenko, 2024). Harnessing natural mechanisms for pest control and implementing cover crops to retain moisture and enhance soil fertility can minimise reliance on synthetic chemicals and pesticides. Consequently, this contributes to the mitigation of environmental degradation and the enhancement of product quality. M. Tariq *et al.* (2020) studied the impact of biological plant protection methods on crop yields. To manage pests and diseases, they employed biological products derived from microbes and beneficial insects. The research conducted has demonstrated that the implementation of biological techniques can effectively decrease the reliance on pesticides without substantially diminishing crop production. Biological methods can be an effective alternative to chemicals. The study also shows the effectiveness of biological methods of plant protection, providing concrete data on the preservation of yields. Ukrainian adoption of biological approaches can mitigate the adverse effects of chemical pesticides on the environment and human health, playing a crucial role in the restoration of ecosystems and enhancement of agricultural product quality.

The results also show that the economic benefits of implementing a circular economy in the agricultural sector are significant. The use of resource-efficient technologies can reduce production costs, increase productivity and create new jobs in waste processing and management. For example, the production of biogas from organic waste can be an additional source of income for farmers and reduce dependence on fossil fuels. M. Ellacuriaga *et al.* (2021) focused on the cost-effectiveness of organic waste conversion to biogas. They investigated the profitability of biogas plants on medium and large farms. M.R. Atelge *et al.* (2020) showed in their results that investments in biogas plants can pay off within 5-7 years and provide additional income to farmers through the sale of electricity and heat. The authors also noted that the use of biogas reduces greenhouse gas emissions by 40%. The authors' findings confirm that biogas plants can be a profitable investment solution for agricultural enterprises in Ukraine. It not only reduces energy costs but also reduces greenhouse gas emissions. Biogas plants can be an effective tool for the economic recovery of the agricultural sector and reduce the ecological footprint.

Digitisation is a crucial component of the circular economy within the agricultural industry. The use of modern digital technologies to monitor soil conditions, manage water resources and optimise processes can significantly increase the efficiency of agricultural production

(Skarbøvik *et al.*, 2014). Sensors, drones, and precision farming systems reduce resource losses and increase productivity. E. Bwambale *et al.* (2022) investigated the impact of digital technologies on water use efficiency in agriculture. They conducted experiments with precision irrigation systems on different types of soils and crops. The results showed that the introduction of such systems can reduce water use and increase yields by optimising water regimes and reducing water losses. The authors' study found that the use of digital technologies, such as precision irrigation, increases resource efficiency and yields. For Ukraine, the introduction of modern digital technologies in water management can significantly improve the efficiency of agricultural production and ensure optimal water use in the face of climate change.

Data analysis shows that the Ukrainian agricultural sector has suffered significant losses due to the war. This emphasises the need to introduce circular practices to restore and support local economies. The results of the study show that the introduction of practices such as recycling organic waste into compost or biogas, using perennial crops, integrating intercrops and applying biological plant protection methods can help restore productivity and improve the environmental status of agricultural areas. Y. Fan & C. Fang (2020) focused on the role of government programmes in supporting the circular economy in the agricultural sector. They analysed the effectiveness of various government initiatives and subsidies that promote the implementation of circular practices on farms. A. Muscio & R. Sisto (2020), in turn, found that effective government programmes significantly accelerate the adoption of circular practices in agriculture. They emphasised that government subsidies and grants not only provide financial support for farms but also stimulate innovation and new technologies in the agricultural sector. The authors' findings highlight the importance of state support for the implementation of circular practices. For Ukraine, subsidies and programmes can provide the necessary financial support for farmers and stimulate innovation in the agricultural sector.

The research findings validate that implementing a circular economy in the agricultural industry can greatly enhance the recovery and sustainable development of regions. This necessitates proactive backing from the government, including the formulation and execution of laws and programs targeted at bolstering environmental schemes and optimising resource utilisation in agriculture. Such measures are important steps towards restoring ecosystems and improving the economic situation of the agricultural sector in the post-war recovery.

▸Conclusions

The results obtained in this study confirm that the implementation of circular practices can contribute to both environmental restoration and economic growth of the agricultural sector. The circular economy has been proven to be an innovative model that allows for the creation of closed production cycles and efficient waste management. The use of resource-efficient technologies, such as closed water cycles, precision agriculture and waste recycling, helps to reduce production costs, increase productivity and create new jobs.

An agroecological strategy, which incorporates biological processes into agricultural production, minimises the use of synthetic chemicals and pesticides, therefore mitigating environmental damage and enhancing product quality. The practical importance of this strategy lies in its contribution to the sustainable growth of the agricultural industry, which serves to decrease reliance on external resources and enhance long-term economic efficiency.

The war in Ukraine has severely damaged the agricultural sector, leading to a significant decline in the production of major crops. The experience of European countries, such as the Netherlands, Sweden, Denmark and France, highlights the importance of implementing circular practices in the Ukrainian agricultural sector. An important example is the experience of Kernel, which is actively implementing circular practices. The introduction of waste recycling technologies, the use of biomass as an energy source, and the application of precision agriculture allowed the company to significantly reduce its total emissions from 1,264 thousand tonnes in 2022 to 1,056 thousand tonnes in 2023.

The study's practical utility lies in its ability to pinpoint particular circular technologies and approaches that might be implemented in Ukraine to rejuvenate the agriculture sector. This encompasses the implementation of closed production cycles, enhanced waste recycling, the utilisation of biomass as an energy source, and the optimisation of agricultural operations through the application of contemporary technologies. The adoption of these methods will not only aid in the rehabilitation of the environment but also yield the economic advantages essential for the continued growth of Ukraine's agricultural industry.

An inherent constraint of the study is the absence of data regarding the influence of particular circular practices on the revival of the agricultural industry in Ukraine. This gap arises from the scarcity of long-term observations and the occurrence of infrastructure damage. Further investigation should concentrate on a comprehensive examination of the efficacy of various circular technologies in particular recovery scenarios and their influence on economic and environmental outcomes.

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▸Conflict of interest

The authors of this study declare no conflict of interest.

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Розвиток циркулярної економіки в аграрному секторі: агроекологічний підхід

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▸ **Анотація.** Це дослідження мало на меті дослідити доцільність використання агроекологічних концепцій для створення циркулярної економіки в сільськогосподарській галузі. У документі розглядається циркулярна економіка як нова парадигма економічного розвитку, спрямована на оптимізацію використання ресурсів і зменшення відходів, особливо в сільськогосподарській галузі. Основним принципом циркулярної економіки є збереження ресурсів, що включає раціональне використання землі, води та енергії, а також збереження біорізноманіття та підвищення родючості ґрунтів. Було проведено аналіз економічних переваг впровадження циркулярної економіки в сільському господарстві, які включають зниження витрат виробництва, підвищення продуктивності та створення нових робочих місць. Також розглянуто значення цифровізації, яка дозволяє значно підвищити ефективність сільськогосподарського виробництва через використання сучасних цифрових технологій для моніторингу стану ґрунтів, управління водними ресурсами та оптимізації процесів. У цій статті досліджено вплив війни в Україні на сільськогосподарську галузь, особливо підкресливши значне зниження виробництва основних сільськогосподарських культур і продуктів тваринництва. Комплексне дослідження руйнування інфраструктури, ґрунту та забруднення води виявило серйозні екологічні проблеми, спричинені атаками. Успішні циклічні концепції, реалізовані такими європейськими країнами, як Нідерланди, Швеція, Данія та Франція, можуть бути застосовані до післявоєнного відродження українського сільського господарства. У дослідженні також розглянуто досвід української компанії "Кернел", яка успішно впроваджує циркулярні практики, такі як переробка відходів виробництва, використання біомаси та впровадження точного землеробства, що дозволяє знизити екологічний вплив та підвищити ефективність виробництва. На основі аналізу запропоновано рекомендації для післявоєнної відбудови аграрного сектору України, які включають ідентифікацію пріоритетних регіонів для відновлення, стимулювання інновацій та сучасних технологій, підтримку малих і середніх фермерських господарств, розвиток іригаційних систем, екологічне відновлення та захист, міжнародну співпрацю та підтримку, а також навчання і підготовку кадрів

▸ **Ключові слова:** забруднення навколишнього середовища; збереження ресурсів; післявоєнна відбудова; відходи війни; сталий розвиток; зміна клімату; викиди парникових газів

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Farmers' adaptation to climate change in Southern Issyk-Kul

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► **Abstract.** Agriculture is a key sector for people's livelihoods in Kyrgyzstan, which highlights the role of local people's perceptions of agricultural practices and optimisation of land use management. The purpose of this study was to assess the understanding of land use practices by local residents in four districts of the Southern Issyk-Kul. The level of awareness of sectoral issues was investigated by randomly selected farmers. The study found that modern farmers are aware of the existing problems and their contribution to the decline in agricultural productivity and increased vulnerability to environmental change. It was generalised that the solution of the problem under study requires practical interaction between government agencies and farmers aimed at providing the necessary information and resources for adaptation to climate-oriented agricultural practices. The potential of innovative precision farming technologies in the context of the studied issues was analysed. An important problem of the lack of a mechanism for the exchange of agricultural knowledge between farmers was identified, as it is difficult for them to determine where and from whom to gain experience. It was substantiated that the integration of agricultural consulting elements into the environment of farm operation has the potential to significantly stimulate the positive dynamics of agricultural development. Such an approach would allow for the most accurate selection of optimisation measures, which would affect the economic efficiency and environmental performance of farming. The practical value of the results of the

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study is seen in the possibility of using them to mitigate the process of adaptation of agricultural production in developing countries to inevitable climate change

▸ **Keywords:** soil; land use practices; perception; precision farming; agricultural consulting

▸ Introduction

Agriculture is an important sector in the livelihoods of the majority of the people in Kyrgyzstan. Kyrgyzstan's agricultural land can be divided into three main categories: arable land (7%), permanent meadows and pastures (48%), and forested areas (3%). Livestock plays a crucial role as a primary source of income for all rural residents (Kyrgyzstan country profile, 2021). Trends in the development of a modern integrated society prioritise organic production and the environmentalization of agricultural production technologies. In developed countries, numerous campaigns are being effectively implemented to adapt the agricultural sector to climate change, ecologise the agricultural sector, and decarbonise technical solutions in the industry, most of which involve a systemic transformation of the development strategies of agricultural enterprises participating in the market, especially the international market. In the context of Kyrgyzstan, the need to create significant competitive advantages in accordance with the new environmental and economic environment of social development deserves special attention today. The agricultural sector is developing within the framework of the strategy of prioritising sustainable development, which requires the gradual integration of precision and organic farming systems.

The analysis of publications on the subject matter suggests that modern researchers are focused on finding alternative technological opportunities in the agricultural sector that would allow them to more actively promote national agricultural progress in a manner complementary to the principles of sustainable development (Maharramova, 2023). For example, G. Jalilova (2018) investigated the specifics of organic farming in Kyrgyzstan, focusing on the analysis of the factors of climate change impact on crop production. The researcher analysed potential environmental risks to the adaptive capacity of agroecosystems. In the system of mitigating the negative impact of destructive climate dynamics, optimisation of production organisation, introduction of innovative technologies and advanced technological processes is of paramount importance (Identification of agroecological…, 2018).

Researchers R. Orozakunova & E. Baibagyshov (2019) considered technologies for intensifying the level of agricultural productivity through the integration of innovative technological solutions as the basis for optimising their position in the market and maximising their use. The study by J. O'Connell & P. Kiparisov (2018) proposed a stage-by-stage process of transition from traditional to organic forms of agricultural production, highlighted functional and structural elements and main parameters. A number of research papers by contemporary researchers, in particular, D. Glover *et al.* (2019) presented the criteria for assessing the effectiveness of modernisation measures of environmental, socio-economic, and managerial orientation aimed at intensifying the process of decarbonisation of agricultural production in different regions. Along with this, J. Clapp & S. Ruder (2020) pointed out the environmental orientation of organic agriculture, substantiated the need to implement decarbonisation technologies, and identified priority vectors of adaptation of the industry in the context of global climate change. Continuing this topic, the study by K. Henryson *et al.* (2019) emphasised the difficulties of implementing innovative agricultural technologies in a crisis economic environment.

Despite the considerable scientific efforts of researchers in this area, the issues of developing programmes to effectively stimulate the modernisation of the agricultural sector in Kyrgyzstan remain fragmented, including the effective management of the strategic development of the sector using the capabilities of economic and legal instruments. Among the ways to solve these problems, the most effective, along with internal and external investment in promising agricultural projects, in particular in the farming sector, implementation of successful international practices, and establishment of mechanisms for financing organic production projects, is the awareness of modern farmers of the need to modernise approaches to agriculture in view of global climate change (Tanchyk *et al.*, 2024).

The agricultural sector in Kyrgyzstan faces the urgent need for modernization and integration of sustainable practices, including precision and organic farming, to remain competitive in the global market amidst climate change challenges. The purpose of the study was to assess the level of awareness of climate change issues in land use practices of local residents in four districts of the Southern Issyk-Kul. The process of achieving this goal involved solving a number of tasks: to investigate the level of awareness of sectoral issues by randomly selected farmers; to identify existing problems and their contribution to a decrease in agricultural productivity, increased vulnerability to environmental changes; to substantiate the need to integrate agricultural consulting into the farm environment to improve the economic efficiency and environmental performance of farming.

▸Materials and methods

The study was conducted between June and October 2020 in four regions in the Southern Issyk-Kul lake: Jeti-Oguz, Aksuu, Tup, and Issyk-Kul districts, which have a combined population of 253,204 inhabitants (The population of the Kyrgyz…, 2020). The proposed plan for data collection and analysis represented the level of farmers' understanding of the problem and its impact on their operations, and identified ways to optimise the situation. To this end, a thematic analysis was carried out, focusing on farmers' perceptions of the economic consequences. The dynamics of certain indicators of agricultural production in the historical context was presented. These data were assimilated with the data from the farmers' survey to identify the dependence of production volumes, its quantitative and qualitative parameters, and, accordingly, economic efficiency, on the level of farmers' awareness of the main aspects of climate change impact. The sample

size was 40 farmers and was limited in this aspect due to COVID-19 restrictions. The sample was represented by representatives of farms in regions of different specialisation and size. Qualitative data from open-ended questions were analysed using thematic analysis. The variance analysis was used to analyse the quantitative data. Statistical sources of information were used, in particular, data from the Agriculture (n.d.) on agricultural production in the region under study, indicators of economic efficiency. In addition, reports by Food and Agriculture Organization (FAO) (2022) and policy documents related to agriculture in Kyrgyzstan and, in particular in the Southern Issyk-Kul, were used (The United Nations…, 2017).

The questionnaire survey of farmers was conducted in four districts of the Eastern Issyk-Kul region in the form of open and closed questions. The questionnaire covered a wide range of information, including household and land ownership characteristics, agricultural production systems, perceptions of land use practices, soil improvement methods and familiarity with modern agricultural technologies (Tables 1 and 2). The questions were as follows: "Is climate change having a significant impact on farmers' livelihoods?", "How do you predict this impact and related changes in the future?", "Do you feel the pressure of pests and diseases increasing?", "Has there been a decrease in income due to climate change over the past two years?", "How aware are you of the benefits of precision farming technologies?". In total, 40 farmers with diverse backgrounds were selected using random sampling techniques. The interviews were conducted in Kyrgyz language, as all respondents were Kyrgyz speakers. At the beginning of each interview, respondents were informed that participation was voluntary. Initially, plan was to collect more data, aiming for a minimum of 20 respondents from each district. However, this became unfeasible due to COVID-19 restrictions in the country. A comprehensive analysis was conducted to address the defined objectives and questions. The results are presented in terms of qualitative and quantitative indicators, including tables, graphs, figures, and descriptive statistics. The statistical package for the social sciences 22 was used to analyse the informative data.

Table 1. Demographic factors of respondents and land distribution in study site

Factor	Classification	n = 40	Distribution
Age	20-40	19	47.5%
	40-65	21	52.5%
Gender	Male	31	77.5%
	Female	9	22.5%
Education	Secondary school	9	22.5%
	College	13	32.5%
	University	18	45%
Profession	State workers	16	40%
	Self-Employers	8	20%
	No extra job	16	40%

Source: summarised and systematised by the authors

Table 2. Land distribution of farmers-respondents in study sites

Land property	Classification	Land distribution for 1 household
Land area ha (mean)	Total land	2.98
	Irrigated land	2.38
	Rainfed land	0.6

Source: summarised and systematised by the authors

All survey participants were informed about how their anonymity is ensured, they were aware of the purpose of the survey, how the data they provided will be used, and the risks involved. The research was conducted in accordance with the rules of the Declaration of Helsinki (1975).

▸ Results

Agricultural products and land management practices. Based on the results, the primary food crops in the study site include wheat (43%), clover and sainfoin (80%), potato (58%), and barley (50%). Sugar beet, corn, and garlic are also grown in this region; however, respondents reported not producing these crops between 2017 and 2019. While bean products are not commonly grown, a few farmers have begun cultivating them due to their popularity in other regions for export, rather than for their role as nutrient-fixing activators or as a source of the healthiest protein for personal consumption (Fig. 1).

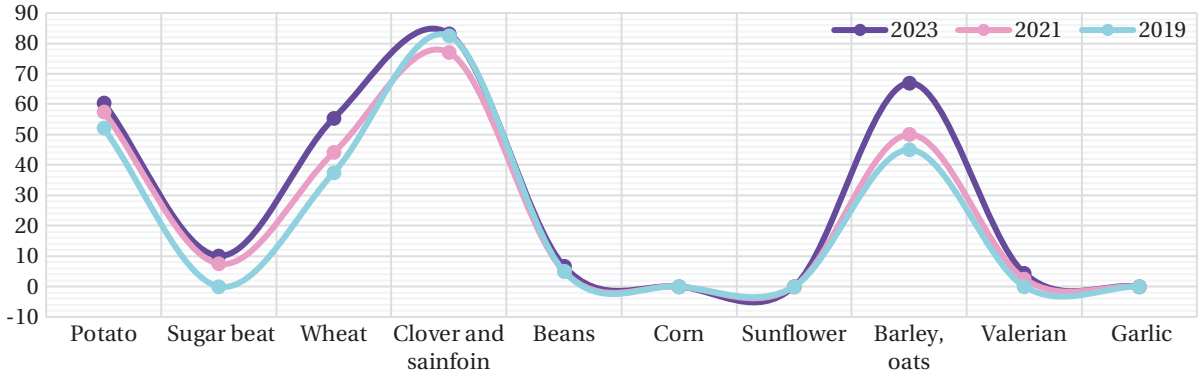

Figure 1. Produced agricultural products between 2018-2023, % of respondents
Source: Agriculture (n.d.)

Various land use practices are employed by farmers on their plots, including crop rotation (72%), the use of organic fertilisers (72%), and the application of mineral fertilisers (potassium, phosphorus, and nitrogen), as well as the use of herbicides and pesticides (25-40%). Upon closer examination of the crop rotation scheme, where the results for three years showed considerable similarity, the reliability of the crop rotation scheme is questionable. However, any significant relationships between independent variables (sex, age, etc.) and plot size in relation to the crop rotation scheme for agricultural products were not identified. Furthermore, 12% of farmers practice mulching to conserve soil moisture and enhance soil fertility. Unfortunately, they do not achieve positive outcomes due to cattle grazing from late autumn to early spring. Notably, all respondents (100%) confirmed this situation, with approximately 63% of them asserting that cattle grazing negatively impacts soil health through trampling.

The next question focused on the challenges they face in farming. The major problems identified were a scarcity of water during the high season (60%), limited access to improved crop varieties (38%), and poor marketing of harvested products (38%). Additionally, 5% of respondents mentioned that they lack sufficient agricultural techniques and rely on observing other farmers' activities (Fig. 2).

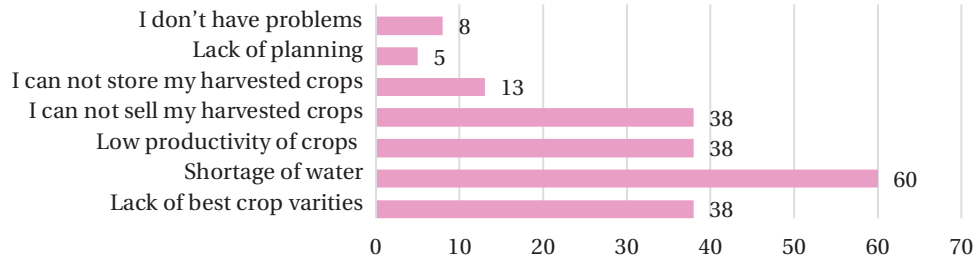

Figure 2. Challenges of farmers in farming, % of respondents
Source: Agriculture (n.d.)

Subsequently, authors inquired about irrigation scheduling in farmlands. As a result, 42% of respondents reported irrigating their land twice per season, while 32% of respondents have access to irrigation water once per year, especially in the Ak-Suu region.

Food security and income from agricultural products. The results show that 78% of respondents sell their agricultural products. Among them, 55% sell their harvest directly to wholesalers from their farms, while 32% of farmers sell at regional markets or even in Bishkek. The primary products for sale include potatoes (averaging 16,000-17,000 kg/ha), wheat (1,800-2,500 kg/ha), and sainfoin or alfalfa (2,000-3,000 kg/ha).

Additional questions were asked regarding their earnings over the three years (net income). Most farmers found this question relatively straightforward yet sensitive; consequently, only 50% of respondents were willing to share their incomes. Interestingly, some farmers who utilise up to seven hectares of land also reported more or less the same income figures (Fig. 3).

The next question was about whether they have additional income at home. Overall, 95% of farmers confirmed that they are involved in livestock farming within their households. Additionally, 40% of the respondents work for the government, and 20% of farmers are engaged in small-scale businesses or provide various private services. Therefore, no farmer solely focuses on farming; almost all farmers are involved in different activities to secure enough income to support their livelihoods.

Furthermore, the study explored the strategies farmers intend to employ to cope with climate change on their farmlands. As a result, 50% of farmers indicated that they need to prioritise the improvement of irrigation facilities and the selection of drought and pest-resistant crops. Approximately 43% of respondents recognised the significance of soil health and fertility as key concerns in a

changing climate. Some farmers (18%) mentioned their intention to focus on livestock management, while 3% of respondents expressed a potential inclination to discontinue farming in the near future (Fig. 4).

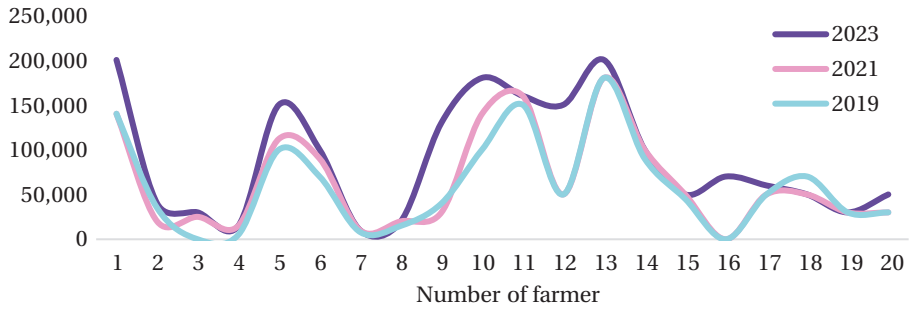

Figure 3. Income of farmers from agricultural products in between 2019-2023, soms
Source: Agriculture (n.d.)

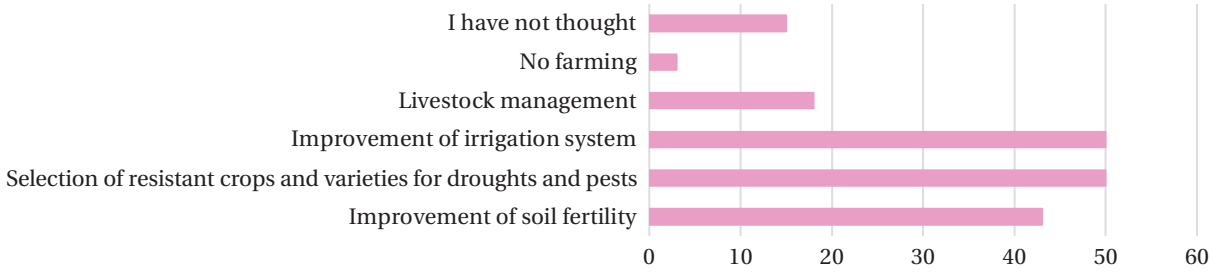

Figure 4. Future plans of farmers in their farmlands towards climate change, % of respondents
Source: Agriculture (n.d.)

Evidently, the economic implications of climate change for agriculture in the Southern Issyk-Kul are representative of global trends in this area. Reduced precipitation and uneven distribution caused by climate change could potentially lead to a shortage of water for irrigation. The level of grain production is significantly reduced. Climate change is shifting the dynamics of the traditional production structure and agricultural technologies. The soils of the Southern Issyk-Kul are facing a potentially dangerous situation, as drought conditions are leading to an increase in the risk of soil degradation.

Farmers' adaptation strategies to these changes demonstrate the effectiveness of crop rotation. Crop rotation is seen as appropriate in the context of livestock development, which involves sowing fodder crops that are less draining on soils (Tykhonova *et al.*, 2021). Thus, support for the livestock sector, including at the state level, is currently needed. Another problem is the lack of effective monitoring and control of soil conditions. Currently, a number of farmers emphasise the importance of using modern irrigation technologies, which is the main available means of adapting to aridity due to climate change on a global scale, ensuring that yields are maintained and, consequently, producer incomes increase (Miroshkina & Borko, 2023). A separate problem is financing the modernisation or construction of irrigation systems, as the expansion of irrigated areas costs an agricultural producer about USD 2.6 thousand per hectare (Kyrgyzstan country profile, 2021). The difficulty of predicting the factors of climate change impact on the factor intensity of agriculture, its profitability, and economic efficiency is caused by the low level of implementation of scientific and practical developments on adaptation of the economy to global environmental dynamics, despite Kyrgyzstan's active integration into the global economic system. The amount of expected losses will vary depending on the ability of modern farmers to effectively adapt their farming to climate change. In this regard, the primary focus should be on diversifying agricultural production, applying energy-saving technologies, and adjusting crop production processes.

The distinctive feature of modern technologies in agricultural production is a precise scientific approach to active influence on crops and soil parameters through the integration of precision land management and organic production systems. This approach ensures high productivity and yields of farmland. The implementation of precision farming technologies in the agricultural sector of Kyrgyzstan to increase the level of resilience to destruction should include the development of a system of monitoring, control, data collection and analytics, an effective management paradigm based on innovative solutions, including the creation of electronic field maps.

Accessibility of information, knowledge management and financial facilities. According to the survey, 95% of farmers have internet connections, while 5% regularly follow television and radio channels. Therefore, all farmers have access to information, but not necessarily to proper agricultural knowledge, as some farmers have mentioned. Furthermore, also was investigated the respondents' participation in educational activities related to farming, livestock, horticulture, and milk production. About 58% of farmers mentioned that they have

participated in various workshops organised by the District Agricultural Development Department in collaboration with non-governmental organisations such as "Agrolead", "Rural Advisory Services", or other initiatives. Additionally, open-ended questions were used to determine whether farmers utilise credit facilities for agricultural development. In general, 48% of respondents take advantage of these opportunities.

However, many farmers noted that these credits are not always accessible to everyone and often depend on decision-makers at the Local Self Government level (Ayil-Okmotu). The leading credit organisations mentioned were Ayil-Bank (6-10%), the Kumtor credit system (up to 50,000 soms only – 7%), and other institutions like "Cash and Savings Company" bank and Bakai-Bank with similar loan rates. Moreover, the authors inquired about the respondents' willingness to enhance their practical knowledge. As a result, the primary interest lies in acquiring knowledge about advanced agricultural technologies such as greenhouses, value chain systems, or organic farming (68%). This was followed by livestock management, with a particular focus on the best breeds and veterinary services (33%). Other areas of interest include the selection of drought-resistant crops and varieties, pest management, and addressing other external factors (23%). Soil fertility (15%) and advanced horticultural techniques (10%) are listed among as important fields to learn (Fig. 5). Further, the final question pertained to the necessary facilities for farmers in general. Consequently, 43% of farmers indicated that local farmers need a continuous knowledge-sharing mechanism (resource centre), 33% suggested the availability of agronomists and veterinary technicians at the LSG level, who can guide farmers in monitoring, evaluation, and planning. Meanwhile, 28% of respondents mentioned the need for the organisation of agricultural logistics centres.

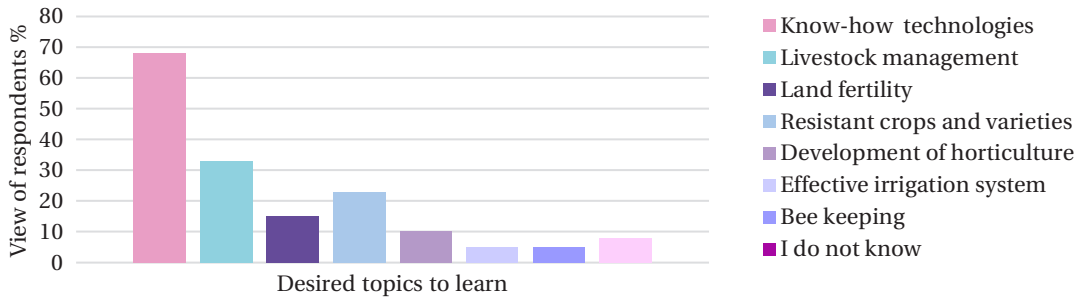

Figure 5. Willingness of farmers to learn

Source: Agriculture (n.d.)

It is obvious that climate change affects the sustainability of agroecosystems, which is especially noticeable in the transformation of conventional crop production to organic. The best preventive way to minimise the destructive ploughing of land affected by farming activities is currently seen as a buffering approach – the creation of field protection strips to regenerate areas and protect biodiversity (Lacoste *et al.*, 2022). Another necessary technological measure within the concept of precision farming is the use of special crop rotations. Irrigated land should be based on crop rotation with plant species that are able to guarantee preventive fertility protection (Clapp, 2021). Effective implementation of the adaptation policy requires a number of managerial, financial, and technological measures, including those at the national level. These include providing agricultural producers with access to innovative opportunities in the areas of organic farming, farming technologies, certification and quality standards, grants, investments and partnerships, international programmes, and consultancy. A modern communication strategy to raise awareness among farmers requires the integration of an agricultural consulting system, stimulation of scientific and practical research and implementation of innovations in the field of organic farming (Gras & Cáceres, 2020; Aldieri *et al.*, 2021).

The basic concept of the modern approach to the development, implementation and improvement of the strategy of innovative development of farms in the context of climate change adaptation covers several key areas of activity. Firstly, the technological and technical direction involves monitoring, accumulation, processing, and control of informative data and diverse information on the state of the environment, productivity of farming methods, economic efficiency of agricultural activities, and effectiveness of the introduction of new technologies, technical means, and crop rotation principles. Secondly, the scientific and legislative aspect includes clarification of the legal and regulatory framework for farming, exploration of investment opportunities, use of grants and international support, modelling and forecasting of potential legislative changes, and research of successful foreign practices. Ultimately, the human resource aspect focuses on the use and development of regional farming potential, motivation to farm, incentives from local authorities, and agricultural advice.

Discussion

The findings of the study indicate that farmers have knowledge about the existing challenges related to climate change, including adaptation in land-use practices and the factors contributing to land degradation. The results highlight that the most significant concern for farmers is the shortage of water. Kyrgyzstan plays a crucial role as a major water supplier for the region. Moreover, water management presents a challenge for agricultural development because water supply often does not align with seasonal needs, primarily due to organisational and management issues. Access to quality seeds for agricultural

products is another major issue. Farmers frequently persist in using seeds long after their productivity has diminished (Shahini *et al.*, 2023).

The absence of a crop rotation scheme is a major contributor to land degradation on farms (Mero *et al.*, 2023). Crop rotation is a fundamental agricultural strategy that enhances nutrient availability, controls pest cycles, improves soil composition, and helps combat biodiversity loss. Recent research suggests that crop rotation schemes can optimise energy use efficiency, preserve or enhance fertility, reduce chemical use, and decrease greenhouse gas emissions (Khakbazan *et al.*, 2019; Liang *et al.*, 2019; MacLaren *et al.*, 2021). According to Crop rotation and its importance in improving soil fertility and protecting soils from erosion (2018), Kyrgyz farmers increased crop yields by up to 20% by implementing crop rotation schemes in their farmlands within pilot projects. Organic mulching has been a long-standing practice in various regions of Kyrgyzstan. However, other mulching systems (like compost, rubber, plastic, or gravel) are rarely used. In selected site, only organic mulching is practiced, but it has become less effective due to livestock overgrazing during the off-season (Steinke *et al.*, 2020; Volanti *et al.*, 2021).

The findings of contemporary researchers (Yin *et al.*, 2022) synergise with the results of this study. In particular, they have highlighted a significant issue: there is a lack of a mechanism for sharing agricultural knowledge among farmers, and they struggle to identify where and from whom to learn. The training of farmers in crop and livestock management primarily falls under the responsibility of the District Agricultural Development Departments within this ministry. These departments organise seminars on agricultural development, covering crop production and livestock breeding, at the beginning of each agricultural season in Local Self-Governments. These seminars feature information provided by specialists from these departments and the Plant Quarantine and Veterinary Control from the Veterinary Services Department. The topics are chosen based on the interests and requests of farmers, though the extent of these activities depends on the ministry's financial resources. Agrolead and FAO (2022) report that 95% of extension services to farmers are carried out by international donors and projects.

According to D. Rose *et al.* (2021), Local Self-Government is responsible for connecting farmers with District Agricultural Development Departments through village leaders. However, this mechanism does not always effectively inform farmers about upcoming seminars or workshops, as reported by many farmers. Therefore, there is a pressing need to establish agricultural centres at the Local Self-Government offices across the country. These centres would provide all farmers with the skills necessary for farming, efficient water resource management, income generation, and adaptability to climate dynamics. For example, an agroforestry training centre was established in 2021 in Kara-Bak Local Self-Government in Batken region, in collaboration with the local non-governmental organisation "Agents of Changes". This centre serves as an educational hub and resource centre for all farmers. Alternatively, appointing an agronomist at the Local Self-Government level, who can take on the responsibility of imparting advanced agricultural knowledge to farmers and providing day-to-day support to those in need, would also be a viable solution.

According to L. Rocchi *et al.* (2020), strategic planning of innovative and technological development of agricultural enterprises is positioned as a priority strategic area of modern management systems of agro-ecological landscape complexes and increase of economic efficiency of agricultural activities. This approach, according to researchers, would allow for effective and rapid adaptation to new competitiveness requirements, including the transformation of agricultural activities in accordance with global market dynamics, product quality requirements and environmental guarantees.

In the process of implementing the research by A. Raihan *et al.* (2022), it was emphasised that the innovative modernisation of farming activities in actively developing countries should be based on the gradual replacement of extensive methods of land cultivation with intensive methods, which is in line with the principles of sustainable agricultural development. The researchers have identified the effectiveness of integrating successful practices of international experience, investment and grant funds for the development of organic farming and precision land use systems. It is worth agreeing with the researchers on the expediency of these measures in the context of optimising agricultural activities at a low level of overall socio-economic development and identifying adaptive reserves.

The economic impacts of climate change on agriculture were analysed by F. Caffaro *et al.* (2020) in the context of the specifics of Italy as a representative country of the modern world community, which is open to innovations in agriculture, but expects practical economic results from them. Italy's experience shows similar results to the findings of the current study, indicating the need to raise farmers' awareness, including through agricultural professional advice, of the possibilities of adapting farm production to global climate change.

Based on the findings of F. Farrokhi & H. Pellegrina (2023), it was found that the main approaches to the process of forming competitive market advantages in farming activities under conditions of drought and disruption of precipitation and hydrology due to destructive changes in climate factors. According to the researchers, they are based on the principles of rationalisation and diversification. The researchers assure that the synergy of managerial and technological innovation measures, the introduction of monitoring and control systems can minimise the negative impact on natural resources, while increasing the quality and quantity of farm production, its profitability and economic efficiency.

According to X. Yang *et al.* (2021), the paradigm of agricultural production modernisation to ensure innovative strategic development of the industry is to ensure the sustainability of farming activities in the concept of maintaining a stable and fair income for producers, increasing their competitiveness; climate-oriented adaptive agriculture, mitigating the effects of climate change. This strategy requires, in turn, the modernisation of farming based on digitalisation, consulting and the active exchange of practical knowledge and skills. The results of scientific research are convergent with the conclusions of the current study on

the direct dependence of the economic efficiency of agricultural production on the level of its adaptability to global environmental dynamics – primarily climate change.

As stated by S. Ruzzante *et al.* (2021), the purpose of a promising study in this area is the development and integration of innovative monitoring capabilities. It is considered today as the basis for the production of analytical information on the search for resources to increase competitiveness, investment in agriculture based on regeneration and sustainable land use.

Conclusions

The assessment of local people's understanding of land use practices in four districts of the Southern Issyk-Kul, in synergy with the analysis of economic aspects, represents the level of farmers' awareness of the problem and its impact on agricultural activities, and identifies ways to optimise the situation. When asked how farmers intend to combat climate change on their farmland, 50% of farmers said they need to prioritise improving irrigation facilities and selecting crops that are resistant to drought and pests. Approximately 43% of respondents recognised the importance of soil health and fertility as key concerns in the face of climate change, with some farmers (18%) indicating that they intend to focus on livestock management, while 3% of respondents expressed a potential inclination to stop farming in the near future.

The main interest of farmers, according to the survey, is to gain knowledge about advanced agricultural technologies, such as greenhouses, value chain systems or organic farming (68%). This is followed by livestock management, with a particular focus on the best breeds and veterinary services (33%). Other areas of interest include breeding drought-resistant crops and varieties, pest management and other external factors (23%). Soil fertility (15%) and advanced horticultural technologies (10%) were cited as important areas for study. In addition, the survey covered the issue of necessary equipment for farmers in general. Thus, 43% of survey participants indicated that local farmers need a mechanism for continuous knowledge exchange (resource centre), 33% suggested the availability of agronomists and veterinary technicians at the local government level who can help farmers with monitoring, evaluation and planning. 28% of respondents noted the need for agricultural logistics centres.

In general, the adaptation of the agricultural sector development process in the Southern Issyk-Kul to climate change is based on ensuring the sustainability of farming activities, climate-oriented adaptive technologies, and active modernisation, development of agricultural advisory services, digitalisation of the industry, and improved access to research and innovation. Prospects for further scientific development of the studied issues are seen in the development of adaptive agricultural modelling programmes and practical consulting for farmers, which will raise awareness of innovations, environmental sustainability and financial instruments to prevent losses in the industry.

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Conflict of interest

The authors of this study declare no conflict of interest.

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Адаптація фермерів до зміни клімату на Південному Іссик-Кулі

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▸ **Анотація.** Сільське господарство є ключовим сектором для забезпечення засобів до існування людей у Киргизстані, що підкреслює роль сприйняття місцевим населенням сільськогосподарських практик та оптимізації управління землекористуванням. Метою цього дослідження було оцінити розуміння практик землекористування місцевими жителями в чотирьох районах Південного Іссик-Кулю. Рівень обізнаності з галузевими питаннями досліджувався за допомогою випадково обраних фермерів. Дослідження показало, що сучасні фермери усвідомлюють існуючі проблеми та їхній внесок у зниження продуктивності сільського господарства та підвищення вразливості до змін навколишнього середовища. Узагальнено, що вирішення досліджуваної проблеми потребує практичної взаємодії між державними органами та фермерами, спрямованої на надання необхідної інформації та ресурсів для адаптації до кліматоорієнтованих сільськогосподарських практик. Проаналізовано потенціал інноваційних технологій точного землеробства в контексті досліджуваної проблематики. Виявлено важливу проблему відсутності механізму обміну сільськогосподарськими знаннями між фермерами, оскільки їм складно визначити, де і від кого отримати досвід. Обґрунтовано, що інтеграція елементів сільськогосподарського дорадництва в середовище функціонування фермерських господарств має потенціал для суттєвого стимулювання позитивної динаміки розвитку сільського господарства. Такий підхід дозволить найбільш точно підібрати оптимізаційні заходи, які впливатимуть на економічну ефективність та екологічну результативність ведення сільського господарства. Практична цінність результатів дослідження полягає у можливості їх використання для пом'якшення процесу адаптації сільськогосподарського виробництва в країнах, що розвиваються, до неминучих змін клімату

▸ **Ключові слова:** ґрунт; практики землекористування; сприйняття; точне землеробство; сільськогосподарське консультування

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Global value chains and their impact on Ukraine's agro-industrial complex

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► **Abstract.** In the contemporary global economic environment, integration into global value chains is a crucial factor for a country's economic growth. The aim of this research was to determine the impact of Ukraine's participation in global value chains on the country's agro-industrial complex. The study employed statistical analysis, regression analysis, econometric modelling, correlation analysis, and analysis of indices of a country's participation and position in global value chains. It was established that during 2010-2011, the Ukrainian economy demonstrated high growth rates of gross domestic product and exports due to the growth of foreign value-added. Starting in 2012, growth rates began to decline due to economic crises, political instability, and the war that began in 2014. The COVID-19 pandemic also had a negative impact on the economic situation in 2020. Despite the full-scale war in 2022, a slow economic recovery was observed in 2023, driven by an increase in foreign gross value-added in exports. Regression analysis showed a strong correlation between Ukraine's gross domestic product and indicators of foreign investment in exports and total exports. It was found that an increase in foreign gross value-added in exports has a negative impact on gross domestic product, while an increase in total exports has a positive impact on economic growth. Despite the complexity of the global value chain system, the results indicate Ukraine's potential for further integration into global economic processes. It has been found that the agricultural sector is also

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affected by fluctuations in foreign gross value-added, which is reflected in the productivity and export capabilities of the agricultural sector. An analysis of the participation of key industries, including the agro-industrial complex, in $GVC_{participation}$ has shown a trend towards a decrease in the share of foreign value-added in the gross export of industrial products, indicating an increase in domestic value-added. The research results can be used to develop an effective strategy for Ukraine's economic development by optimising participation in global value chains and reducing dependence on foreign value-added in exports

Keywords: exports; economic growth; regression analysis; country position index; gross exports; volatility

Introduction

The contemporary economic landscape is characterised by the growth of global value chains, which integrate various sectors of the economy, including agriculture, into a unified international production chain. Global Value Chains (GVCs) are intricate networks of companies that collaborate to produce and deliver goods and services on the global market. For the agro-industrial complex, this signifies that every aspect of agricultural production, from sowing to market delivery, can be significantly reliant on international markets, technologies, and standards (Wang *et al.*, 2020; Cigna *et al.*, 2022).

Research conducted by scientists to study the impact of global value chains on the agro-industrial complex reflects a wide range of approaches and methods that enable strategic decision-making. As Z. Mao (2022) points out, one of the crucial aspects of global value chains is international competition. Participation in such chains requires agro-industrial businesses to not only ensure high-quality products but also continuously improve efficiency and reduce costs to maintain competitiveness in the international market.

Many countries rely on imports of certain agricultural products, such as grains, oils, or meat. Changes in global value chains, such as trade restrictions or tariff modifications, can significantly impact product prices and availability, thus threatening food security in these nations (Demi *et al.*, 2021). J. Barbero & E. Rodríguez-Crespo (2020) argue that participation in global value chains compels businesses to seek new technologies and production methods, which can improve efficiency, enhance product quality, and reduce costs. This involves the implementation of modern irrigation systems, the use of advanced soil cultivation techniques, and the improvement of genetic resources for agricultural crops.

Global value chains in the agro-industrial complex play a pivotal role in the production and supply of agricultural products to consumers (Shahini *et al.*, 2023). However, as noted by M. Keping *et al.* (2022), price fluctuations are a significant factor within GVCs. Global value chains often lead to substantial price fluctuations in agricultural products due to changes in demand, yields, or trade agreements. This can create instability for farmers and agribusinesses, who must adapt to such changes to maintain profitability. Moreover, G. Ellison *et al.* (2010) argue that participation in GVCs typically requires compliance with international quality standards, which is crucial for accessing international markets and maintaining consumer trust in products.

Researchers highlight that Ukraine possesses significant potential for developing its agro-industrial complex, which can be integrated into global value chains. Specifically, M. Mykhailova *et al.* (2024) assert that Ukraine actively competes in international markets with other countries that are also major exporters of agricultural products. GVCs determine the conditions of access to these markets and influence the competitiveness of Ukrainian products. N. Kutsmus *et al.* (2024) emphasise that participation in GVCs enables the Ukrainian agro-industrial complex to attract investments, implement modern technologies, and enhance economic efficiency.

Several researchers, including M. Chepeliev *et al.* (2022), O. Krpec & V. Hodulak (2019), argue that Ukrainian agricultural enterprises are actively adopting modern agricultural technologies and production methods, enabling them to increase yields and product quality. However, this requires access to modern technologies, which are typically supplied through global value chains. Additionally, Ukrainian farmers often face significant instability in agricultural product prices, creating substantial economic risks for agribusinesses (Musayeva *et al.*, 2024). Therefore, it is necessary to understand the impact of GVCs on Ukraine's agro-industrial complex and develop effective strategies to improve its competitiveness in the global market.

Despite the significant amount of research on the impact of GVCs on various economic sectors, there are research gaps related to diversification, import dependency, lack of competitiveness, vulnerability to price fluctuations, limited access to international standards, insufficient investment in technology, and limited cooperation with international organisations. Filling these gaps is urgent as global value chains play a key role in the production and supply of agricultural products from Ukraine.

This research aimed to assess the impact of Ukraine's integration into global value chains on the country's economic development and identify ways to enhance the competitiveness of the national economy. To achieve this goal, the following analyses were conducted: an evaluation of the current state of Ukraine's agricultural sector and its competitiveness in the global market, the identification of promising directions for Ukraine's integration into global value chains, and an assessment of the impact of this integration on Ukraine's economic development.

Materials and methods

To analyse Ukraine's participation in GVCs, data sources providing information on trade, economic growth, and the competitiveness of the national economy were used, including data from the Key indicators of socio-economic development of Ukraine (n.d.). Additionally, data from the World Bank supports Ukraine to maintain economic stability (2024) and the Organisation for Economic Co-operation and Development (OECD) (2024) were utilised.

Statistical data from 2010-2023, including the growth rate of Gross Domestic Product (GDP), exports, and the

foreign gross value-added content in Ukraine's exports, indicators of Ukraine's economic growth and its participation in GVCs, as well as the share of foreign value-added in the gross exports of Ukrainian industrial products, formed the information component of the study. The period 2010-2023 was chosen for the study for four key reasons: the recovery of the global economy and Ukraine after the 2008 financial crisis, political changes in Ukraine, and trade liberalisation through membership in the World Trade Organization. The study used indicators of a country's GVCs participation index and a country's GVCs status index. The country's participation index in GVCs ($GVC_{participation}$) was calculated using formula (1):

$$GVC_{participation} = \frac{IV}{E} + \frac{FV}{E}, \quad (1)$$

where IV – a value-added domestically that is not directly linked to exports; FV – a value-added from abroad that is linked to exports; E – a total export of the country.

The formula for calculating the country's GVCs status index is as follows (2):

$$GVC_{Position} = \ln\left(1 + \frac{IV}{E}\right) + \ln\left(1 + \frac{FV}{E}\right). \quad (2)$$

Based on the results of contemporary research, a functional dependency (3) was used to model the impact of a country's GVCs participation index on economic growth:

$$Y = f(GVC_{participation}; GVC_{position}), \quad (3)$$

where Y – the economic growth of the country.

To conduct a regression analysis based on the functional relationship, an econometric equation was formulated, with the calculation of the Fisher criterion, in which α is a constant term, β_i is the coefficients to be estimated, and ε_t is the error term (4):

$$Y_t = \alpha + \beta 1 * FVA_{export} + \beta 2 * Export + \\ + \beta 3 * GVC_{participation} + \beta 4 * GVC_{position} + \varepsilon_t, \quad (4)$$

where Y_t – a vector of dependent variables, particularly Ukraine's GDP volume figures, GDP per capita, and the index of annual changes in Ukraine's GDP; FVA_{export} – a foreign value-added content in exports; Export – a gross export.

To further investigate the impact of involving major manufacturing industries in GVCs on economic growth, a functional dependency (5) was tested:

$$Y_t = \alpha + \beta i * \left(\frac{FV}{E}\right)_n + \varepsilon_t, \quad (5)$$

where $(FV/E)_n$ – a vector of indicators of the share of foreign value-added embodied in imported resources within gross exports, by industrial sector.

Thus, the research methodology is based on theoretical foundations and empirical evidence of the impact of countries' GVCs participation on economic growth. To determine the relationship between the participation of state-owned enterprises in GVCs and a country's economic growth, the study employed statistical correlation analysis, which involves constructing a regression model of GDP indicators against changes in indicators of forward, backwards, and total GVCs participation, the country's GVCs position, and the content of imported value-added in exports of major industrial sectors.

Results

Ukraine experienced significant fluctuations in economic growth between 2010 and 2023. In the period from 2010 to 2011, Ukraine's economy demonstrated exceptionally high GDP growth rates of 118% and 120%, respectively. This was driven by rapid growth in foreign value-added in exports, which increased by 122% and 138%, respectively. Additionally, gross exports also showed high growth rates, reaching 120% and 122%, respectively (Simakhova, 2022). However, in 2012, the growth rates of GDP and gross exports began to decline, which was linked to the economic crisis. In 2014, the growth rates of GDP and gross exports reached a minimum, reaching 70% and 90%, respectively. In 2016, the Ukrainian economy began to show signs of recovery, which was associated with the growth of foreign value-added in exports. And already in 2017, the growth rates of GDP and gross exports reached high values again, reaching 120% and 118%, respectively.

Nevertheless, in 2020, the Ukrainian economy again faced crisis phenomena due to the COVID-19 pandemic. The growth rates of GDP and gross exports began to decline, reaching 101% and 100%, respectively. In 2022, a full-scale war began in Ukraine, causing the growth rates of GDP and gross exports to reach a minimum again, reaching 70% and 75%, respectively. However, in 2023, there is a slow recovery of the Ukrainian economy, which is associated with the growth of foreign value-added in exports (OECD, 2024). The growth rates of GDP and gross exports are 91% and 80%, respectively. The analysis of the dynamics of Ukraine's GDP and gross exports revealed that they demonstrate synchronised fluctuations, which indicates a close link between economic growth and the country's exports (Fig. 1).

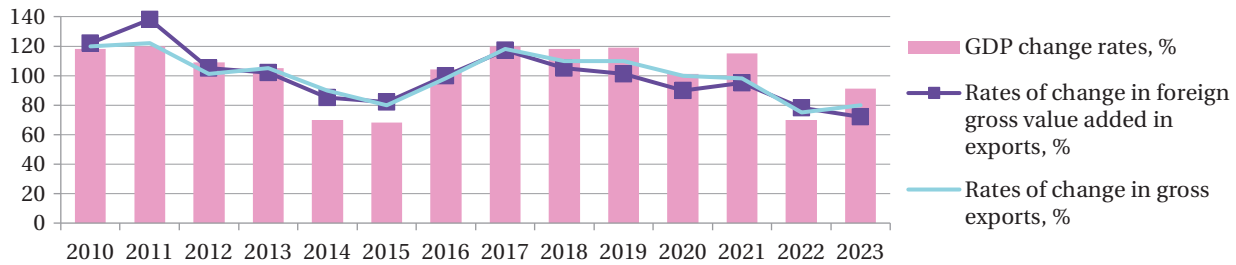

Figure 1. Growth rates of GDP, exports, and the share of foreign value-added in Ukraine's exports in 2010-2023, as a percentage compared to the previous year

Source: compiled by the authors

It is worth noting that in 2013 and 2023, years marked by the exacerbation of the economic crisis, foreign value-added to Ukraine's exports was more sensitive to the economic crisis than GDP and gross exports. In 2013, Ukraine's GDP and gross exports decreased by 0.05% and 0.05%, respectively, while foreign value-added in exports decreased by 0.02%. This suggests that foreign value-added in exports was more volatile and sensitive to the economic crisis. In 2023, the situation repeated itself. Ukraine's GDP and gross exports decreased by 0.09% and 0.2%, respectively, while foreign value-added in exports decreased by 0.28%. This again suggests that foreign value-added in exports was more volatile and sensitive to the economic crisis. These findings may indicate that foreign value-added in exports is more volatile and sensitive to economic crises than GDP and gross exports. This is because foreign value-added in exports depends on many factors, such as global economic trends, political risks, changes in world trade, and others. To identify the impact of Ukraine's participation in GVCs on economic growth, a correlation regression analysis was conducted, where the dependent variable was represented by the following indicators: GDP index, GDP, and GDP per capita (Table 1).

Table 1. Indicators of economic growth in Ukraine

Year	GDP, billion USD	GDP per capita, USD	GDP index, % compared to the previous year
2010	141.2	3,078.4	104.1
2011	169.3	3,704.8	105.4
2012	182.6	4,004.8	100.2
2013	190.5	4,187.7	100
2014	133.5	3,104.7	89.9
2015	91	2,124.7	90.2
2016	93.4	2,187.7	102.4
2017	112.1	2,638.3	102.4
2018	130.9	3,096.6	103.5
2019	153.9	3,661.5	103.2
2020	156.6	3,751.7	96.2
2021	164.3	3,932	104.9
2022	130	3,111.2	79.1
2023	135	3,245.6	103.8

Source: Key indicators of socio-economic development of Ukraine (n.d.)

As independent variables, the coefficients of the country's GVCs participation, as well as indicators of Ukraine's exports and the content of foreign value-added in exports, were used (Table 2). The analysis of the results showed that Ukraine integrated into the global economy during 2010-2012, as evidenced by the increase in the content of foreign value-added in exports. However, the political and economic instability that began in 2013, including the war in eastern Ukraine and the annexation of Crimea, led to a decrease in these indicators. Gross exports increased until 2013, after which they experienced a significant decline until 2015. From 2016, exports began to recover gradually, reaching a peak in 2019. In 2020, due to the pandemic and economic difficulties, there was a decline, but forecast data for 2021-2023 indicates a gradual recovery of exports. The backward and forward GVCs participation coefficients remained relatively stable, despite economic challenges. The backward participation coefficient fluctuated between 22.9% and 28.6%, while the forward participation coefficient varied from 19.8% to 22.9%. The overall GVCs participation index ranged from 44.3% to 49.8%, with the highest value in 2018. The country's GVCs position also fluctuated, but forecast data for 2021-2023 indicates an improvement in these indicators. Thus, the overall indicators of Ukraine's GVCs participation demonstrate the impact of political and economic instability on the country's economy, but there are signs of recovery and improvement in recent years. These data indicate Ukraine's potential for further integration into global economic processes, which can serve as a basis for developing strategies to increase its GVCs participation. The results of assessing Ukraine's GVCs position have shown at which stages of production (initial or final) the Ukrainian economy specialises. During 2011-2016, the Ukrainian economy specialised in the final stages of production, as the backward participation coefficient had a high value, indicating significant volumes of imported intermediate goods, and the country's GVCs position index had a negative value, which increased from -0.152 in 2010 to -0.321 in 2016 (Revak & Kondro, 2020). Starting from 2017, Ukraine's GVCs position index has shown a tendency to decrease, reaching -0.12 in 2023, although it remains negative. The position index in global supply chains also illustrates the impact of production fragmentation on Ukraine's trade. Over the period under review, there has been a decrease in the negative position, indicating an increase in imports of raw materials and semi-finished products, accompanied by an increase in exports of finished goods.

Table 2. Indicators of Ukraine's GVCs participation

Year	The content of foreign gross value-added in Ukraine's exports, million USD	Gross exports, million USD	Backward participation coefficient, %	Forward participation coefficient, %	Total GVCs participation indicator	The country's GVCs position
2010	10,703.6	43,433.5	24.6	21	45.6	-0.152

Table 2, Continued

Year	The content of foreign gross value-added in Ukraine's exports, million USD	Gross exports, million USD	Backward participation coefficient, %	Forward participation coefficient, %	Total GVCs participation indicator	The country's GVCs position
2011	14,690.3	54,314.5	27	21.9	48.9	-0.201
2012	17,084.2	59,719.6	28.6	19.8	48.4	-0.353
2013	15,936.8	60,044.8	26.5	20.3	46.8	-0.255
2014	14,023.2	51,808	27.1	22	49.1	-0.2
2015	11,369.2	39,988.7	28.4	20.1	48.5	-0.332
2016	10,709	38,527.2	27.8	19.9	47.7	-0.321
2017	12,567.4	45,051.5	27.9	21.4	49.3	-0.255
2018	13,329.2	49,611.7	26.9	22.9	49.8	-0.155
2019	13,497.9	53,832.4	25.1	22.1	47.2	-0.122
2020	11,936.8	52,091.3	22.9	21.4	44.3	-0.065
2021	12,500	55,000	22.7	21	43.7	-0.1
2022	11,000	45,000	24.4	20.5	44.9	-0.15
2023	11,500	47,500	24.2	21	45.2	-0.12

Source: Key indicators of socio-economic development of Ukraine (n.d.)

To conduct the regression analysis, natural logarithms of the data presented in Tables 1 and 2 were calculated. The results of the analysis revealed a strong correlation between Ukraine's GDP and indicators of foreign investment in exports and total exports of Ukraine, as confirmed by the high correlation coefficient (Table 3). According to the analysis results, a 1% increase in foreign investment in exports leads to a 1.453% decrease in GDP, assuming other conditions remain constant. This could be due to the replacement of domestic production with foreign investments. On the other hand, a 1% increase in total exports leads to a 2.59% increase in GDP, assuming other conditions remain equal, which is associated with an increase in production and value-added in Ukraine. The coefficient of determination shows that 84.9% of the variations in Ukraine's GDP are explained by changes in foreign investment in exports and total exports, while 15.1% are attributed to other factors not included in the regression model. The results of the calculation of Fisher's criterion show a statistically significant relationship between the variables, and the statistical error of the regression is insignificant (less than 1%), confirming the reliability of the results. However, the analysis did not reveal a statistically significant relationship between Ukraine's GDP and indicators of Ukraine's participation in global value chains. This could be due to the fact that the global value chain is a complex phenomenon that depends on many factors, and its impact on Ukraine's GDP may not be as direct.

Table 3. Dependence of economic growth on Ukraine's GVCs participation

Features	Dependent variable	
	GDP	GDP per capita
Number of observations	16	16
Constant	-9.259*** (1.698)	11.236*** (2.212)
FVA_{export}	-1.452*** (0.404)	1.214*** (0.13)
Export	2.590*** (0.468)	-
$GVC_{participation}$	-	-3.797*** (0.732)
R	0.921	0.933
R^2	0.849	0.871
F-test	F(2.13)=36.72	F(2.13)=43.93

Note: * – error with a probability of 10%; ** – error with a probability of 5%; *** – error with a probability of 1%; R (correlation coefficient) – indicates the level of linear dependence between the dependent variable and independent variables; R2 (coefficient of determination) – indicates the level of dependent variable by the independent variables; F (F-test) – indicates the level of significance of the regression model
Source: compiled by the authors

The regression analysis revealed a strong connection between GDP per capita and Ukraine's participation in the global value chain. Specifically, a 1% increase in the share of foreign value-added in exports leads to a 1.214% increase in GDP per capita, while a 1% increase in the overall participation coefficient in the global value chain results in a 3.797% decrease in GDP per capita. The coefficient of determination indicates that 87.1% of the variations in GDP per capita can be explained by the dynamics of the share of foreign value-added in exports and the coefficient of Ukraine's overall participation in global value chains. The results of the Fisher test confirm a statistically significant relationship between these variables. However, no statistically significant relationship was found between GDP per capita and the coefficients of Ukraine's forward and overall participation in global value chains, nor with the indicator of Ukraine's gross exports (World Bank supports…, 2024).

The results of the regression analysis indicate the need for further research into the impact of involving major industrial sectors in GVCs on Ukraine's economic growth. To this end, a regression analysis was conducted to examine the dependence of GDP, GDP per capita, and the GDP index on indicators of the share of foreign value-added in the gross exports of various industrial sectors (Table 4).

Table 4. The share of foreign value-added in gross exports of industrial products of Ukraine, %

Year	Food products, beverages, tobacco	Chemical and pharmaceutical products	Basic metals and finished metal products	Computers, electronic and electrical equipment	Machinery and equipment (non-electrical)	Vehicles
	FVA_{food}	$FVA_{chemicals}$	FVA_{metal}	$FVA_{electric}$	$FVA_{machinery}$	$FVA_{transport}$
2010	1.7	1.5	8.8	0.8	1	0.9
2011	1.7	1.6	10.2	0.9	1.1	1.1
2012	1.5	1.7	10.3	0.8	1.1	1.1
2013	1.1	1	8.8	0.6	0.8	0.6
2014	1.7	0.8	9.6	0.4	0.7	0.3
2015	2.3	0.7	8.3	0.4	0.6	0.2
2016	2.7	0.5	6.9	0.4	0.6	0.2
2017	2.7	0.5	7	0.4	0.5	0.2
2018	2.4	0.5	6.5	0.4	0.4	0.2
2019	2.4	0.4	4.9	0.4	0.4	0.3
2020	2.3	0.4	4.6	0.4	0.4	0.3
2021	2.2	0.4	4.4	0.4	0.4	0.3
2022	2.1	0.4	4.2	0.4	0.4	0.3
2023	2.1	0.4	4	0.4	0.4	0.3

Source: compiled by the authors

An analysis of Ukraine's industrial product exports from 2010 to 2023 revealed a trend of decreasing foreign value-added. In the food products, beverages, and tobacco sector, the share of foreign value-added increased to 2.7% in 2016-2017 but then declined to 2.1% in 2022-2023, indicating a growth in domestic value-added. In the chemicals and pharmaceuticals sector, the share of foreign value-added consistently decreased from 1.5% to 0.4%, suggesting a reduced reliance on imported components. In the basic metals and finished metal products sector, the share of foreign value-added decreased from 8.8% to 4%, which is a result of structural changes in the metallurgy industry and an increase in production with higher domestic value-added. In the computer, electronics, and electrical equipment sector, the share of foreign value-added remained relatively stable, fluctuating between 0.4% and 0.9%. In the machinery and equipment sector, the share of foreign value-added decreased from 1% to 0.4%, indicating a growth in domestic production of necessary components and a decrease in the import component. In the vehicles sector, the share of foreign value-added decreased from 0.9% to 0.3%, which is a sign of decreased reliance on foreign components in the production of transport vehicles or changes in the structure of transport vehicle production in Ukraine.

Overall, the analysis indicates a trend towards a decrease in the share of foreign value-added to Ukraine's gross industrial product exports, which may point to the development of domestic production and reduced dependence on imported components. These changes may be the result of both structural economic reforms and the adaptation of industrial enterprises to new market conditions and requirements. Regression analysis revealed a strong negative correlation between Ukraine's GDP and the share of foreign value-added in exports of food products, beverages, tobacco, basic metals and finished metal products. This means that an increase in the share of foreign value-added in the exports of these products leads to a decrease in Ukraine's GDP. On the other hand, a positive correlation was found between GDP and the share of foreign value-added in exports of vehicles, suggesting that an increase in the share of foreign value-added in the exports of vehicles contributes to GDP growth.

The analysis revealed that the negative impact of foreign value-added in exports of food industry products and metallurgical products on Ukraine's economic growth was greater than the positive impact of foreign value-added in exports of vehicles. Furthermore, it was found that Ukraine's GDP was 85.4% dependent on the import content in exports of food products, metallurgical products, and vehicles. The results of the regression analysis were statistically significant, confirming a strong relationship between the variables. Therefore, the results of the analysis can be used to conclude the relationship between Ukraine's GDP and the share of foreign value-added in exports of various products (Table 5).

Table 5. The impact of industry participation in GVCs on Ukraine's economic growth

Factor features	Dependent variable			
	GDP	GDP per capita		GDP index
Number of observations	11	11	11	11

Table 5, Continued

Factor features	Dependent variable GDP	GDP per capita		GDP index
Constant	6.723*** (0.431)	8.267*** (0.063)	9.775*** (0.548)	4.785*** (0.047)
FVA_{food}	-0.602** (0.209)	-	-0.880*** (0.213)	-
FVA_{metal}	-0.585** (0.173)	-	-0.553** (0.218)	-
$FVA_{transport}$	0.215** (0.079)	0.523*** (0.101)	-	-
$FVA_{machinery}$	-	-0.653*** (0.181)	-	-
$FVA_{chemicals}$	-	-	-	-0.183*** (0.054)
$FVA_{electric}$	-	-	-	0.346*** (0.088)
R	0.924	0.884	0.824	0.815
R^2	0.854	0.781	0.679	0.665
F-test	F(3.7)=13.65	F(2.8)=14.34	F(2.8)=8.49	F(2.8)=7.95

Note: * – error with a probability of 10%; ** – error with a probability of 5%; *** – error with a probability of 1%
Source: compiled by the authors

The research confirmed a statistically significant relationship between Ukraine's GDP per capita and the dynamics of foreign value-added content in the exports of specific industrial sectors. Two models of the dependence of Ukraine's GDP per capita on changes in the share of foreign value-added in the exports of specific industrial sectors were constructed. The first model revealed a positive correlation between GDP per capita and the import component in exports of vehicles, as well as a negative correlation between GDP per capita and the import content in exports of non-electrical machinery. The second model confirmed the presence of a significant inverse relationship between Ukraine's GDP per capita and the dynamics of the share of foreign value-added in exports of food products, beverages, tobacco, basic metals and finished metal products. Additionally, a significant inverse relationship was found between Ukraine's GDP index and the change in the share of foreign value-added in exports of chemical and pharmaceutical products, as well as a positive relationship between Ukraine's GDP index and the change in the share of foreign value-added in exports of computers, electronics, and electrical equipment.

The research confirmed that the impact of Ukraine's participation in global value chains on economic growth is manifested through the dependence of economic growth indicators on the content of foreign value-added in exports. Moreover, the study confirmed the negative role of exports of products with high raw material content on Ukraine's economic growth in 2010-2023 and the advisability of deepening the participation of Ukrainian enterprises producing vehicles, computers, electronics, and electrical equipment in GVCs as one of the ways to accelerate economic growth.

▸ Discussion

Globalisation and technological advancements have led to GVCs, which have revolutionised the production, trade, and consumption of goods and services. In these chains, companies from all over the world collaborate to produce components, assemble finished products, and market, and sell goods on the global market. This allows them to specialise in their strengths, access new markets and resources, and increase their competitiveness (Miroudot & Ye, 2019; Meng *et al.*, 2020). In the modern economy, global value chains play a key role, providing international cooperation and interdependence between countries and companies. They increase production efficiency, reduce costs, and improve product quality by integrating all stages of production, from raw materials to the finished product (Lin *et al.*, 2023; Martínez-Martínez *et al.*, 2023).

GVCs are characterised by a high degree of globalisation, production fragmentation, a growing role of services in production and trade, and an increasing influence of transnational corporations on the global economy. S. Sotelo (2020) notes that global value chains create new opportunities for economic growth, job creation, and exports, but also pose risks such as dependence on global events, environmental risks, and social challenges. Participation in GVCs encourages enterprises to improve product quality, as they must meet international standards and market demands. W. McKibbin & R. Fernando (2021) note that this, in turn, increases the competitiveness of products in global markets. In particular, in countries that are actively integrated into global value chains, exports of high-quality products are growing, which contributes to increased foreign exchange earnings and the development of the national economy.

The conducted research confirms the opinion of N. Fernandes (2020), who emphasises that countries and enterprises that participate in GVCs have greater resilience to global economic fluctuations due to the diversification of their production and trade links. They can more easily adapt to changes in supply and demand in global markets, reducing risks and ensuring the stability of economic development. Further evidence of this and confirmation of the results obtained can be found in the opinion of Y. Fang & Z. Shao (2022), who believe that integration into GVCs contributes to the growth of productivity and economic efficiency of enterprises through access to advanced technologies, innovations, and know-how. For example, agricultural enterprises gain access to new soil cultivation methods, efficient fertilisers, and genetically modified crops that have higher yields and disease resistance (Kalinichenko, 2023). This allows them to reduce production costs and increase output.

The results obtained coincide with the research conducted by A. Abdelaaziz *et al.* (2022), also note that the integration of agricultural enterprises into global value

chains contributes to increased productivity through the implementation of advanced technologies and better access to resources. This is especially important for developing countries, where the modernisation of agricultural production is a key factor in economic growth (Park & Park, 2021). Global value chains are a critical element of modern agriculture. They not only provide opportunities for development and expansion but also create significant challenges that require a comprehensive approach to management and strategic planning by agricultural enterprises and governments (Hu *et al.*, 2021). This view is supported by P. Hellegers (2022), who argues that countries can become dependent on international markets and the economic situation in other countries. Additionally, there may be a need for significant investments to modernise production facilities and upgrade the skills of workers. It is also important to consider environmental risks and the need to comply with sustainable development standards.

The results of the conducted research align with other studies on the impact of GVCs on economic growth. Participation in GVCs can have a varying impact on economic growth, depending on the level of foreign value-added and the type of industry involved. Research conducted by J.M. Silva & S. Tenreyro (2022) showed that GVCs can lead to economic growth but also create risks such as dependence on external markets and the loss of domestic value-added. However, there are studies that, in contrast to the one conducted, demonstrate that participation in GVCs can have negative consequences for a country's economy. For example, research conducted by M. Keping *et al.* (2022) showed that countries that are actively involved in GVCs may face high vulnerability to external shocks, such as economic crises or changes in the trade policies of other countries. Additionally, countries that are actively involved in GVCs may face challenges in technology transfer and capital accumulation.

It should be noted that countries that rely heavily on GVCs may experience a decline in domestic industries and job losses due to outsourcing and offshoring (Silagadze *et al.*, 2022). J. Lin *et al.* (2020) emphasise that there are environmental and social costs associated with participation in GVCs, such as increased carbon emissions and labour exploitation. Several researchers, including E.H. Herlina & T. Kudo (2020), raise concerns about the potential risk of participation in global value chains for social justice and economic equality. They argue that the benefits of participating in the global chain may be concentrated among a limited group of privileged individuals, leaving the majority of the population without the benefits of economic growth.

Between 2000 and 2020, the global agricultural industry underwent significant changes due to integration into global value chains. Researchers such as V. Hrushko & R. Kovchar (2023), and S. Osendarp *et al.* (2022) note that global value chains have radically transformed the ways in which agricultural products are produced, processed, and traded, opening up new opportunities and challenges for countries. Ukraine is actively integrating into global value chains, which is associated with both positive and negative consequences for its agricultural sector. Furthermore, Ukraine, as a major producer and exporter of agricultural products, faces several risks associated with its dependence on fluctuating global prices, trade conflicts, and natural disasters (The impact of the war…, 2023). This can lead to fluctuations in export earnings, disruptions in product supply, and production losses. Therefore, it is important to strengthen practical cooperation in crisis management to increase Ukraine's GVCs participation and reduce its dependence on fluctuating global prices.

Supporting this argument, S. Berenda & L. Grygorova-Berenda (2022) believe that Ukraine itself should rationally utilise its natural resources, and develop the primary, secondary, and tertiary sectors of the global economy to reduce its dependence on imports and increase its export competitiveness. Thus, Ukraine not only experiences the influence of global value chains but also actively interacts with them, seeking to leverage opportunities and manage risks to support the sustainable development of its agro-industrial sector. Ukraine should focus on increasing domestic value-added in exports, particularly in sectors such as vehicles, computers, and electronic and electrical equipment, as advised by Y. Konrad & T. Melnyk (2017). Furthermore, Ukraine should seek to diversify its exports, strengthen trade relations with other countries, and develop cooperation with international organisations to obtain financial and technical support.

Global value chains play a crucial role in the modern economy, facilitating interconnectedness and cooperation between countries and businesses at an international level. They contribute to increased production efficiency, improved product quality, and reduced costs. Participation in GVCs has a positive impact on economic growth, job creation, and increased exports, but also carries risks such as dependence on global events and social challenges.

Conclusions

The study's findings establish that Ukraine's integration into global value chains significantly impacts its economic development. Regression analysis confirmed a strong correlation between Ukraine's GDP and foreign value-added in exports and total exports. The analysis of Ukraine's GVCs participation showed that from 2011 to 2016 the country specialised in the final stages of production, but later shifted to intermediate stages. This indicates a strategic reorientation of the economy towards greater participation in GVCs. A positive aspect is the increase in exports of high-tech goods, which contributes to the technological advancement of the country and attracts foreign investment. However, a significant dependence on foreign components in export products hinders economic progress and increases vulnerability to changes in the international market.

The study found a negative correlation between a country's level of economic development (GDP per capita) and its dependence on foreign components in exports across most industries. For instance, in the machinery industry, every 10% increase in the share of imported components led to a 0.5% decrease in GDP per capita. Similarly, in the chemical and pharmaceutical industries, a 15% increase in component imports reduced GDP per capita by 0.8%. However, in the production of vehicles, computers, electronics, and electrical appliances, a positive effect was observed from increasing foreign content in exports. Therefore, to ensure sustainable economic growth in a

globalised world, countries should focus on developing strategies that increase domestic value-added, and invest in innovation and technological progress, to enhance their competitiveness in the global market.

The limitation of this study is that it covers the period from 2010 to 2023, not taking into account earlier changes in the Ukrainian economy, which may also have influenced the results. Further research should focus on studying the earlier stages of Ukraine's economic development to gain a full understanding of Ukraine's integration into GVCs. Additionally, studies should also focus on examining the impact of innovation and technological changes on Ukraine's integration into GVCs and their reflection on economic growth.

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None.

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Глобальні ланцюги доданої вартості та їх вплив на агрокомплекс України

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► **Анотація.** У сучасному глобальному економічному середовищі інтеграція до світових ланцюгів доданої вартості є вирішальним фактором економічного зростання країн. Мета дослідження полягала у визначенні впливу участі України у глобальних ланцюгах доданої вартості на агрокомплекс країни. У дослідженні використано статистичний аналіз, регресійний аналіз, економетричне моделювання, кореляційний аналіз та аналіз індексів участі і позиції країни у глобальних ланцюгах створення доданої вартості. Було встановлено, що протягом 2010-2011 років українська економіка демонструвала високі темпи зростання валового внутрішнього продукту та експорту завдяки зростанню іноземної валової доданої вартості. Починаючи з 2012 року, темпи зростання почали знижуватися через економічні кризи, політичну нестабільність та війну, що почалася у 2014 році. Пандемія COVID-19 також негативно вплинула на економічну ситуацію у 2020 році. Незважаючи на повномасштабну війну у 2022 році, у 2023 році спостерігається повільне відновлення економіки, обумовлене зростанням іноземної валової доданої вартості в експорті. Регресійний аналіз показав сильну кореляцію між валовим внутрішнім продуктом України та показниками іноземної інвестиції в експорті та загального експорту. Виявлено, що збільшення іноземної валової доданої вартості в експорті негативно впливає на валовий внутрішній продукт, тоді як збільшення загального експорту позитивно впливає на економічне зростання. Незважаючи на складність глобальної ланцюгової системи вартості, результати свідчать про потенціал України до подальшої інтеграції у світові економічні процеси. З'ясовано, що сільськогосподарська галузь також відчуває вплив від коливань іноземної валової доданої вартості, що відбивається на продуктивності та експортних можливостях аграрного сектору. Аналіз участі основних галузей промисловості, в тому числі агрокомплексу, у глобальних ланцюгах доданої вартості показав тенденцію зменшення частки іноземної доданої вартості у валовому експорті промислової продукції, що свідчить про зростання внутрішньої доданої вартості. Результати дослідження можуть бути використані для розробки ефективної стратегії економічного розвитку України шляхом оптимізації участі в глобальних ланцюгах доданої вартості та зменшення залежності від іноземної доданої вартості в експорті

► **Ключові слова:** експорт; економічне зростання; регресійний аналіз; індекс позиції країни; валовий експорт; волатильність

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Small farms in Spain common agricultural policy (2023-2027): A critical review

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▸ **Abstract.** The role of small-scale farming in forming a sustainable food system is significant due to its greater ability to support biodiversity, ensure food and job availability for the population in remote rural areas, and preserve the identity of local production. Accordingly, any Commission Agricultural Policy reform requires evaluation from this perspective. The aim of this study was to critically assess the potential for adapting the needs of small-scale farming in Spain's new Commission Agricultural Policy Strategic Plan and to provide recommendations to address identified imbalances. Consequently, an analytical review of the agricultural sector was conducted, guided by statistical information, to investigate the main trends in the transformative changes within Spain's farming structure. The analysis of the political document allowed for the identification of component changes in line with the agricultural policy reform. The method of analytical-critical thinking was used to analyse the payment structure and fair distribution of funds for small-scale farming. As a result, the study identified weaknesses and disparities in Spain's new Commission Agricultural Policy Strategic Plan and provided relevant recommendations that could facilitate better adaptation of small farms to the new agricultural policy. The provided recommendations can serve as a basis for further scientific discussion and improvement of agricultural policy. This research can be useful for stakeholders in making political decisions to better adapt to the stated ambitious goals of the new Commission Agricultural Policy Strategic Plan

▸ **Keywords:** eco-schemes; active farming; redistributive income support; rural development; organic farming

▸ Introduction

Effective agricultural policy is a crucial part of a country's economic development and a driver for the preservation of rural areas. Economic challenges and climate change make government support for the agricultural sector a necessary condition for ensuring sustainable development, stimulating innovation, and supporting farmers. A recent study by A. Magrini (2022) assessed the resilience of agriculture in European Union countries, identifying positive shifts in achieving sustainable development goals due to government support. On the one hand, such state support is due to the importance of the sector in shaping food security in the country and regions (Volkov *et al.,* 2019), but on the other hand, paradoxically, can lead to certain imbalances and dependencies that, as a result, will have a negative impact on the sustainability of agriculture as highlighted in the work of C. Détang-Dessendre & H. Guyomard, (2022). The European Commission Agricultural Policy (CAP) was originally introduced with the aim of expanding agricultural production, regulating market relations and developing rural areas, but to date it has undergone reforms in many areas, shifting its priorities to meet the goals of The European Green Deal (2019). A recent study by C. Boix-Fayos & J. de Vente (2023) provided a contextual review of the policy tools in approach-

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es to sustainable agricultural systems, which to varying degrees contribute to achieving the goals of the European Green Deal. The authors of the study emphasised the necessity of socio-economic recognition for agricultural stakeholders who prioritise ecosystem services, thereby being more capable of effectively achieving sustainable development goals. The latest policy review (Regulation (EU) 2021/2115…, 2021) focused on strengthening green ambitions through attention to biodiversity, providing stronger incentives for agroecological farming practices, taking into account climate relevance, and improving equity and competitiveness. As noted in the study by, P. Homet *et al.* (2024), the new CAP is the most ambitious in the environmental context. The latest reform aims to provide a new way of working with greater efficiency and effectiveness, primarily by introducing national strategic plans for each Member State, which, in this context, will provide some leeway in placing financial emphasis (Approved 28 CAP strategic plans, 2023). In addition, the new CAP framework provided an opportunity to take into account the needs of small-scale farming by developing each Member State's own strategic plans, adapting social, environmental and economic mechanisms to its own food supply system. Attention to small-scale farming in the new CAP is especially relevant at local levels of food supply. The role of small-scale farming in food security remains significant (Analysis of the characterization…, 2023). Its importance is especially relevant at local levels of food supply. In many ways, the effectiveness of small-scale farming depends on the established interaction between local food systems and supply chains. It is the latter that open up the possibility for small farms to move from self-sufficiency to a viable business (Small Farms' Role in the EU Food System, 2022). The development of small-scale farming in Spain is particularly relevant in the context of maintaining the viability of rural and remote areas, preserving landscape features and biodiversity. In the study by A. Pardo *et al.* (2020), evidence can be found that greater ability to maintain biodiversity through a more diversified product portfolio reduces the risks of monoculture cultivation. Moreover, small-scale farming contributes to the preservation of the identity of local production and employment of the local population in remote parts of rural areas, makes a greater contribution to food production compared to large farms due to higher productivity and a larger share of food products than non-food products in total production. In addition, small farms allocate a larger share of their plant production to food (almost 60%) compared to larger farms (Lowder *et al.*, 2019).

Given this flexibility in the strategic approach of the new CAP framework in developing by Member States their national plans that should take into account local needs and specific conditions in the reallocation of funding, it is of interest to analytically evaluate individual plans of Member States, especially those countries that are able to meet not only national food needs, but also have significant export potential and play a significant role in providing food to the EU. The agricultural policy of Spain, as a country with an average annual export growth rate of 7%, ranking 8th in the world and 4th in the EU in terms of agri-food trade balance (Analysis of the characterization…, 2023).

In this context, the main question remains whether Spain's new strategic plan will effectively fulfil its stated ambitious promises in areas such as stronger incentives for agroecological farming methods and maximum adaptation to the needs of small-scale farming. This article aimed to foster a discussion on how to adapt the needs of small-scale farming within Spain's new agricultural policy, providing a comprehensive analysis of weaknesses and disparities that could lead to gaps in the resilience of agricultural systems.

Materials and methods

The primary sources, such as the Strategic Plan of the Common Agricultural Policy of Spain 2023-2027 (Spain: CAP Strategic Plan 2023-27, 2022), have enabled to determine the subject-object component using the method of structural generalization and proposed a compilation scheme of the goals of the Strategic Plan. The analysis of policy documents is a common method of critically reviewing government policies. The scientific sources selected on the principle of reliability have served as a scientific basis and evidence base for determining the relevance and urgency of considering small-scale farming as a significant component in the formation of the Spanish food system. The analytical conclusions and recommendations provided are formed on the basis of an analysis of databases of the European Commission (Data and analysis, n.d.), the International Organization for Economic Cooperation and Development (OECD agriculture statistics, 2023), as well as the Spanish Ministry of Agriculture, Fisheries and Food (Annual Performance Report – CSP Spain, 2024). The EU Regulations, the Green European Deal and the UN Global Sustainable Development Goals have served as the starting point for the review of governance requirements, as well as environmental and agricultural conditions. The dialectical method to clarify the causal relationships between the analysed phenomena. When analysing the structure of payments for contributions to the development of small farming, the method of analytical and critical thinking has been used to identify imbalances and bottlenecks in the approach to the redistribution of funds. The study by A. Giuliani & H. Baron (2023) served as a starting point for analysing the structure of payments and the fair redistribution of funds for small-scale farming. This document provided a benchmarking basis for formulating recommendations for the Spanish agricultural sector. The presentation of statistical information using graphical methods has enabled to demonstrate the main trends of transformational changes in the structure of farming in Spain and support the evidence base with digital arguments. An example of cooperation between the State and the private sector based on a platform for spreading digital innovations in one of the regions of Spain (Andalusia) has been considered using the method of analysis. The information and statistical method have been used to provide a brief overview of the Spanish agri-food sector, environmental impacts and general trends. Finally, the abstract and logical method, which involves providing key recommendations based on an analysis of a current policy document or a new academic study, has been used to discuss and draw conclusions from this review.

▸ Results

Spain's agriculture accounts for more than 10% of the total economy and provides jobs for more than 2.6 million persons. The share of agricultural land in Spain is 52.33%, while the average for EU countries is 41.03%. About 7% of Spain's workforce works in the agricultural sector (OECD, 2023). The average annual growth rate of export volume is 7%. Spain annually exports more than 55,000 million agricultural products. euro, ranked 8th in the world ranking and 4th in the EU in terms of agri-food trade balance (Data and analysis, n.d.). Olive oil, wine, citrus fruits, strawberries, pepper form the main volume of exports, and since 2010 pork meat has been added to this list. Such a rapid development of animal husbandry creates an import demand for corn and soybeans to provide a feed base for livestock. Spain ranks the 6th place in the world and 2nd in Europe in terms of organic land area with the highest concentration in Andalusia (50%). The number of agricultural organic farms as of 2020 was 42,312 (Analysis of the characterization…, 2023). Most organic products are export-oriented, as domestic consumption is still low. These indicators characterise the economic and social significance of the sector and the strategic importance associated with the formation of food security not only at the state level, but also with the corresponding impact on the global agricultural market. At the same time, the environmental price of a highly productive agricultural sector is extremely high. Agriculture accounts for 14% of Spain's total greenhouse gas emissions. The sector is also responsible for 63% of methane emissions and 77% of nitrous oxide. Due to the need for irrigation, the agricultural sector is the largest consumer of water and puts significant pressure on Spain's underground and surface waters. Nitrates and other nutrients from agriculture negatively affect groundwater and soil condition. As of 2022, Spain is the only country in the EU that has not yet reached an acceptable level of ammonia emissions into the air, mainly due to the agricultural sector. The rate of soil erosion in Spain is higher than the EU average, and 74% of Spain's surface is at risk of desertification (OECD, 2023).

Another important characteristic of the Spanish agricultural sector is the transformational changes in the structure of farming. As of 2022, the total number of farms in Spain was 914,000. More than 50% of all agricultural land are occupied by 6% of farms that exceed 100 hectares in size. The level of contract labor increased by 14%, while the reduction of family workers by 50% (OECD, 2023).

The Spanish food system is quite well formed, but at the same time it needs to maintain a territorial balance and reduce the level of depopulation in rural areas. Accordingly, the Strategic Plan (2023-2027) of the Common Agricultural Policy of Spain is presented as a ten-year basis for balanced agricultural development in economic, environmental and social dimensions (Spain: CAP Strategic Plan 2023-27, 2022). While retaining key elements of previous achievements, the 2023-2027 Strategic Plan declares gradual changes towards improving efficiency to reward farmers' environmental and climate commitments (Huyghe *et al.*, 2023), which should contribute to the achievement of the three main goals. Special attention is paid to the implementation of the goals of the Green Deal, such as achieving progress in: reducing the use of pesticides, antimicrobials and chemical fertilizers; increasing the area of organic farming, restoring and preserving biodiversity, expanding broadband in remote rural areas. The overall and specific goals of the Strategic Plan (2023-2027) of the Common Agricultural Policy of Spain are presented in Table 1.

Table 1. Compilation of objectives of the Strategic Plan (2023-2027) of the Common Agricultural Policy of Spain (compiled on the basis of the Spain CAP Strategic Plan (2023-2027)

SP goal units	*Overall goa*	Specific goals	Intermediate goal
Economic	Promoting the development of a smart, sustainable, competitive agricultural sector with a focus on its diversification to ensure long-term food supplies	Ensuring stable incomes for farmers	Promoting the exchange of innovation and knowledge, digitalization and modernization of agriculture.
		Increasing the level of competitiveness of farming	
		Balancing in the middle of supply chains	
Ecological	Promoting increased environmental care and adaptation to climate change	Preventing climate change	
		Environmental protection	
		Conservation of biodiversity and local landscape	
Social	Promoting the socio-economic context in rural areas	Support for generational change in farming	
		Rural revival	
		Protecting the quality and health of food products	

Source: compiled by the authors based on Spain: CAP Strategic Plan 2023-27 (2022)

According to Spain SP (Annual Performance Report – CSP Spain, 2024), the annual budget for financing agricultural activities is EUR 4,800 per year. The structure by funding areas is shown in Figure 1. The largest amount of funding is allocated to support basic income for sustainable development.

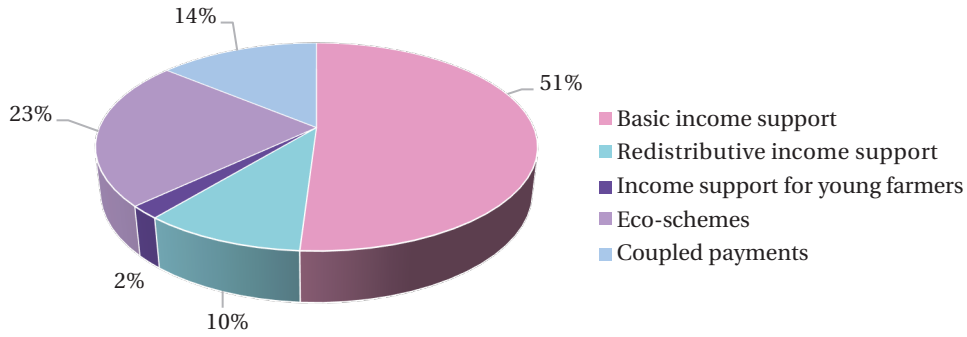

Figure 1. General directions of financial support for the new Strategic Plan of Spain
Source: compiled by the authors based on Annual Performance Report – CSP Spain (2024)

It should be noted that almost a fifth of the basic income support (EUR 483) is allocated to pay only for the first hectares of the farm. This can be considered as a new step in the policy of supporting small-scale farming. At the same time, support of EUR 677 per year (14%) for vulnerable sectors of large-scale agriculture in terms of socio-economic development is maintained. An innovation is that almost 23% of the total direct funding is allocated to encourage farmers' initiatives to implement specific agricultural environmental practices that meet higher requirements. In addition, a small part of the budget (EUR 96.5 M per year) is allocated to support the income of young farmers for the first 100 hectares, with a 15% advantage for female farmers. Thus, the financial support provided under the EU Common Agricultural Policy is an important security cushion for the Spanish agricultural sector, which has a 30% lag in profitability compared to other sectors of the economy. Such direct payments reward farmers for certain measures in their activities (socially important services, such as environmental and climate actions, provision of products, viability of rural areas), which cannot be rewarded by the market without losing competitiveness in price. On the one hand, this approach makes the agricultural sector resistant to fluctuations in market prices and provides an opportunity to ensure continuous agricultural activity, and on the other hand, it makes the sector dependent on changes in financing (Amorim *et al.*, 2023). The main changes that are taken into account in the new plan for the development of the Spanish agricultural sector are systematised in Figure 2.

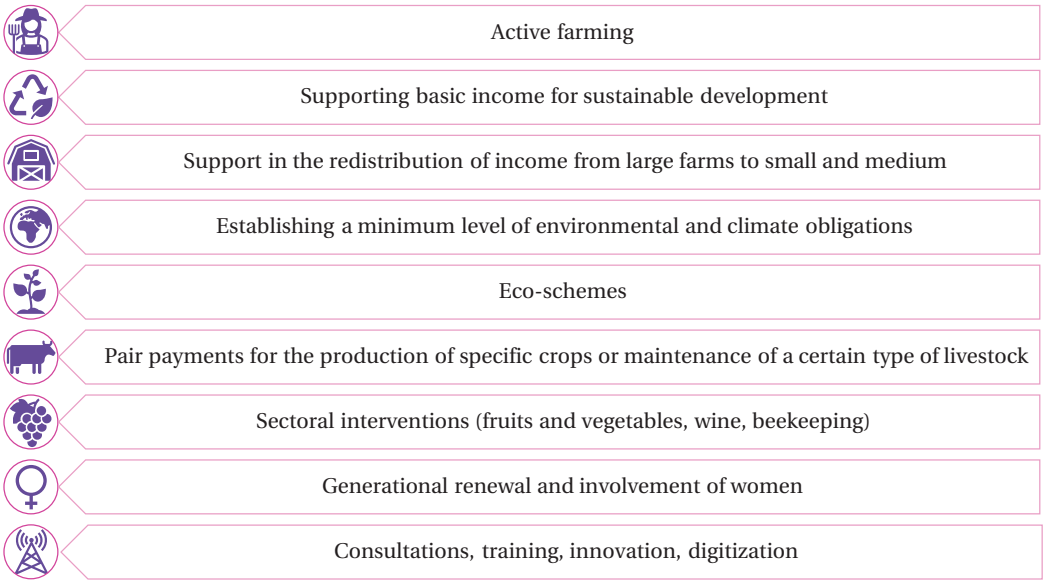

Figure 2. Component changes in line with Spanish agricultural policy reform (2023-2027)
Source: compiled by the authors based on Spain: CAP Strategic Plan 2023-27 (2022)

Active farming involves employment in the agricultural sector, both full- and part-time. To receive financial support from CAP, a farmer shall meet one of the following conditions to be considered an active farmer: 1) be self-employed in the agricultural sector through the Social Security System; 2) a minimum of 25% of the farmer's total income shall be provided by agricultural activities; 3) the amount of income received shall be EUR 5,000 per year, or less (Annual Performance Report – CSP Spain, 2024).

Basic income support for sustainable development will be provided by regional differentiation. Regions are defined as agricultural areas with similar agronomic conditions. One of the changes in the existing Spain SP is a significant reduction in the number of regions (from 50 regions

to 20 regions), which can contribute to a more equitable distribution of the budget through convergence at the regional level. All 20 regions are divided into 5 categories by land type: 1) rainfed arable land (5 regions); 2) irrigated arable land (5 regions); 3) permanent crops (4 regions); 4) permanent grassland (5 regions); 5) Balear region (1 region). The category 2) irrigated arable land has the highest basic support, and category 4) permanent grassland has the lowest support. Moreover, thanks to the internal convergence mechanism, the level of differences between the cost of payment rights of farms is reduced that has made it possible to achieve a fairer financial distribution in regions with similar requirements and circumstances. It is planned that such an innovation will eliminate the disparity in regional distribution that has arisen over the past 10-15 years of funding under the CAP Policy and will enable each farmer to reach 85% of the right to payment by 2026, and full convergence should be achieved by 2029 (Spain: CAP Strategic Plan 2023-27, 2022).

Supporting income redistribution from large farms to medium and small-sized farms is in addition to supporting basic income for sustainable development. This support depends on the set threshold levels, of which there are only 2 and which depend on the category and type of region. It should be noted that Spain has introduced such a redistribution in favour of medium-sized professional farms, since it means 40% of the average regional cost of medium-sized farms. But small-scale farming will not benefit from such a redistribution. For each of the 20 regions, our own thresholds have been calculated, taking into account the structural composition of farms in a particular region. Category 2) irrigated arable land has the highest level of support for income redistribution from large farms, and category 4) permanent grassland has the lowest level.

Establishing a minimum level of environmental and climate obligations requires compliance with 11 management requirements and 10 environmental and agricultural conditions to be met in order to preserve the environment, resist climate change, maintain public health and the health of livestock and plants, and animal welfare. The new management requirements include the EU Directive establishing a framework for Community action in the field of water policy (Directive 2000/60/EC…, 2000) and the EU Directive on community action to achieve sustainable pesticide use (Directive 2009/128/EC…, 2009). The new environmental and agricultural conditions are "Protection of wetlands and peatlands" and "Sustainable fertilization" (Peatlands and wetlands in the new CAP…, 2022; New CAP unpacked…, 2022).

Eco-schemes are agricultural practices that are good for the environment and climate. The list of such practices includes the following: 1) extensive grazing, 2) sustainable mowing and creation of biodiversity islands, 3) crop rotation with improving species, 4) direct seeding, 5) sustainable water layer management, 6) spontaneous or sown vegetation cover, 7) inert vegetation cover. The farmer may choose one of the suggested options and apply it to a specific plot. It should be noted that funding is provided only for one selected practice. If a farmer chooses several sustainable practices, only one is funded (Will CAP eco-schemes…, 2021).

Coupled payments for the maintenance of a certain type of livestock or the cultivation of a certain type of crop are established by Spain for the purpose of economic and social support for vulnerable categories of production. The focus is mainly on animal husbandry and growing protein crops to avoid import dependence on plant proteins. As a percentage, the largest assistance is provided for the maintenance of cattle (27.6%), the second place in terms of funding is the sustainable maintenance of sheep and goats in extensive or semi-expanded animal husbandry (19.4%), followed by the maintenance of dairy cattle (18%), and the sustainable production of vegetable protein accounts for 7.6% of funding. In addition to this support, separate funding for ecological cotton of specific varieties is provided in the amount of EUR 59.7 million.

Sectoral intervention provides for 3 directions: 1) production of vegetables and fruit with a 15% level of environmental costs and a 2% level of research costs (total financial support will amount to EUR 377 million); 2) wine production with its 5% level of costs for achieving climate and environmental goals (total financial support will amount to EUR 202.1 million); beekeeping (total financial support will amount to EUR 19.1 million).

Generational renewal and involvement of women. A specific annual budget of EUR 220 million is provided for the renewal of generations. Clearly setting an age limit (persons under 40) reduces the risk of bureaucracy. In addition, young farmers will have access to all other payments provided for by the CAP. An additional incentive for farmers who have recently established farms to prioritise the distribution of rights to payments from the National Reserve. The gender component is also taken into account in the reformed CAP, giving a 15% preference to women. Autonomous communities may apply rural development measures aimed at promoting youth engagement in their territories, such as young farmers' settlements, among other measures that may have a differentiated and supportive regime for young people, such as training and counselling services, and launching rural businesses.

Consultations, training, innovation, digitization. The Strategic Plan (2023-2027) of the Common Agricultural Policy of Spain provides for the modernization and digitalization of the agricultural sector. Special attention is paid to consultations and training programs that are designed to expand knowledge and innovation. The budget for consulting services and training will increase to 60% (Spain: CAP Strategic Plan 2023-27, 2022).

While the new CAP framework focuses on supporting small-scale farming, there are a few key points that may be overlooked, which will ultimately jeopardise the fulfilment of announced ambitious promises. The greatest danger is concentrated in the transformational structural and demographic changes of small-scale farming. Recent decades have been marked by a tendency to reduce small family farms (Fig. 3). The main reasons for this trend are related to demographic changes in remote rural areas, climate changes associated with extreme weather conditions, as well as market pressures and inequality in access to innovation and new technology. According to statistics, small farms are run by older farmers (Fig. 4). The generational inheritance factor is very weak in Spanish

agriculture, which leads to the fact that at the end of farm management with the onset of retirement age, the farmer's land may be abandoned or merged with another farm. This trend is confirmed by an increase in the average farm size in Spain. Moreover, abandoned land creates more opportunities for expanding activities, rather than encouraging young people to enter business because of the risks associated with the cost of starting a new farm and the lower level of attractiveness of agriculture compared to other sectors of the economy. Not the least role in this regard is played by the low level of agricultural education, which is below the EU average (only 18% of Spanish agricultural workers have a middle-level education and 75% have a low level (OECD, 2023). The above socio-economic context can create demotivating factors for the younger generation of potential farmers.

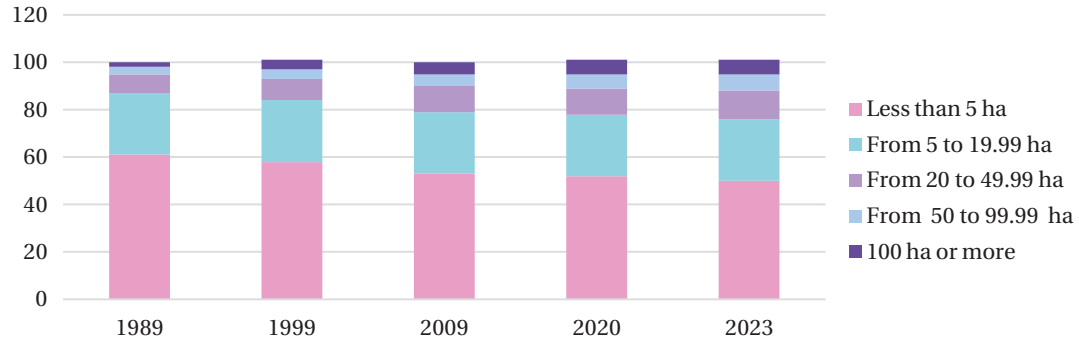

Figure 3. Distribution of the number of farms by size 1989-2023
Source: Data and analysis (n.d.)

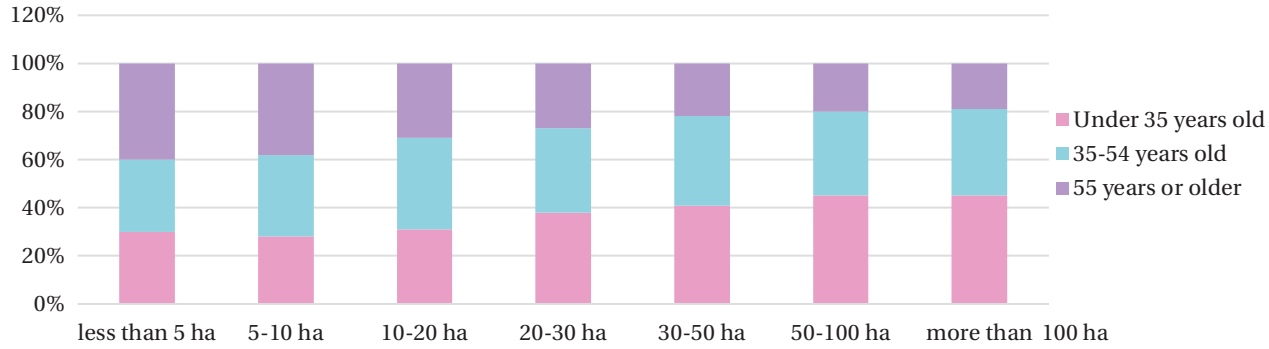

Figure 4. Age composition of farm management in Spain
Source: Farms and farmland in the EU: Tables and figures (n.d.)

The Spain Strategic Agricultural Plan has introduced certain mechanisms for redistributing funds from large farms to medium and small-sized farms in order to avoid concentrating funds in the hands of large beneficiaries. Such mechanisms include a new approach to the definition of "active farmer", as well as payment restrictions (no more than EUR 200,000 per beneficiary). The next mechanism is the introduction of redistributive income support, which provides for additional payment for the first hectares of the farm. A fairer redistribution specifically for small-scale farming, i.e. a 20% increase in support for the first 5 hectares, could reduce concerns about a higher level of support for medium-sized farming compared to small-scale production. An analysis of the structure of payments for contributions to the development of small farms (Table 2) shows some weaknesses in the approach to reallocation of funds.

Table 2. Agriculture policy support for small farms in Spain according to the Strategic Plan (2023-2027)

Policy area	Description	Amount of funding	Contribution
Redistributive income support	To be paid for the first hectares of the farm	Total support amount of €483M/year	This redistribution is more supportive of average farms, as the average area of up to 5 hectares is 20%, and more than 5 hectares-40%
Rural development	Investments are planned in 9 areas, the largest volume in environmental and climatic.	Total support amount of €1,762/YEAR	Despite the problem with education and farmers and the disproportionality of technological development in remote regions, the reallocation of funds to knowledge exchange and information dissemination is only 2.2%, and to technical assistance 1.9%

Table 2, Continued

Policy area	Description	Amount of funding	Contribution
Eco-schemes	Assistance is provided only for one selected practice	Total support amount of €1,107M/year	For small firms, which often use multiple sustainable practices at the same time, such a reallocation of funds may not be fair
Support for young farmers	Farmers under the age of 40 will receive additional benefits; for women, pay increases by 15%.	Total support amount of €96.5M/year	Given that most small farm owners are people over the age of 55, this reallocation does not support existing small farms
Active farmer mechanism	Criterion for receiving benefits is self-employment in the agricultural sector or 25% income from agricultural activities	Basic support, paid for all hectares €2,460M/year	The main funding is focused on supporting farmers' incomes, while there is still little financial support for new businesses, small farming cooperation tools, and marketing for agricultural markets.

Source: compiled by the authors based on Spain: CAP Strategic Plan 2023-27 (2022)

The analysis of the payment structure revealed that the financial mechanisms for supporting small-scale farming in Spain's new agricultural strategic plan remain suboptimal. A. Giuliani & H. Baron (2023) highlight the uneven management of financial flows favouring large companies. This imbalance could ultimately exacerbate risks related to biodiversity and the underutilization of agricultural knowledge and innovations by small farms. A number of important lessons can be found for a fairer distribution in favor of small-scale farming in Spain. Rural development could be improved by supporting new rural businesses and encouraging young people to start their own farming businesses. Support for the purchase of land, animals, and agricultural infrastructure elements could improve the situation for small market operators. Promoting collective action on small farms will also be useful, especially for the development of short supply chains. Given that the percentage of direct sales in Spain is only 5%, attention to developing partnership approaches is desirable for the development of local markets, especially in remote rural regions. Stronger links could be expected between the local agricultural, food and tourism sectors.

More equitable support for eco-schemes could be achieved through the provision of basic incentives and bonuses for the implementation of integrated and systemic practices, not limited to funding just one practice. Given that small farms are more capable of maintaining biodiversity through a more diversified product portfolio and reducing the risk of monoculture cultivation, funding multiple practices at the same time could help improve the environmental sustainability of small-scale production.

The gap in digital skills and the use of digital technology are still significant for rural areas in Spain. Targeted and broader support in providing advisory services to small-scale farmers can help narrow the skills gap and achieve a more equitable distribution of income, taking into account the training needs of the agricultural sector labour force (Policies for the future…, 2023). There is a need for more concentrated government support, taking into account the specific needs of small farmers on digital issues. Funding for the training and involvement of consultants on the application of sustainable technology and practices in agriculture, marketing and distribution support, technology and innovations for improving productivity, and other issues is considered a useful area. The use of digital skills by small farm managers can contribute to the development of a more sustainable agricultural model. Today, there are already examples of cooperation between the State and the private sector of Spain in this area and they should be disseminated. The AGROTECH DIH platform (Andalucía Agrotech Digital…, n.d.) is an example of public-private partnership. Their goal is to promote digital transformation in the agri-food sector by introducing cutting-edge technologies, promoting innovation and collaboration, and connecting with the European digital ecosystem. The company provides technology and training services. The basic function of the platform is to help farmers find providers of services such as big data, precision farming, and artificial intelligence. The platform contains open sources of data on entrepreneurship training and other educational elements. Another new example of interaction between R&D and small-scale farming, which is not yet widespread in Spain, is the creation of "living laboratories", whose activities are based on consumer-oriented innovations. This approach is the direction of spreading the concept of agroecology in Europe. It promotes the simultaneous involvement of farmers and scientists in joint efforts to design environmentally oriented land use.

▸ Discussion

The development of small-scale farming in Spain is particularly relevant in the context of maintaining the viability of rural and remote areas, preserving landscape features and biodiversity. The presented results of the critical review of Spain's strategic agricultural plan raise a discussion on enhancing support for small-scale farming. Transformational changes in the structure of farming in Spain demonstrate a trend towards a reduction in the number of small farms and a low rate of generational succession. A number of studies raise debates about the contribution of small-scale farming in the new strategic CAP plans of member countries (Toma *et al.*, 2021; Petsakos *et al.*, 2022; Giuliani & Baron, 2023). The study by I. Toma *et al.* (2021) provides an evidence-based analytical foundation of the existing needs of small-scale farming in Poland, Romania, and Latvia, as these countries where small-scale farming is a dominant feature. For each of these countries, national

narratives related to market integration, rural infrastructure, innovation, and agricultural education have been developed. By drawing an analogy in forming a narrative for Spanish small-scale farming, the following national narratives can be identified: 1) higher support rates for the first hectares; 2) improved mechanisms for encouraging young farmers; 3) development of innovations, technologies, and agricultural infrastructure for small-scale farming; 4) promotion of short supply chains.

A higher rate of support for the very first hectares of farms can improve the design of reallocation of payments and help avoid concentrating support for medium and large beneficiaries. Following the example of the Netherlands and Germany, as indicated in the study by J. Poláková *et al.* (2024), the enhancement of rural development could be achieved by reallocating direct payments to national-level funding. In agreement with the assessment provided in the study by the European Parliament, a significant achievement should be considered the 50% funding for rural development, which is associated with agri-environmental measures for areas with specific constraints (Comparative analysis…, 2023). The amount of payments received for the implementation of eco-schemes should encourage the simultaneous use of more than one practice in order to be fair for small-scale farming.

Mechanisms should be improved to encourage young farmers to enter the business and follow the family business by increasing the attractiveness of the farmer's profession and the level of agricultural education. In developing appropriate programs to stimulate small-scale farming and attract young people, their typology should be considered. For example, in the study by V. Graskemper *et al.* (2021), one can find an example of the typology of German farmers. Implementing such a clustering methodology could be beneficial for the development of these proposed programs in Spain.

Investments in reducing the gap between the innovative, technological and information levels of large- and small-sized farms will help to increase the competitiveness of the latter. The digitalization of the agricultural sector also plays a key role in this context. The complexity of calculations for obtaining funding under eco-schemes requires proper communication with farmers and assistance in these calculations. Following the example of the Netherlands (Jongeneel & Gonzalez-Martinez, 2023), the creation of a user-friendly modelling tool designed to facilitate calculations and enable the testing of different options could simplify decision-making regarding eco-schemes for Spanish farmers. Enhancing agricultural infrastructure through public funding, such as a 30% reimbursement of funds invested in the reconstruction of infrastructure for storage and processing (Pietrzyk, 2022), could also be an effective measure in supporting small-scale farming.

Stimulating the development of short supply chains in remote agricultural regions will help stabilise the profitability of small farms and reduce the market burden. Alternative food networks aimed at reducing the number of intermediaries from producer to end consumer could address this issue by implementing the goals of the EU's Common Agricultural Policy. The development of infrastructure for cooperation of small farmers will help strengthen their position in market negotiations.

In addition to adapting to the needs of small-scale farming, it is also important to address the general bottlenecks within Spain's SP that affect all beneficiaries of the agricultural sector. In the updated Strategic Plan, the developers have not managed to get rid of the contradictions between traditional and organic agricultural production, which raises the issue of further sustainability of the agricultural sector. No significant changes are observed in the industry structure or the mass transition of certain types of activities to organic production. As noted in a recent study by G. Calabro & S. Vieri (2023), merely promoting the expansion of organic acreage is unlikely to result in the desired shift from conventional farming methods to organic farming. In this context, it should be agreed that achieving ambitious goals of 25% organic acreage, as exemplified by Spain, mainly involves engaging farmers who are already more sustainable, which does little to facilitate the overall transition to organic farming. Additionally, the situation in Spain is exacerbated by the fact that none of the eco-schemes provide support for organic farming. This situation arose because representatives of organic farms were not involved in formulating recommendations for the development of the government's agricultural policy.

Overall, the situation with eco-schemes for organic farming is uncertain in the CAP strategic plans of many EU member states (Evaluation of support…, 2022). Only countries like Denmark, Italy, and Poland have planned the creation of eco-schemes that specifically support organic farming. The Danish government has planned to allocate support amounting to 3.5 million Danish kroner to promote organic farming, which is considered sufficient to achieve the goal of a 20% increase in organic acreage (Evaluation of support for organic farming…, 2022). Overall, Denmark serves as an example of a country that supports organic farming not only from the producer's side but also from the consumer's side. The example of promoting the consumption of organic products through the introduction of organic food procurement programs by public institutions (Daugbjerg, 2023) could be useful for Spain, where the level of organic product consumption is low compared to the EU average. For many Spanish farmers, marketing policies remain one of the biggest challenges, despite the consumption culture and focus on healthy eating in society (Amorim *et al.*, 2023). And here traditional economic laws play a role, the effect of which cannot be cancelled. For example, small-sized farms cannot compete with large producers in marketing support. Accordingly, they cannot receive an additional price premium. The study shows that the greater the distance of sale of organic products, the greater its carbon footprint becomes, and accordingly the logic of organic production disappears. Hence, it is essential to create a system of support for the local distribution of products of a local producer (Simón-Rojo *et al.*, 2020; Stefanovic *et al.*, 2020). In this context, the issues of marketing support for local organic producers, popularizing their preferences and consumer benefits are not decisive. The protectionist support policy provides only support through financial incentives, such as subsidies, but does not play a role in ensuring its sustainability. The dilemma of the "long-short" supply chain is not solved in the updated Strategic Plan as well.

At the same time, countries such as Germany and Luxembourg do not include eco-schemes suitable for organic farms in their strategic plans due to the avoidance of double funding. These discrepancies in agricultural strategic plans have arisen because, on the one hand, the new CAP model has become more flexible, allowing member states to adjust national CAP tools, while on the other hand, as rightly noted in the study by N. Röder *et al.* (2024), the lack of clear restrictions and the vague recommendations provided by the European Commission may lead to a decrease in the expected environmental contribution of the new CAP. Consequently, in the case of Spain, to avoid a situation where the advantages of organic farming compared to conventional farming disappear, support measures for organic farming should be considered as additional measures compatible with agri-environmental and climate measures. The recommendations presented could serve as a foundation for further scholarly debate and encourage stakeholders to re-evaluate specific aspects of agricultural policy, with the aim of enhancing its alignment with the implementation of the stated ambitious objectives.

Conclusions

Given the importance of small-scale farming for the formation of a sustainable European food system, an evaluation of Spain's new CAP Strategic Plan was conducted in this context. The reformed European agricultural policy is undoubtedly aimed at developing agroecological and sustainable systems, yet it still lacks effective mechanisms to support small-scale farming, which may pose risks to food security in the future. The analysis presented in this study identified weaknesses that could negatively impact the ambitious goals of Spain's new CAP Strategic Plan: transformative structural and demographic imbalances (more than 50% of all agricultural land is occupied by 6% of farms larger than 100 hectares); the increasing average age of farmers and insufficient level of agricultural education (only 18% of Spanish agricultural workers have a medium level of education and 75% have a low level); the digital skills gap and the use of digital technologies in rural areas; and the low competitiveness of small-scale farming. In addition to the need for adaptation to the requirements of small-scale farming, the new CAP Strategic Plan for Spain lacks adequate attention to organic farming, which is a bottleneck for all agricultural sector beneficiaries. To maintain territorial balance and reduce disparity levels, this study provides a set of narratives that could improve the adaptation of small-scale farming to the new CAP Strategic Plan for Spain. Leveraging the positive experiences of other countries could be beneficial in overcoming these disparities. The provided recommendations can serve as a basis for further scientific discussion and the improvement of agricultural policy. Further research could focus on a more in-depth analysis of the effectiveness of eco-schemes for small-scale farming and the socio-economic impacts of new policy initiatives on small family farms and remote rural areas.

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Conflict of interest

None.

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Спільна сільськогосподарська політика для малих фермерських господарств в Іспанії (2023-2027): критичний огляд

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► **Анотація.** Роль малого фермерства у формуванні сталої продовольчої системи є значною через його більшу здатність підтримувати біорізноманіття, забезпечувати доступність продуктами харчування та робочими місцями населення віддалених районів сільської місцевості, зберігати ідентичність локального виробництва. Відповідно, будь-яка реформа Commission Agricultural Policy потребує оцінки з цієї точки зору. Метою цього дослідження було критично оцінити потенціал адаптації потреб малого фермерства у новому стратегічному плані Commission Agricultural Policy Іспанії та надати рекомендації, які допоможуть подолати виявлені диспропорції. Відповідно, керуючись статистичною інформацією було зроблено аналітичний огляд сільськогосподарського сектору та досліджено головні тенденції трансформаційних змін у структурі фермерства Іспанії. Аналіз політичного документу дозволив виокремити компонентні зміни відповідно до реформування сільськогосподарської політики. Метод аналітично-критичного мислення було використано для аналізу структури платежів та справедливого перерозподілу коштів для малого фермерства. Результатом стало виявлення вузьких місць та диспропорцій у новому стратегічному плані Commission Agricultural Policy Іспанії та надання відповідних рекомендацій, які б могли сприяти кращій адаптації малих ферм нової сільськогосподарської політики. Надані рекомендації можуть стати основою для подальшої наукової дискусії та удосконалення сільськогосподарської політики. Це дослідження може бути корисним для зацікавлених сторін у прийнятті політичних рішень в процесі кращої адаптації до виконання заявлених амбітних цілей нового стратегічного плану Commission Agricultural Policy

► **Ключові слова:** еко-схеми; активне фермерство; підтримка перерозподільного доходу; розвиток сільських територій; органічне землеробство

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Economic aspects of Industry 4.0 marketing technologies implementation in the agricultural sector of Ukraine

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► **Abstract.** The study aimed to assess the impact of Industry 4.0 marketing technologies on the efficiency of business processes in the agro-industrial complex of Ukraine in the current market conditions. The study established that Industry 4.0, as a new stage of technological development, radically changes traditional methods of production, business and management by integrating digital technologies with physical processes. With the use of big data, artificial intelligence, and machine learning, agricultural businesses can create accurate customer profiles, develop personalised marketing campaigns, and automate routine tasks such as audience segmentation and forecasting market changes. The study also addressed the impact of the Internet of Things, social media and digital platforms on customer engagement and supply chain management. Innovations in e-commerce and the use of augmented and virtual reality also substantially improve the marketing efficiency of agricultural enterprises. The impact of the war in Ukraine on the introduction of digital technologies in the farming sector was emphasised. While investment in digitalisation declined during the conflict, the war also stimulated the search for innovative solutions, such as the use of drones to monitor fields and technology to improve cybersecurity. The impact of the war on consumer habits and priorities has also necessitated rapid adaptation of marketing strategies. Based on the study, which included a survey

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of 727 enterprises, the level of adoption of Industry 4.0 technologies among large, medium and small enterprises, as well as their plans for further implementation, was determined. The results showed that large enterprises are leading the way in adopting new technologies such as data analytics and artificial intelligence, while small and medium enterprises are just beginning to implement these solutions

▸ **Keywords:** digital transformation; business efficiency; process optimisation; customer interaction; competitive advantages

▸ Introduction

The Ukrainian modern agricultural sector is on the verge of significant transformations driven by global digitalisation trends and the transition to Industry 4.0. These trends reflect a new approach to agriculture, where the integration of marketing technologies is becoming a key factor in achieving competitive advantage and ensuring the sustainable development of enterprises. Faced with the challenges of global competition, and the need to improve production efficiency and adapt to climate change, Ukrainian agricultural companies are increasingly looking to the opportunities offered by the latest technologies. The research relevance is determined by the agricultural sector being one of the main sectors of the Ukrainian economy, which provides a significant share of the country's gross domestic product (GDP) and affects its economic stability. At the same time, the application of Industry 4.0 marketing technologies in the agricultural sector remains at an early stage, which requires in-depth analysis and development of practical recommendations for enterprises. The implementation of innovative solutions will not only optimise production and sales processes but also help develop new markets, improve product quality and increase consumer confidence.

The main problem is that most agricultural enterprises in Ukraine do not fully realise the potential of Industry 4.0 marketing technologies, which can lead to a loss of competitiveness in the global market (Davlikanova & Osadchuk, 2022). Challenges such as insufficient digital literacy, lack of financial resources to implement modern technologies, and a shortage of specialists capable of working with new tools are significant obstacles to digital transformation. In addition, there is a need to develop comprehensive strategies that would address the specifics of Ukraine's agricultural sector and promote the effective use of marketing technologies. Industry 4.0 involves the widespread adoption of digital technologies such as artificial intelligence, big data, the Internet of Things, blockchain and other innovations that can radically change approaches to business management (Bodi *et al.*, 2021). In the context of the agricultural sector, these technologies can be used to automate production processes, analyse market data, forecast demand, and develop personalised marketing strategies. The use of such tools increases the accuracy of forecasts, reduces costs and improves customer interaction, which contributes to the competitiveness of enterprises in the global market. The analysis of scientific papers by leading experts in the field of Industry 4.0 implementation in the agro-industrial complex demonstrates that marketing technologies play a critical role in improving the efficiency and sustainability of agricultural enterprises. M. Huang & R.T. Rust (2020) addressed the use of big data and artificial intelligence to personalise marketing strategies. He argued that the integration of these technologies can improve the accuracy of market forecasts, which in turn helps to optimise production processes and reduce marketing costs. A. Duhinets (2018), in turn, studied the impact of the Internet of Things (IoT) on the automation of marketing campaigns in the agricultural sector. The author noted that IoT makes it possible to track consumer behaviour in real-time.

S. Menon & K. Jain (2024) addressed the role of blockchain technologies in ensuring transparency and trust in agricultural supply chains. Following their opinion, blockchain not only simplifies product tracking but also strengthens consumer confidence in the brand, which is a key factor in the current market environment. I. Ponomarenko *et al.* (2023) also analysed the use of artificial intelligence in marketing analytics, for market segmentation and demand forecasting. J.D. Borrero & J. Mariscal (2022) addressed the impact of digital platforms on the development of agricultural business. They noted that such platforms not only simplify the interaction between businesses and consumers but also provide new opportunities for promoting products on the global market. M.S. Azimi Mahmud *et al.* (2020) studied the impact of automation on the operational efficiency of agricultural enterprises. They noted that the introduction of robotic systems and automated analytical tools into marketing processes can significantly reduce costs and increase productivity. G. Dalmarco *et al.* (2019) emphasised that data security is a necessary element for the successful implementation of Industry 4.0 marketing technologies, as it directly affects customer trust. L. Klerkx *et al.* (2019) highlighted the social aspects of the digitalisation of the agricultural sector, in particular, the impact of new technologies on the level of employment and qualifications of workers. U.O. Nnaji *et al.* (2024) noted that companies that effectively use customer data can significantly increase their competitiveness in the market. E. Raji *et al.* (2024a) studied the impact of the integration of digital tools on management decisions in the agricultural sector.

The results of these studies emphasise the importance of implementing Industry 4.0 marketing technologies in the agro-industrial complex of Ukraine to increase its competitiveness and sustainability in the face of global challenges. Despite the significant contribution of previous studies to the development of Industry 4.0 marketing technologies in the agricultural sector, there are still areas that remain insufficiently studied. Little attention was devoted to the integration of marketing technologies with traditional business processes in Ukrainian agricultural enterprises, especially in the context of small and medium-sized companies that have limited resources for digitalisation. The impact of such technologies on socio-economic aspects, including employment and income levels, has also been insufficiently studied.

The study aimed to analyse the integration of Industry 4.0 marketing technologies into the business processes of Ukrainian agro-industrial enterprises, covering various aspects and challenges. The objectives of the study are to identify key barriers and opportunities for integrating Industry 4.0 marketing technologies into business processes; and to study the impact of marketing technologies on the socio-economic indicators of rural areas, on employment and income.

▸Materials and methods

The study analysed the level of implementation and planning of the use of technologies such as Big Data, artificial intelligence (AI), machine learning, IoT, blockchain and cloud technologies in agribusinesses of various sizes. The research also included a qualitative study of practical cases of marketing technology implementation on the example of large agricultural companies such as Kernel (2019) and MHP (2021). For this purpose, the corporate reports of these companies, which contain detailed information on the implementation of innovative technologies in their business processes, were employed. These reports provided valuable data on the specific technologies that were integrated and the results of their use. This approach was used to capture not only theoretical aspects but also the practical experience of large agricultural enterprises. In addition, an important aspect of the study was the analysis of the impact of military operations in Ukraine on the digitalisation of the agricultural sector. During the war, many businesses were forced to adapt their business processes to ensure sustainability and efficiency.

In 2021, researchers from the Department of Marketing of Odesa Polytechnic National University, together with the analytical group of the National Qualifications Agency, State Employment Service and the Representation of the Friedrich-Ebert-Stiftung Fund, with the support of experts from the Odesa State Academy of Civil Engineering and Architecture, conducted research work. The results of this survey were used to assess the level of adoption of Industry 4.0 technologies, their impact on business processes, and to analyse changes in the marketing strategies of enterprises in the face of current challenges. The study included a quantitative survey of representatives of agricultural, forestry and fisheries enterprises, which included sending questionnaires to the heads of these enterprises. To create the sample, the number of large, medium and small enterprises in the specified industries was initially designated. Based on the similarity in the areas of application and implementation of Industry 4.0 technologies, the sub-sectors were grouped into 6 main categories for the study: crop production, livestock farming, mixed agriculture, forestry, hunting and fishing.

The sample size consisted of 727 enterprises, ensuring an error margin of no more than 3.7% with a 95% confidence level. Companies were selected based on specific criteria. Large enterprises, which have significantly greater financial resources and technological equipment enabling them to implement Industry 4.0 technologies earlier, were fully surveyed, amounting to 43 companies. Medium-sized enterprises were randomly selected, representing 10.5% of the total, as they are also actively implementing innovations. This group comprised 240 medium-sized enterprises. Small enterprises, selected at a rate of 0.93% due to their size and lower innovation activity, totaled 444 businesses.

The survey covered two key multiple-choice questions to assess the state of implementation of Industry 4.0 technologies at various enterprises and their plans, as well as the impact of these technologies on various aspects of their operations. The first question was about the technologies that have already been implemented since the company was founded and those that are planned to be implemented in the short and long term. The second question of the survey: "What transformations (personnel, economic, business processes) has the introduction of new technologies caused?" the questionnaire provided multiple choice answers. All survey participants were informed about how their anonymity is ensured, they know why the survey is being conducted, how the data they provide will be used, and the risks involved. The research was conducted following the rules of the The Declaration of Helsinki (1975).

▸ Results

Industry 4.0, also known as the Fourth Industrial Revolution, represents a new era in technology development that is transforming traditional methods of production, business and management. Unlike previous phases of industrial revolutions that focused on mechanisation, electrification and automation, Industry 4.0 integrates digital technologies with physical processes, creating smart systems that can autonomously respond to changes and optimise operations in real-time. Industry 4.0, as the latest stage of technology development, is fundamentally changing not only production processes but also the marketing strategies of enterprises. In this context, marketing is becoming more integrated, personalised and data-driven, allowing businesses to better understand consumer needs and quickly adapt to market changes. One of the key characteristics of marketing technologies in Industry 4.0 is their ability to collect and analyse large amounts of data. Thanks to modern analytical tools, companies can obtain detailed information about consumer behaviour, preferences, demographics, and even emotional reactions to certain products (Lin *et al.*, 2020). This data can be used to create highly accurate customer profiles and develop personalised marketing campaigns, which significantly increases their effectiveness. AI and machine learning allow automating routine tasks such as audience segmentation, creating personalised offers, and optimising marketing campaigns. Thanks to AI, companies can predict changes in the market and adapt their strategies to new conditions, which gives them a significant advantage over competitors.

In the context of Industry 4.0, marketing technologies also have a significant impact on customer interaction. Modern digital marketing platforms allow for a dialogue with customers through various channels, such as social media, messengers, email. This creates a new level of interaction, where the client becomes an active participant in the process, not just a consumer of a product or service. Feedback from customers is used to improve the quality of goods and services, as well as to create new products that best meet their expectations. The use of cloud technologies is also becoming an important aspect of marketing

in Industry 4.0. They allow storing and processing large amounts of data, providing quick access to information from anywhere and at any time (Misra *et al.*, 2022). This allows companies to be more flexible and adaptive, as well as to respond quickly to changes in the market situation. In the context of agribusinesses, digital innovations play a crucial role in transforming marketing activities, increasing their efficiency and contributing to the development of sustainable business models. The use of modern technologies allows agribusinesses not only to improve customer interaction but also to optimise all stages of the marketing process – from market research to product promotion and sales management (Ievoli *et al.*, 2019). One of the most significant areas is the use of big data for market analytics. In the agriculture sector, data can be collected from numerous sources, such as climatic conditions, yields, changes in raw material prices, consumer behaviour, and even social media (Lioutas *et al.*, 2019). Using this data, businesses can more accurately forecast demand, adjust their products to meet market needs and increase profitability by optimising costs.

Artificial intelligence is also having a significant impact on the marketing of agricultural companies. Thanks to machine learning algorithms, companies can automate processes such as market segmentation, targeted campaign development, and sales forecasting. This allows them to respond quickly to changes in consumer preferences and market conditions, which is especially important in times of instability caused by, for example, climate change or global crises. The IoT opens new opportunities for precise supply chain management and transparency at all stages of production. This is especially true for agribusinesses, where product quality often depends on factors such as weather conditions, storage and logistics. Thanks to IoT, companies can monitor all these aspects in real-time, which not only improves product quality but also better informs consumers about the conditions of its production, thereby increasing brand trust (Yue *et al.*, 2021). Social media and digital platforms are becoming an important communication channel for agribusinesses, especially in a globally competitive environment. Using these platforms, companies can interact directly with their customers, gather feedback and respond quickly to market demands. Digital platforms also allow companies to expand their markets by entering new geographical regions and attracting new consumers. Innovations in e-commerce are also playing a significant role, as it is becoming an important part of the marketing activities of agribusinesses. Online sales allow agribusinesses to expand their customer base by offering products directly to consumers (Dash *et al.*, 2021). This not only increases sales but also contributes to the loyalty of customers who value convenience and accessibility.

Augmented reality (AR) and virtual reality (VR) are finding their way into the marketing of agricultural enterprises, allowing for interactive product presentations and virtual tours of farms. This is particularly relevant for premium products, where demonstrating the production process and quality assurance plays an important role. With AR and VR, consumers can "visit" the farm where their products are grown, which creates a deeper emotional connection with the brand (Bowen & Morris, 2019). Blockchain technologies are also becoming an important element of digital innovation in the marketing of agricultural enterprises. They ensure transparency and security of transactions, which is important for maintaining trust between all market participants – from producers to end consumers. In addition, blockchain allows tracking the entire supply chain of products, which is especially important for organic and environmentally friendly products, where proof of compliance with quality standards plays an important role (Lin *et al.*, 2020). The digitalisation of the Ukrainian agricultural sector is an important process aimed at increasing the productivity, efficiency and competitiveness of agricultural enterprises. However, despite certain achievements, the level of digitalisation in the Ukrainian agricultural sector remains uneven and requires significant improvement. This process has faced new challenges since the beginning of the Russian invasion of Ukraine, which has added even more difficulties in achieving sustainable development in the sector. One of the key indicators that characterise the level of digitalisation is the use of modern technologies to manage production processes and analyse data.

Ukrainian agribusiness companies such as Kernel (2019) and MHP (2021) demonstrate impressive examples of how they have implemented marketing technologies to improve the efficiency of their business processes and strengthen their market positions. Kernel, one of the largest agro-industrial holdings in Ukraine, is implementing various marketing technologies to improve its management and communication processes. One of the main drivers is digital marketing, including the use of analytical platforms to collect and process data. The company uses business intelligence systems to study market trends, the competitive environment and consumer preferences. This supports informed decision-making, the development of targeted advertising campaigns and the optimisation of marketing strategies. For example, Kernel implements loyalty programmes and personalised advertising campaigns, focusing on the individual needs of customers. The company actively uses social media to promote its brand and interact with the audience. This includes publishing information about company news, environmental initiatives and product innovations. The use of marketing process automation platforms, such as customer relationship management (CRM) systems, helps to effectively manage customer and partner relations.

MHP (former Myronivsky bread product), one of the leaders in the Ukrainian poultry and feed market, is also actively implementing marketing technologies to improve its competitiveness. One of its key practices is the use of digital platforms to expand market opportunities. The company uses online marketing to promote its products both domestically and internationally. This includes search engine optimisation (SEO), content marketing, brand reputation management and online advertising. MHP implements integrated marketing campaigns that combine online and offline channels. For example, the company uses social media management tools to keep in touch with end users and inform them about new products, promotions and special offers. This helps to create a positive brand image and increase brand awareness. In addition, MHP invests in technology to analyse data

and market trends, which allows the company to adapt its strategies to changing market conditions. The use of analytical tools determines the effectiveness of advertising campaigns, identifies new business opportunities and optimises marketing costs. At the same time, small and medium-sized farms face financial constraints, a lack of skilled labour and insufficient access to modern technology. As a result, they may be at the stage of implementing basic digital solutions, such as electronic resource records or simple financial management software. These farms are not yet ready to implement complex analytical systems or automation. State support for the digitalisation of the agricultural sector remains fragmented. Despite government initiatives to provide subsidies and grants, their scope and accessibility to small and medium-sized farmers are limited. The low level of digital literacy among farmers also hampers the widespread adoption of new technologies. In addition, poor infrastructure, especially in rural areas, including poor access to the internet and modern communications, hinders digitalisation.

The war in Ukraine has significantly worsened the situation. It destroyed infrastructure, especially in the areas of active hostilities, making it difficult for many farmers to operate. The loss of internet access in some regions has made it impossible to use digital technologies to manage fields, supply chains or exchange data with partners. The war has also reduced investment in the agricultural sector, including investment in digitalisation. In the face of high uncertainty, businesses are allocating resources to ensure safety and survival, leading to the postponement of modernisation plans. However, the war has also stimulated the search for innovative solutions. Agribusinesses that continue to operate are making greater use of drones to monitor fields and collect information, as well as remote technologies to reduce their physical presence in the field. The rise in cyber threats during the war has pushed businesses to pay more attention to cybersecurity. The war has also changed consumer behaviour and priorities, requiring agribusinesses to quickly adapt marketing strategies and make greater use of digital platforms to stay connected with customers, especially in international markets. In 2021, a study was conducted on the implementation of Industry 4.0 technologies and their impact on the transformation of enterprises in the agriculture, forestry and fisheries sectors of Ukraine (Fig. 1).

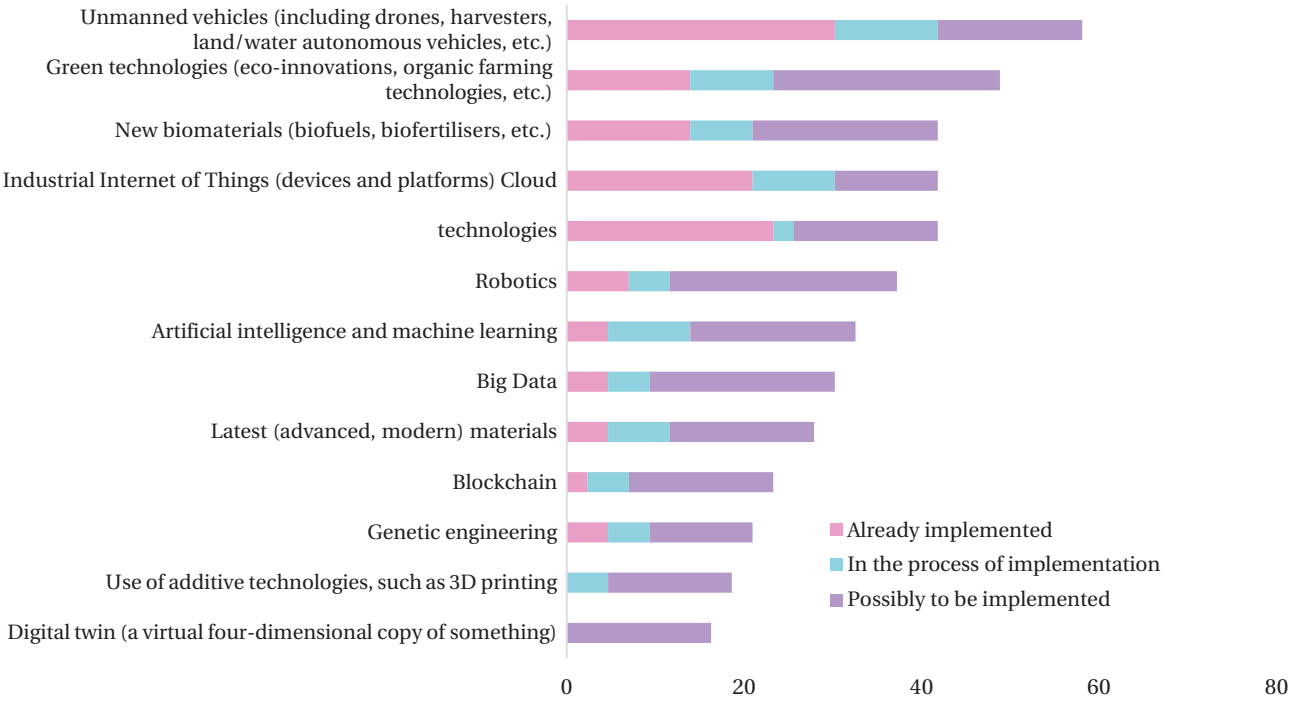

Figure 1. Implemented technologies and technologies that may be implemented at large enterprises, %
Source: compiled by the authors based on Kernel (2019)

Figure 1 illustrates the level of adoption and the potential for further use of Industry 4.0 technologies in large enterprises. Large enterprises are leading the way in technology adoption: about 50% of them have already integrated or plan to integrate green technologies; about 40% are actively working on the introduction of new biomaterials, the industrial Internet of Things, cloud technologies and robotics. In terms of marketing technologies, innovations such as Big Data, artificial intelligence machine learning, and blockchain are key to improving the effectiveness of marketing strategies. They allow for more accurate market analysis, forecasting consumer behaviour and optimising marketing campaigns in real-time. Most of the technologies are in the process of active implementation, which indicates their prospects for further development. Cloud technologies also play an important role in creating flexible marketing tools, allowing for faster adaptation to changes in market conditions. Although some of these

technologies have already been implemented, a significant number are in the process of being implemented or have the potential for future use, indicating that this area is actively developing at large enterprises (Fig. 2).

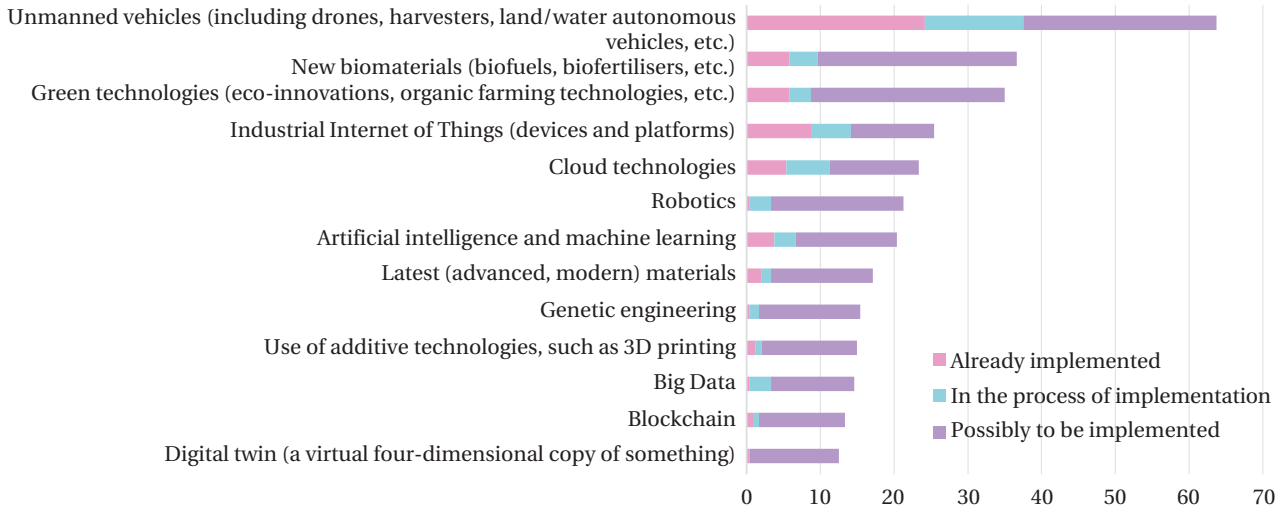

Figure 2. Implemented technologies and technologies that may be implemented at medium enterprises, %
Source: compiled by the authors based on Kernel (2019)

Figure 2 shows the level of adoption and prospects for the development of Industry 4.0 technologies in medium-sized enterprises. About 35% of medium-sized enterprises have already implemented or are planning to implement new biomaterials and green technologies; about 25% are working on the implementation of the industrial Internet of Things and cloud technologies. In terms of marketing technologies, it is important to pay attention to Big Data, Blockchain, artificial intelligence and machine learning, as well as cloud technologies, where they have already been partially implemented or are in the process of being implemented, which indicates that medium-sized enterprises are beginning to realise their importance for increasing competitiveness. The use of these technologies allows for more effective market analysis, personalised marketing campaigns, optimised advertising costs, and improved customer experience. However, adoption remains at an early stage, indicating significant potential for further development in this area (Fig. 3).

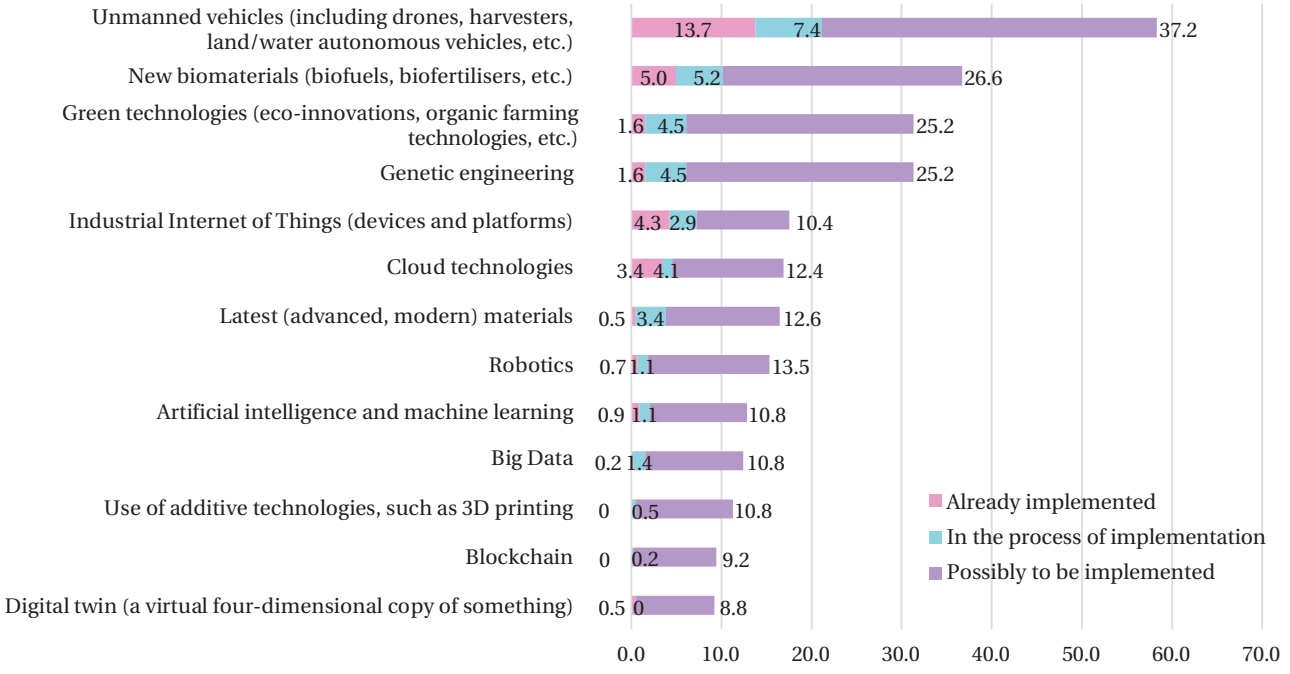

Figure 3. Implemented technologies and technologies that may be implemented at small enterprises, %
Source: compiled by the authors based on Kernel (2019)

Figure 3 shows the adoption and possible development of Industry 4.0 technologies in small enterprises. About 35% of small businesses have already integrated or are planning to introduce new biomaterials and green technologies; about 17% are working on the introduction of the industrial Internet of Things, cloud technologies, new materials and robotics. In terms of marketing technology, these technologies have not yet been implemented in small businesses, but their potential remains significant. Big Data and artificial intelligence can significantly improve the accuracy of marketing decisions, allowing small businesses to better understand the market and customers, while cloud technologies provide access to analytical tools and marketing platforms without significant investment. At the same time, the low level of adoption indicates certain barriers, such as limited resources or lack of relevant skills, which require further attention to realise the marketing potential of Industry 4.0 in small businesses. The next aspect of the Industry 4.0 survey concerned the transformations that their introduction causes. 74% of respondents believe that new technologies will improve the efficiency of their company; 27% expect an increase in sales; 18% of respondents predict a reduction in the number of employees and an increase in the need for investment. There are significant differences in expectations of efficiency gains by business size, indicating that larger businesses are adopting more technology and experiencing more transformation as a result of its implementation (Fig. 4).

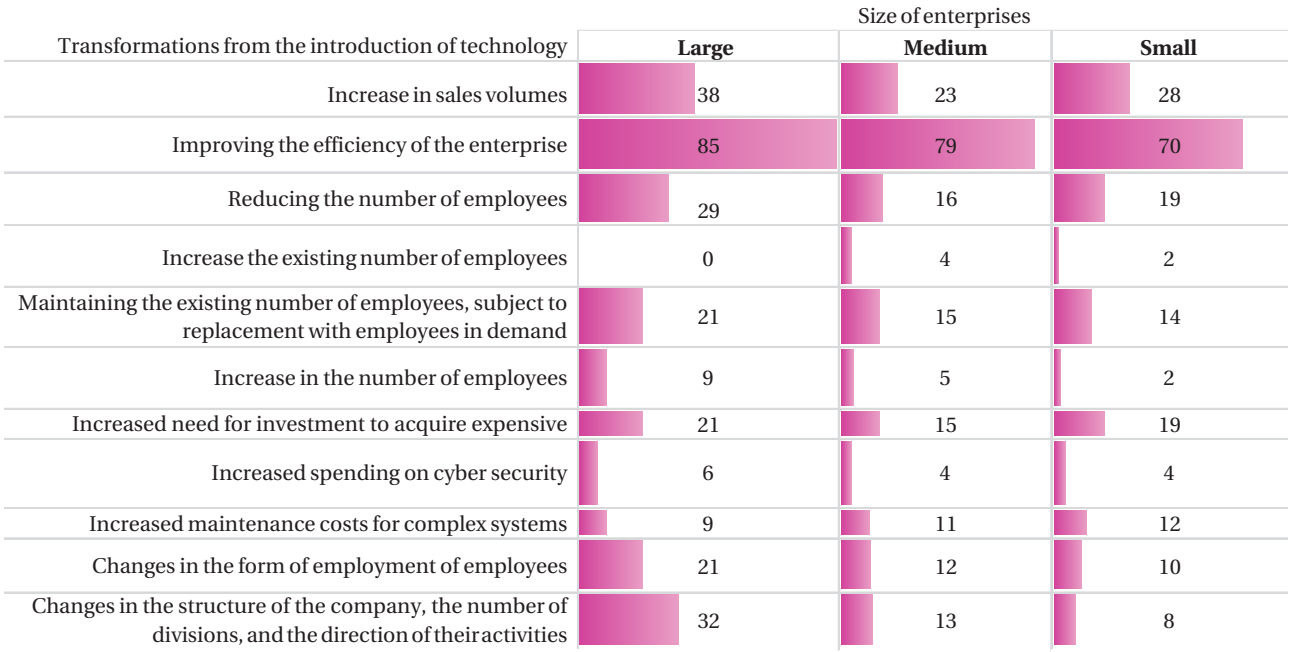

Figure 4. Transformations expected by enterprises from the introduction of Industry 4.0 technologies by enterprise size, %
Source: compiled by the authors based on Kernel (2019)

Large enterprises expect significant improvements in operational efficiency (85%) and sales (38%), indicating their desire to make the most of new technologies to optimise marketing processes and expand their markets. This reflects their ability to integrate advanced marketing tools, such as Big Data analytics and the use of artificial intelligence, to improve targeting and personalisation. Small and medium enterprises (SMEs) also expect to increase efficiency (79% and 70% respectively) but with lower expectations of increased sales (23% and 28%). This indicates that they are just beginning to use Industry 4.0 marketing technologies, focusing on internal processes and cost optimisation. However, these businesses recognise the need for investment (19% of small businesses), indicating that they are ready to further develop and implement new marketing technologies to achieve competitive advantage.

The war in Ukraine has a potentially significant impact on the adoption and use of digital technologies in agricultural enterprises, which will certainly affect the data presented in the previous tables. The priorities of agricultural enterprises have changed significantly during the war. While they used to focus on implementing innovative technologies to increase efficiency and expand markets, they may now be forced to postpone or reconsider their investments in digital solutions. The main goal may be to ensure the safety of production, preserve existing facilities and recover from destruction. War causes economic difficulties, including reduced financial resources and limited investment. Agribusinesses may have to redirect their budgets to reconstruction and urgent needs, which will affect their ability to introduce new technologies. In an environment of volatility and risk, there may be a growing need for solutions to manage risks, better monitor resources and ensure the sustainability of production processes. This may lead to an increase in demand for safety and sustainability technologies, which may shift the focus from marketing innovations to technical and operational solutions. The introduction of marketing technologies in the agricultural sector has significant potential to change the structure of employment and social services in rural

areas. On the one hand, the automation of marketing processes and the use of digital platforms may lead to a reduction in the need for some traditional roles, such as sales agents or distributors. However, on the other hand, the emergence of new technologies is creating new jobs that require specific knowledge and skills in digital marketing, data analytics, online platform management, and customer support (Peter & Dalla Vecchia, 2021). This opens up opportunities for young professionals in rural areas who can gain new skills and knowledge while staying in their communities. Instead of migrating to cities to find work, they can work locally, contributing to the preservation and development of rural communities. In addition, increasing digital literacy in rural areas can promote social inclusion and engage local people in global economic processes.

By using digital tools for market analysis and product promotion, small farmers and craft producers can access wider markets, including international markets. This contributes to the development of small and medium-sized enterprises, the creation of new jobs, and increased incomes for the local population. However, this process requires government support and investment in education and infrastructure. Marketing technologies also contribute to the development of regional branding. Regions with unique natural conditions or traditional production practices can use these advantages to create brands that are recognisable at the national and international levels (Egieya *et al.*, 2023). This increases the added value of products and helps to attract investment in the development of the regional economy. In the context of global climate change, marketing technologies play an important role in ensuring the sustainable development of agricultural enterprises. One of the key areas is the use of technology to promote environmentally friendly and organic products. Modern consumers are increasingly paying attention to the environmental friendliness of products, so agricultural companies that implement sustainable practices can gain competitive advantages in the market. Thanks to marketing technologies, agrarians can communicate more effectively with consumers, informing them about the environmental benefits of their products, sustainable use of resources, and responsible business practices (Matzembacher & Meira, 2019). This not only increases demand for such products but also encourages other businesses to adopt sustainable practices that reduce their environmental impact.

Overall, modern technology opens up new opportunities to optimise business processes, improve product quality and expand markets. However, to realise these benefits, agricultural businesses need to carefully consider several key aspects and strategies. One of the key elements of Industry 4.0 is big data and analytics. Agribusinesses need to integrate data management systems that allow them to collect, store and analyse information about production, product quality, market conditions and consumer preferences (Rivera *et al.*, 2020). This can be achieved through the implementation of enterprise resource planning (ERP) and CRM systems, which help automate business processes and improve customer interaction. The use of analytical platforms allows agricultural enterprises to make more informed decisions, forecast demand and adapt their strategies to changing market conditions. Digital marketing is an effective instrument for promoting the products of agricultural enterprises. It is recommended to implement comprehensive marketing campaigns that include SEO, content marketing, social media and email marketing. Businesses should actively use social media to communicate with end users, promote products and increase brand awareness. Content marketing, in particular, can include blogging, posting on news platforms and creating video content to help raise awareness of products and branding.

Automating marketing processes reduces the time and resources spent on routine tasks for agricultural businesses. Marketing automation platforms can be used to manage advertising campaigns, segment audiences, manage email campaigns and conduct campaign analytics. This ensures more efficient use of marketing budgets and improves campaign results through accurate targeting and personalisation. For the successful implementation of marketing technologies, it is important to invest not only in the technology itself but also in staff training. Businesses need to provide their employees with the necessary knowledge and skills for new systems and technologies. This can include regular training sessions, seminars and educational programmes. In addition, it is important to have digital marketing and analytics specialists who can help develop and implement strategies. Continuous evaluation of the effectiveness of implemented technologies is critical. Agribusinesses should regularly analyse the results of their marketing campaigns, use the data to adjust strategies and implement new solutions depending on changes in market conditions and consumer needs. The use of key performance indicators (KPIs) helps to identify weaknesses and improve results. Thus, the implementation of Industry 4.0 marketing technologies in agricultural enterprises is a complex but important process. The use of data analytics, digital marketing, process automation, investment in training, performance measurement and support for sustainable development help agricultural enterprises adapt to modern market requirements, improve their competitiveness and ensure sustainable development in the face of global change.

▸ Discussion

The results of the study of the implementation of Industry 4.0 technologies in the Ukrainian agricultural sector have shown that these innovations can significantly transform the agricultural business while posing new challenges to enterprises. Industry 4.0 envisages the integration of modern digital technologies into all aspects of production and management, which has the potential to increase the efficiency, transparency and sustainability of the agricultural sector. E.D. Lioutas *et al.* (2019) investigated the impact of big data on the marketing strategies of agricultural enterprises. Their findings support the conclusion that big data contributes to more accurate market segmentation and personalisation of marketing campaigns. E. Raji *et al.* (2024b) emphasise that enterprises that actively use big data analytics demonstrate better financial performance and increased competitiveness. The current results in this regard coincide with the findings, confirming the effectiveness of big data in modern marketing strategies of agricultural enterprises.

Industry 4.0 technologies have significant potential to transform marketing approaches in the agricultural sector. Big data, artificial intelligence and blockchain can radically change the approach to market segmentation, targeted marketing and supply chain management (Lipych *et al.*, 2023). The use of big data allows agricultural businesses to analyse consumer behaviour and predict market trends with greater accuracy, which in turn allows them to develop more personalised and effective marketing campaigns. Artificial intelligence can automate complex processes such as audience segmentation and optimisation of advertising campaigns (Shtovba, 2023). Blockchain, for its part, can provide greater transparency in supply chains, which is critical for marketing strategies focused on environmental and social responsibility. A. Subeesh & C. Mehta (2021) investigated the impact of artificial intelligence on the automation of production processes in large agricultural holdings. Their findings highlight that AI technologies can reduce operating costs and increase the efficiency of enterprise management. However, in contrast to the current study, the authors note that AI has not yet been widely implemented in small and medium-sized enterprises due to high costs and a lack of knowledge among managers. This underscores the existence of a gap between large and small enterprises, which was also found in the current study, but less emphasised.

G. Mirabelli & V. Solina (2020) analysed the impact of blockchain technologies on supply chain transparency in the agricultural sector. Their findings show that blockchain adoption is effective in ensuring transparency and increasing consumer confidence, especially in the context of exports. They highlight the importance of blockchain technologies for the marketing of environmentally friendly products. The current study confirms these findings, especially concerning the potential of blockchain to increase transparency and sustainability of marketing strategies. However, the introduction of such technologies in the agricultural sector faces several serious challenges. One of the key constraints is the lack of digital literacy among agricultural workers, especially in small and medium-sized enterprises. While large agricultural holdings, such as Kernel and MHP, are actively implementing the latest technologies, small and medium-sized enterprises often lack the resources to do so. This leads to a significant part of the agricultural sector being left out of the digital transformation. A. Rejeb *et al.* (2022) investigated the impact of the IoT on the efficiency of agricultural enterprise management. In their work, they emphasise that the introduction of IoT allows farmers to significantly optimise production processes, through automated monitoring of soil conditions, weather conditions, and plant health. A. Rehman *et al.* (2022) note that the use of IoT helps to increase yields and reduce the cost of agricultural work, especially in large agricultural holdings. Compared to the current results, the findings confirm the significant role of IoT in improving the efficiency of agricultural enterprises. However, the current findings also show that SMEs face challenges in implementing IoT due to high initial investments and a lack of necessary infrastructure.

The war in Ukraine has created additional barriers to the adoption of Industry 4.0 technologies in the agricultural sector (Semenenko *et al.*, 2023). The destruction of infrastructure, interruptions in internet access and general economic instability have forced many agricultural businesses to rethink their priorities and postpone investments in digital technologies (Stender *et al.*, 2024). At the same time, changing market conditions and the need to ensure business security and sustainability have created a demand for new technological solutions that can help businesses adapt to new realities. M. Gupta *et al.* (2020) investigated the impact of various factors on the digital transformation of the agricultural sector, including cybersecurity. Their study showed that external risks have pushed businesses to actively implement cybersecurity measures to protect critical data. A. Sridhar *et al.* (2022), in turn, noted the growing demand for remote management and monitoring. They emphasised that remote solutions have become key tools for agricultural enterprises during crises, ensuring the continuity of operations even in unforeseen situations. The results of these authors confirm the importance of data security and integration of remote technologies, which coincides with the findings of the current study. On the other hand, their research is more focused on specific aspects of digital transformation, such as cybersecurity and remote management, while the current study covers these issues more broadly.

The introduction of Industry 4.0 technologies not only affects the economic efficiency of agricultural enterprises but also has significant social implications. Automation and digitalisation may lead to job losses in traditional roles, especially in rural areas where the agricultural sector is the main source of employment. However, at the same time, there is a demand for new skills, which creates employment opportunities for young IT and digital professionals. S. Rolandi *et al.* (2021) examined the impact of digital transformation on the social sphere, on employment in rural areas. They conclude that automation and digitalisation can lead to significant job losses, especially among unskilled workers. This result is fully consistent with the current study, which also highlights the risks associated with the loss of traditional jobs in the agricultural sector. From an economic development perspective, the introduction of digital marketing technologies can open up new markets for small and medium-sized enterprises (Shahini *et al.*, 2023). This, in turn, contributes to revenue growth and can support the development of local economies. Digital platforms provide small businesses with access to global markets, enabling them to compete with larger players. N.T. Loan *et al.* (2023) focused on the impact of digital platforms on export opportunities for small and medium-sized agricultural enterprises. They note that digital platforms provide small enterprises with access to international markets, which contributes to revenue growth and business expansion. These findings are in line with current findings on the role of digital technologies in expanding market opportunities for small enterprises, confirming the importance of digital innovation for their development.

Industry 4.0 has significant potential to transform the Ukrainian agricultural sector. However, several issues need to be overcome to realise this potential. These include insufficient investment in digital infrastructure, a

lack of digital skills among employees, and the absence of a comprehensive digital transformation strategy at the state level. To successfully implement marketing strategies based on Industry 4.0 technologies, agricultural enterprises need to more actively implement digital solutions, invest in staff training, and use government support. It is also important to develop infrastructure that will provide reliable access to the Internet even in remote regions.

Conclusions

The study analysed the adoption of Industry 4.0 technologies and their impact on the transformation of marketing strategies of Ukrainian agribusinesses. The study showed that Industry 4.0 is a crucial factor in improving marketing strategies through the introduction of analytical platforms, AI, Big Data and other advanced technologies. These technologies allow agribusinesses not only to optimise decision-making processes but also to better understand consumer needs and quickly adapt to changes in the market.

Agricultural enterprises such as Kernel and MHP demonstrate positive examples of implementing marketing technologies to improve the efficiency of business processes and strengthen their market position. However, small and medium-sized farms face financial constraints and insufficient access to modern technologies. Further government support and investment in education and infrastructure development are needed to ensure the sustainable development of the agricultural sector. The study also examines the impact of the war in Ukraine on the processes of digital transformation of the agricultural sector. It is noted that the war has created new challenges, such as the destruction of infrastructure and reduced investment in digitalisation, which complicates the process of introducing modern technologies. However, these same conditions have also encouraged businesses to look for innovative solutions, such as the use of drones to monitor fields and remote technologies to reduce physical presence in the fields.

The study findings highlight the need for government support and investment in the development of digital infrastructure, especially for small and medium-sized enterprises, to ensure a more even adoption of Industry 4.0 technologies. In addition, the importance of staff training for the effective use of new systems and technologies was highlighted as a critical factor for the successful digital transformation of Ukrainian agricultural sector. A limitation of this study is the focus on large and medium-sized enterprises, which may not fully reflect the situation in small agricultural enterprises. Further research should include an analysis of the adoption of marketing technologies in small agricultural enterprises and their impact on economic sustainability in the context of post-war reconstruction.

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Conflict of interest

None.

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Економічні аспекти впровадження маркетингових технологій Індустрії 4.0 в агропромисловому комплексі України

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► **Анотація.** Дане дослідження було направлене на аналіз впливу маркетингових технологій Індустрії 4.0 на ефективність бізнес-процесів в агропромисловому комплексі України в умовах сучасного ринку. Встановлено, що Індустрія 4.0, як новий етап технологічного розвитку, радикально змінює традиційні методи виробництва, бізнесу та управління, інтегруючи цифрові технології з фізичними процесами. Завдяки використанню великих даних, штучного інтелекту та машинного навчання, аграрні підприємства отримують можливість створювати точні профілі клієнтів, розробляти персоналізовані маркетингові кампанії та автоматизувати рутинні завдання, такі як сегментація аудиторії і прогнозування змін на ринку. Дослідження також розглядало вплив Інтернету речей, соціальних медіа та цифрових платформ на взаємодію з клієнтами і управління ланцюгами постачання. Інновації в електронній комерції та використання розширеної і віртуальної реальності також відіграють важливу роль у підвищенні ефективності маркетингу агропідприємств. Особливу увагу приділено впливу війни в Україні на впровадження цифрових технологій у аграрному секторі. В умовах конфлікту інвестиції в цифровізацію зменшилися, проте війна також стимулювала пошук інноваційних рішень, таких як використання дронів для моніторингу полів і технологій для підвищення кібербезпеки. Вплив війни на споживацькі звички та пріоритети також зумовив необхідність швидкої адаптації маркетингових стратегій. На основі проведеного дослідження, яке включало опитування 727 підприємств, визначено рівень впровадження технологій Індустрії 4.0 серед великих, середніх та малих підприємств, а також їхні плани щодо подальшого впровадження. Результати показали, що великі підприємства є лідерами у впровадженні нових технологій, таких як аналітика даних та штучний інтелект, тоді як середні та малі підприємства лише починають реалізовувати ці рішення

► **Ключові слова:** цифрова трансформація; ефективність бізнесу; оптимізація процесів; взаємодія з клієнтами; конкурентні переваги

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Food company competitiveness determination using marketing monitoring

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► **Abstract.** The study aimed to assess the market position of food enterprises and identify the key factors influencing consumer satisfaction with products. The study included a survey of 200 consumers and 50 business representatives, stratification analysis, Student's t-test and Fisher's test. The main results showed that product quality was the most important factor with a weight of 40%, while price had a weight of 25%, availability 20% and packaging 15%. Younger consumers (18-35 years old) prefer innovative and aesthetic products, while older groups value functionality and safety more. Consumers with higher education prefer environmentally friendly products, while consumers with secondary education are more likely to trust trusted brands. The analysis of professional differences demonstrated that business professionals focus on brand and price, healthcare professionals on health and safety, and educators on the value and educational impact of the product. In addition, the study found that women were significantly more likely to state that aesthetic and functional aspects of packaging were important compared to men, with average satisfaction levels of 4.5 and 3.8 respectively ($p < 0.05$). The study also determined that consumers with higher incomes are more likely to choose products with premium packaging and additional benefits. The conclusions highlight the need to adapt marketing strategies to meet the specific needs of different demographic groups, which will help to increase the

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competitiveness of food companies in the market. This research provides valuable information for food producers, improving consumer awareness and tailoring products to meet the needs

▸ **Keywords:** demographic characteristics; product quality; customer satisfaction; product evaluation; market strategy; selection factors

▸ Introduction

Competitiveness is a key factor in the success of businesses in the modern market, especially in the food industry, where consumer demands are constantly changing. Food businesses face challenges in meeting the diverse preferences of consumers, including product quality, price, availability and packaging. These factors play a critical role in shaping brand perception and customer satisfaction. However, the question of which factors have the greatest impact on customer satisfaction and preferences remains under-researched, especially in the context of different demographic and professional groups.

In Ukraine, research on the competitiveness of food companies and consumer preferences is also relevant, as the market is constantly evolving and changing (Remizova *et al.*, 2024). A.D. Berher (2023) addressed the impact of product quality on customer satisfaction and found that high-quality standards contribute to increased customer loyalty. As emphasised, the importance of quality control at all stages of production, confirms the need to implement quality management systems in enterprises. However, the study did not address the impact of packaging and other external factors on customer satisfaction.

V. Moskalenko & I. Ryabchenko (2021) addressed the influence of price on the choice of products by Ukrainian consumers. Their research has demonstrated that while price is an important factor, consumers are willing to pay more for products that meet expectations of quality and safety. This demonstrates the need to position products with high-added value in the market. The study conclusions are limited, as the influence of demographic factors such as age and education on consumer choice were not addressed.

Various studies also highlight the importance of considering demographic factors in marketing strategies. I. Kovshova & V. Hlushchenk (2021) addressed the influence of age groups on consumer preferences and determined that younger consumers prefer innovative and aesthetic products, while older consumers value functionality and safety more. They also found that older consumers are more likely to choose products with traditional recipes and natural ingredients. However, the study did not address the impact of income on consumer preferences.

Education also has a significant impact on consumer preferences. A study by I. Panova & D. Zernenkova (2023) showed that educated consumers consider the environmental and social aspects of products. They are more likely to choose products that have quality certificates and meet sustainability standards. These consumers are willing to pay more for products that align with their values. However, the study did not analyse how the impact of educational attainment varies among different professional groups.

The professional characteristics of consumers also influence their preferences. A study by Y. Yegupov & I. Yegupova (2021) determined that healthcare professionals value products that support a healthy lifestyle and contain natural ingredients more. They stressed that these consumers often choose organic and low-preservative products. However, the study did not address the influence of other professional groups on consumer preferences, which leaves room for further research in this area.

The literature analysis shows that many studies focus on specific aspects of customer satisfaction, such as quality, price or environmental friendliness of products. T. Balanovska *et al.* (2021) studied the importance of packaging for consumers and determined that modern design and sustainable materials have a positive impact on product choice, especially among young people. This confirms the need for innovation in packaging design to attract a younger audience.

Another study conducted by O. Kovalenko & L. Yashchenko (2021) addressed the impact of marketing communications on consumer preferences. They determined that effective advertising campaigns that emphasise the uniqueness and quality of products significantly increase consumer interest and trust. They also noted that the use of social media is particularly effective for younger audiences, who are active users of these platforms.

A study by A. Tanasiichuk *et al.* (2021) focused on regional differences in consumer preferences. The author determined that consumers in the western regions of Ukraine are more focused on the environmental aspects of products, while those in the eastern regions value availability and price more. This highlights the importance of adapting marketing strategies to specific regional needs.

Lastly, V. Onegina *et al.* (2022) demonstrated that high-income consumers are more likely to choose premium products that emphasise status and exclusivity. The author also determined that these consumers pay more attention to details such as the origin of ingredients and ethical aspects of production.

The literature analysis shows that many studies focus on specific aspects of customer satisfaction, such as quality, price or environmental friendliness of products. However, a comprehensive approach that addresses the influence of various demographic and professional characteristics on consumer preferences remains insufficiently researched. The study aimed to identify the key factors that influence consumer satisfaction with food products, with a focus on different demographic and professional groups.

▸Materials and methods

A comprehensive methodological approach was developed to assess the company's market position in comparison with key competitors. The competitiveness assessment was based on data obtained through consumer surveys, market research and financial analysis of market participants. The survey of consumers and representatives of the food industry was conducted between January and March 2024 using the SurveyMonkey online survey platform. The survey contained 30 detailed questions aimed at identifying consumer preferences and product satisfaction.

The sample included 200 consumers, and 50 representatives of businesses selected by random sampling from people aged 18 to 65 from different regions of Ukraine.

The demographic questions included in the questionnaire included age, gender, education, occupation, income and region of residence. This data was used for stratification analysis to determine how demographic factors influence consumer preferences and product satisfaction. Thus, the study determined which aspects of the product were most important to different consumer groups, which can be used in formulating marketing strategies. All study participants were informed about the objectives and procedures of the study, as well as the confidentiality of the data provided. The survey was anonymous, and all participants were aware of how their anonymity was ensured, the purpose of the survey, how the data they provided would be used, and the possible risks involved.

The Statistical Package for the Social Sciences software was used to analyse the collected data. Several statistical methods were used, including the Student's t-test, which was used to assess the statistical significance of differences between groups by comparing the mean values of two independent samples. For instance, this criterion was used to compare product satisfaction between men and women. In addition, Fisher's test was used to determine the significance of differences in frequency distributions. This method was used to analyse the percentage of respondents who believed that product packaging was important. All analyses were performed with a statistical significance level of $p < 0.05$. Both methods contributed to a deeper understanding of the data collected and allowed for a reasonable assessment of statistical differences and trends identified during the study.

To assess the impact of various aspects of the product on overall brand perception and customer satisfaction, a component importance analysis based on regression analysis was used. This approach was used to accurately calculate the weight of each aspect of the product, including quality, price, availability and packaging. This was used to identify the key factors that most influenced consumers' decisions. The regression analysis determined how individual product components contributed to the overall level of customer satisfaction and which ones should be improved or changed to increase brand loyalty and market perception.

As part of the marketing analysis, SWOT analysis and Porter's five forces analysis was used. The SWOT analysis was used to identify the organisation's strengths and weaknesses, as well as opportunities and threats that affected competitiveness. The analysis of Porter's five forces was used to assess the overall structure of the industry, including the threat of new competitors, the degree of rivalry between existing enterprises, the threat of product substitution, and the bargaining power of suppliers and consumers. These analyses provided information on which industry forces had the greatest impact on competitiveness.

All study participants were informed about the objectives and procedures of the study, as well as the confidentiality of the data provided. Participation in the study was voluntary, and all data was used exclusively in aggregate form for scientific analysis. The study was conducted following the rules of The Declaration of Helsinki (1975).

▸ Results

The primary task for companies should be to analyse the age preferences of consumers. Accounting for these differences is critical for the determination of the needs of customers, which can be used to develop products that not only meet their expectations but also reflect their specific needs. Adapting the product line to different age segments helps to attract and retain customers more effectively, ensuring longer and more effective relationships between consumers and brands (Table 1).

Table 1. Consumer preferences depending on their age

Age groups	Advantages in products	The main characteristics that influence the choice	Media activity	Environmental friendliness and social responsibility	Number of respondents (%)
18-35 years	Modern trends in style and technology	The importance of aesthetics and innovation	High, especially in social media	Choosing products that support sustainable development	100 (50%)
36-50 years	Functionality, improved health characteristics	Demanding quality and durability	Moderate	Preference for products that offer added value	60 (30%)
50+ years	Health, safety, convenience	Prefer products that promote health and well-being	Low	Preference for natural ingredients, minimal additives	40 (20%)

Source: compiled by the authors

The analysis of data among consumers aged 18 to 35, which covers 50% of the target audience, revealed that modern trends in style and technology play a key role in this demographic. This indicates a deep interest of young people in the latest innovations that influence their purchasing decisions. The study determined that 30% of consumers aged 36 to 50 prefer products that offer improved functional and health benefits, while 20% of consumers over 50 focus on products that promote health and safety. This data highlights the importance of adapting products and marketing strategies to the age-specific characteristics of consumers.

A detailed study of age preferences shows significant differences in consumer behaviour between younger and older age groups. Younger consumers (18 to 35 years old) highly value the aesthetic appearance and innovation of

products that are in line with modern stylistic trends and technological innovations. They actively use social media as their primary channel for product information and are often responsive to marketing that uses these platforms. The study also determined that young consumers are more likely to choose products that reflect their social and environmental outlook, such as products that promote sustainable development.

The middle age segment, aged 36-50, is more demanding of product quality and durability. These consumers are looking for brands that demonstrate a commitment to high quality and reliability, choosing products that offer added value through enhanced functionality or improved health-promoting features. People over 50 address the healthiness, safety and convenience of products. They prefer products that support their health and well-being, including products with low levels of preservatives and artificial additives. This group also prefers products that are easy to use and consume, especially if it contributes to their ability to lead an active lifestyle. These findings point to the critical need for companies to focus on creating products that meet the age-specific needs of consumers, as well as the importance of adapting marketing strategies to specific age requirements and preferences to effectively engage different market segments.

The educational level of consumers has a decisive influence on the formation of their preferences and product selection criteria. Knowing these educational parameters allows companies to gain a deeper understanding of their target audience and effectively tailor their products and marketing strategies to meet the educational and cultural requirements of their customers. This approach contributes to the creation of more balanced and customer-oriented products, ensuring a high level of customer satisfaction and loyalty (Table 2).

Table 2. Consumer preferences depending on their level of education

Level of education	Advantages of products	Key characteristics of the choice	Brand orientation	Environmental and social requirements	Number of respondents (%)
Higher education	Sustainable development products	High awareness of environmental and social aspects	Low	High, prioritising certification and innovations to reduce environmental impact	80 (40%)
Secondary specialised	Time-tested products	Better value for money	High	Low, less inclined to innovate	70 (35%)
The main general	Simple and affordable products	Simplicity and ease of use	Average	Very low, driven by availability and price	50 (25%)

Source: compiled by the authors

The analysis of consumer preferences revealed that 40% of consumers with higher education prefer products that support sustainable development and are highly aware of environmental and social aspects. This highlights the trend among educated consumers towards making informed choices focused on environmental responsibility and social justice. On the other hand, 35% of consumers with secondary specialised education prefer time-tested products, where reliability and a favourable price-quality ratio are important. This category of consumers tends to make conservative choices, avoiding the risks associated with new market offers. Meanwhile, 25% of consumers with a basic general education focus on the simplicity and convenience of products, choosing those options that are easy to use and consume.

A detailed examination of consumers' educational levels revealed distinct differences in product choice, reflecting the different values and awareness they attach to a product. Consumers with higher education often seek additional information about the source of ingredients, labour conditions, and corporate responsibility of brands. They highly value innovations that minimise environmental impact, such as reducing the use of plastic in packaging. Consumers with secondary specialised education, in turn, are more conservative in their choices, preferring time-tested brands and products that have already proven themselves in the market. They are less inclined to experiment with new products and are looking for the best value for money. People with basic general education are guided by simplicity and convenience in choosing products, where availability, low price and ease of use are important.

These findings demonstrate the need for businesses to focus on creating products that meet the educational and cultural characteristics of consumers, as well as the importance of adapting marketing strategies to specific age, educational and cultural requirements and preferences to effectively engage different market segments. Knowledge of consumers' professional activities is essential for the determination of their product selection criteria and preferences. An analysis of the professional characteristics of clients illustrates how specific professional obligations and working conditions affect consumer requirements. Different professional groups have their specific needs and priorities, which creates a need for companies to adapt their products and marketing strategies to more targeted attract and retain clients from different professional fields (Table 3).

Table 3. Consumer preferences depend on their professional activity

Professional group	The main criteria for product selection	Key characteristics of the preferences	Additional factors of influence	Number of respondents (%)
Business professionals	Brand, price	Quality, reliability, professional image	Famous brands, products of the highest price category	90 (45%)

Table 3, Continued

Professional group	The main criteria for product selection	Key characteristics of the preferences	Additional factors of influence	Number of respondents (%)
Healthcare professionals	Health and Safety	Natural ingredients, no harmful additives	Professional knowledge of the impact of nutrition on health	60 (30%)
Teachers and educational staff	Cost, educational impact	Products as educational resources, stimulating creativity	Discounts for educators, special educational packages	50 (25%)

Source: compiled by the authors

The analysis of professional differences among respondents revealed significant variations in preferences and product selection criteria, which are closely related to the professional activities and everyday needs of people of different professions. Each professional group has unique priorities that influence their choice of products. 45% of business professionals give preference to brand and price when determining quality, reliability and professional image. Among business professionals, high attention to brand and price are critical factors. This group often associates a brand with quality and reliability, choosing well-known and trusted brands that provide stability and confidence in their purchases. Their choice is also motivated by the need to maintain their status, which makes them prefer products of a higher price category, which are considered to be symbols of success.

30% of healthcare professionals are focused on health and safety, identifying natural ingredients and the absence of harmful additives. They prefer products that support a healthy lifestyle, contain natural ingredients and are free of harmful additives. Their choice is often driven by professional knowledge of the impact of nutrition on health, which makes them more likely to choose organic and environmentally friendly products.

Moreover, 25% of teachers and educators are focused on the value and educational impact of the product. They are looking for products that can be used as educational resources or stimulate creativity and learning. This group also often prefers products that offer discounts for educators or special educational packages that can be used in the classroom.

These professional differences provide important information for companies seeking to attract diverse market segments by providing products and services that meet the specific needs and preferences of different professional groups. Tailoring products and marketing strategies to the professional characteristics of consumers can significantly increase customer engagement and loyalty.

The Student's t-test was used to assess the levels of satisfaction with product packaging between men and women. This statistical method is indispensable in research, as it can be used to reasonably assess whether there is a statistically significant difference between the mean values of two independent groups. The application of the t-test in the context of the study identified the extent to which gender differences affect packaging perceptions, providing valuable guidance for developing more effective marketing strategies that take these differences into account (Table 4).

Table 4. The difference in satisfaction with product packaging between men and women

Group of respondents	Average level of satisfaction with packaging (on a 5-point scale)	Standard deviation	P-value (Student's t-test)
Females	4.5	0.7	<0.05
Males	3.8	0.9	<0.05

Source: compiled by the authors

The use of the Student t-test to analyse the levels of satisfaction with product packaging between men and women revealed significant differences between these groups. The analysis showed that women showed a significantly higher level of satisfaction with product packaging compared to men, with a significance level of $p < 0.05$. This shows that women prioritise to packaging details such as aesthetics, usability and environmental friendliness.

Men, on the other hand, are less critical of these aspects of packaging, focusing more on other product characteristics such as functionality and price. This indicates that to increase men's satisfaction, it may be worth prioritising other aspects of the product, not just its packaging. A detailed analysis of the results showed that the average level of satisfaction among women was 4.5 out of 5, while among men it was 3.8 out of 5. The standard deviation also indicates that women's scores are more consolidated around the mean, suggesting a more consistent and homogeneous attitude towards packaging among women compared to men. This may indicate that female consumers have clearer and more stable requirements for product packaging, while men show more variability in their assessments.

Given this data, it is possible to recommend improving packaging design for the female audience by introducing more attractive colours, and textures and using environmentally friendly materials. It is also advisable to develop marketing campaigns that emphasise these aesthetic and environmental aspects, as they are important to the female audience. For men, who show greater variability in satisfaction and a preference for functional features, product quality and functionality improvement should be prioritised. It is also necessary to include favourable price offers in marketing strategies, which can help increase satisfaction and loyalty among male customers.

The Fisher's test is an important statistical tool for analysing categorical data, and it is particularly effective in contexts where it is necessary to compare frequency distributions between different groups. In the study, Fisher's criterion was used to analyse data reflecting respondents' preferences and assessments of product packaging among different demographic groups. This made it possible to identify statistically significant differences, providing a deeper understanding of the specifics of consumer behaviour and marketing approaches that take these differences into account (Table 5).

Table 5. The impact of demographic factors on the perceived importance of product packaging

Demographic group	Number of respondents who consider packaging important	Total respondent number	Share (%)	P-value (Fisher's criterion)
Higher education	120	150	80%	<0.05
Secondary specialised	60	100	60%	<0.05
The main general	30	100	30%	<0.05
18-35 years	85	120	71%	<0.05
36-50 years	50	80	62.5%	<0.05
50+ years	35	70	50%	<0.05
Males	70	110	63.6%	<0.05
Females	115	140	82.1%	<0.05
High income	90	100	90%	<0.05
Average income	60	100	60%	<0.05

Source: compiled by the authors

The application of Fisher's criterion in the analysis of the impact of education level on product packaging preferences showed that a significantly higher percentage of respondents with higher education attach great importance to packaging aspects compared to those with secondary specialised or basic general education. This shows that education is substantial in shaping consumer preferences and requirements for product quality and aesthetics.

Fisher's criterion was also used to analyse the impact of age on packaging perception. The results show that younger consumers (aged 18 to 35) are more likely to prioritise packaging design and innovation, while older age groups (50 and over) are more focused on functionality and usability, indicating different priorities depending on age.

Gender differences in packaging perception were also analysed. Women are much more likely than men to note the importance of aesthetic and functional aspects of packaging, such as ease of opening and eco-friendly materials. Men, in turn, are more focused on other product characteristics, such as overall functionality and price.

Respondent income also has an impact on their packaging preferences. Consumers with higher incomes are more likely to seek premium packaging and the additional benefits it can offer, including innovative materials and environmental certifications. Those with lower incomes are more focused on affordability and ease of use of packaging.

The results of Fisher's analysis highlight the importance of considering the diverse demographic characteristics of consumers when designing packaging. For younger consumers, companies should focus on innovation and packaging design, while for older consumers, they should focus on functionality and convenience. For educated consumers, environmental benefits and certification should be emphasised, and for high-income consumers, premium packaging with additional benefits should be offered. This will allow companies to attract different market segments more effectively and increase overall customer satisfaction.

The regression analysis used in this study identified the most relevant factors that influence overall brand perception and customer satisfaction. Determination of the key factors allows companies to focus on those aspects of their operations that maximise their competitiveness in the market (Table 6).

Table 6. The contribution of different product components to the overall brand perception

Component	Relevance (%)
Quality	40%
Price	25%
Availability	20%
Package	15%

Source: compiled by the authors

The regression analysis conducted as part of the study highlighted the importance of product quality as a key factor influencing overall brand perception and customer satisfaction. According to the results, product quality plays a key role in shaping a positive brand image and customer satisfaction, accounting for 40% of the overall perception. This highlights how much customer loyalty, and repeat purchases depend on the quality of the goods. The analysis also showed that the price of the product is important, with a weight of 25%. This points to the need to ensure competitive prices as customers actively compare prices and look for the best deals. Balancing price and quality can be a key factor in ensuring customer loyalty.

The availability of products with a weight of 20% in the perception structure is also important. Consumers highly appreciate the product's easy access, availability in stores, fast delivery and availability in convenient outlets. Efficient logistics and wide distribution are essential to meet this need.

Product packaging, although less important (15%), is still important, as the aesthetics, convenience and environmental friendliness of packaging can play an important role in customer perception. High-quality packaging can significantly increase the attractiveness of a product on the shelf and encourage purchases.

The correlation between consumer preferences and sales has shown that packaging that appeals more to certain demographics is associated with higher sales for certain products. For example, packaging that meets modern trends in style and technology leads to increased sales among consumers aged 18-35. Such observations help companies adapt their products and marketing strategies to maximise sales.

The application of SWOT analysis and Porter's Five Forces methodology assessed in detail the strategic position of food companies in the current market. The analysis identified key strengths and weaknesses, as well as opportunities and threats affecting their competitiveness. Strengths include high product quality, which contributes to customer loyalty; a wide range of products, which meet the diverse needs of customers; and the use of innovation and modern technology to improve efficiency and product quality. Weaknesses include high production costs, which limits competitiveness in the market; limited flexibility in changing the product mix, which makes it difficult to adapt to market conditions; and high dependence on suppliers, which creates risks to the stability of supply. Opportunities include expanding into new markets to increase sales and competitiveness; introducing new technologies to reduce costs and improve quality; and developing partnerships to ensure supply security. Threats include increasing competition that may reduce market share; changes in legislation that may increase costs; and economic and political fluctuations that may affect market stability.

Competition in the food market remains intense due to a wide range of products and insignificant differentiation between available selection. The threat of new entrants and substitutes remains moderate due to high barriers to entry and innovation. Suppliers and consumers have moderate to high power, which requires companies to work actively to attract and retain customers and ensure the stability of supply.

▸ Discussion

The results of the study, based on interviews with consumers and food businesses, provide a deeper understanding of the preferences and product selection criteria of different demographic groups. This research is significant because it provides valuable insights for food producers, helping them to tailor their products and marketing strategies to meet the needs of different consumer segments. It also helps to identify the key factors that influence customer satisfaction, which is critical for increasing the competitiveness of enterprises.

The research results showed that product quality is the most important factor that affects overall brand perception and customer satisfaction. This is consistent with the research of other scholars, S. Said *et al.* (2021) and F. Babayev & T. Balajayeva (2023), who also emphasise the importance of quality as a key element in building customer loyalty. High-quality products not only help to meet current consumer needs but also create a positive brand image, which in turn leads to increased repeat purchases.

The results of the study confirm the conclusions drawn in other studies regarding the impact of demographic characteristics on consumer preferences. For instance, a study conducted by K. Brunsø *et al.* (2021), and S. Moghildea (2023), showed that younger consumers place a high value on aesthetics and product innovation, while older consumers place a higher value on functionality and convenience. This indicates the need to develop differentiated marketing strategies for different age groups, which is consistent with the findings.

In addition, the analysis of the impact of education on consumer preferences in this paper is consistent with the findings of X. Luo *et al.* (2022) and L. Tavares *et al.* (2021), who found that educated consumers pay more attention to environmental and social aspects of products. They note that educated consumers are more aware of sustainability and tend to support brands that demonstrate environmental responsibility. P. Abeysiriwardana *et al.* (2023) and K. Hennyeyová *et al.* (2021) also confirm that the level of education influences consumer preferences, especially in terms of choosing products with environmentally friendly and natural ingredients.

Research conducted by P. Ghisellini *et al.* (2023) and D. Hadi *et al.* (2023) also emphasised the importance of understanding the impact of occupation on consumer preferences. They determined that healthcare professionals attach great importance to products that support a healthy lifestyle and contain natural ingredients. The results confirm these findings and highlight the need to tailor marketing strategies to the specific needs of different professional groups.

Despite the high degree of consistency with the results of other studies, certain discrepancies were found. In particular, the study determined that women are much more likely than men to note the importance of aesthetic and functional aspects of packaging. At the same time, the results of a study conducted by A. Buallay (2021) and V. Basile *et al.* (2023) did not confirm significant gender differences in this context. They noted that men and women equally value the quality of packaging. However, according to the data, women demonstrate a more demanding attitude towards aesthetic and environmental aspects. These differences may be due to cultural or regional factors, which underlines the need to take these differences into account in future research to better analyse the impact of socio-cultural conditions on consumer preferences.

A study conducted in Japan by S. Yang *et al.* (2021) and I. Tsuchimoto & Y. Kajikawa (2022) showed that consumers of all age groups prioritise product quality and price, while the results suggest that younger consumers are more focused on product innovation and aesthetics. This can be explained by differences in cultural values and consumer behaviour between different countries (Maharramova &

Maharramov, 2023). The researchers noted that Japanese consumers are more focused on traditional values and stability, while the survey respondents, mostly from Western countries, have more modern and dynamic preferences.

In addition, a study conducted in Germany by J. Winterstein & A. Habisch (2021) and M. Lehberger *et al.* (2021) found that product price is the most significant factor for all age groups. At the same time, other analyses show that product quality is a higher priority for consumers. Such differences may be due to differences in economic conditions and income levels between countries. The authors also emphasised the importance of product availability, but in other results, this factor was given less weight than quality and price. This highlights the importance of the global context and local characteristics of economies in shaping consumer priorities, which is key to developing effective marketing strategies (Markovych, 2023).

The results revealed certain differences in consumer preferences depending on the region of residence of the respondents. This is in line with data obtained in different countries. For instance, a study by M. Dereva & M. Rajcaniova (2021) and J. Crick & D. Crick (2021) in the United States found that consumers in different states set different priorities for product packaging, which may be due to cultural and economic differences between regions. In particular, the researchers noted that consumers in the southwest of the US place a higher value on packaging convenience, while in the northeast of the country, more attention is paid to environmental aspects of packaging. This underscores the need to address regional specifics when formulating marketing strategies and developing products.

Similar results were obtained in studies conducted in European countries by I. Dam *et al.* (2021), where consumers also showed different preferences depending on cultural and socioeconomic factors. In France, for example, consumers prefer products with premium packaging that emphasises high status, while in Germany, they value the functionality and environmental friendliness of packaging more (Mukhametov *et al.*, 2023).

A study conducted by X. Chen *et al.* (2021) in China determined that young consumers prefer products with innovative and eco-friendly packaging, which is in line with trends found among younger consumers in other studies. At the same time, older Chinese consumers also prioritised the environmental aspects of packaging, in contrast to older respondents in other studies who focused more on the functionality and convenience of packaging. This discrepancy may be due to the higher level of environmental awareness among all age groups in China. Such differences highlight the need for companies to consider cultural and regional specificities in their global marketing strategy and product policies (Musayeva *et al.*, 2024).

A study conducted by B. Kelly *et al.* (2021) in Australia also highlighted the importance of adapting products to regional preferences. The study determined that Australian consumers place a high value on natural and organic ingredients, which is consistent with the findings on the impact of education on consumer preferences in Ukraine. This indicates a global trend of increasing environmental awareness among educated consumers. B. Kelly *et al.* (2021) also noted that high-income consumers are more likely to choose premium products, emphasising the importance of socioeconomic factors in shaping preferences. This is consistent with the findings that high-income consumers in Ukraine also prefer premium products and pay more attention to details such as packaging quality and sustainability.

A study conducted by L. Carmona & G. Gomes (2021) in Brazil determined that consumers place a high value on local products, which are associated with supporting local producers and the economy. This contrasts with the findings in Ukraine, where consumers are more focused on global brands and product quality. Ukrainian consumers prefer well-known international brands, which may be due to trust in their quality and reliability (Palamarchuk & Korkach, 2023). L. Carmona & G. Gomes (2021) also noted that Brazilian consumers are more price-oriented, which may be due to the country's economic conditions. Similarly, the results of the study in Ukraine showed that price is an important factor for consumers, but they are willing to pay more for products that meet their high quality and environmental requirements.

Thus, the study is consistent with many previous works but also reveals some discrepancies, which emphasises the importance of addressing cultural and regional differences in consumer behaviour. Further research in this area could help to identify additional factors that influence consumer preferences and develop more effective strategies to increase the competitiveness of enterprises in the global market.

Overall, the findings of the study provide valuable insights for food businesses, helping them to better understand their customers' needs and tailor their products and marketing strategies to meet those needs. This helps to increase customer satisfaction, build brand loyalty and ensure long-term market success.

Conclusions

An analysis of consumer age preferences showed that younger consumers (aged 18 to 35) prefer innovative and aesthetic products, while older consumers (aged 50 and over) value functionality and safety more. The influence of educational level on consumer preferences is manifested in the fact that consumers with higher education (40%) pay more attention to the environmental friendliness of products, while consumers with secondary specialised education (35%) trust trusted brands more. Occupation also has a significant impact on consumer preferences. Business professionals (45%) focus on brand and price, healthcare professionals (30%) on health and safety, and educators (25%) on the value and educational impact of the product. Gender differences in satisfaction with packaging revealed that women are significantly more likely to say that the aesthetic and functional aspects of packaging are important. The average level of satisfaction with packaging among women was 4.5 out of 5, while among men it was 3.8 out of 5. The impact of demographic factors on packaging perceptions showed that consumers with higher incomes (90%) are more likely to pay attention to premium packaging and the additional benefits it can offer, including innovative materials and environmental certifications. Those with lower incomes (60%) are more focused on affordability and ease of use.

The research findings highlight the importance of considering the demographic and professional characteristics of consumers when developing products and marketing strategies. This will help increase customer satisfaction, and brand loyalty and ensure long-term market success. The study has several limitations. The sample of respondents may not fully reflect the diversity of consumers in Ukraine. The study did not address the impact of seasonal factors and cultural characteristics on consumer preferences. The main areas for further research include analysing the impact of cultural characteristics and new technologies on consumer behaviour. The main areas for further research include a more detailed analysis of the impact of cultural characteristics on consumer preferences, as well as research on the impact of new technologies on consumer behaviour. It is also important to address global trends, such as sustainable development and environmental awareness, and their impact on consumer behaviour in different regions of the world.

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The authors of this study declare no conflict of interest.

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Маркетинговий моніторинг для визначення конкурентоспроможності харчового підприємства

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▸ **Анотація.** Метою статті було оцінити ринкову позицію харчових підприємств та виявити ключові чинники, що впливають на задоволеність споживачів продукцією. Дослідження включало опитування 200 споживачів та 50 представників підприємств, стратифікаційний аналіз, t-критерій Стьюдента та критерій Фішера. Основні результати показали, що якість продукції є найважливішим чинником із вагою 40 %, тоді як ціна мала вагу 25 %, доступність 20 % і упаковка 15 %. Молодші споживачі (18-35 років) надають перевагу інноваційним і естетичним продуктам, тоді як старші групи більше цінують функціональність і безпеку. Споживачі з вищою освітою віддають перевагу екологічним продуктам, тоді як споживачі з середньою спеціальною освітою більше довіряють перевіреним брендам. Аналіз професійних відмінностей показав, що бізнес-професіонали зосереджуються на бренді та ціні, медичні працівники – на здоров'ї та безпеці, а освітяни – на вартості та освітньому впливі продукту. Крім того, дослідження виявило, що жінки значно частіше відзначають важливість естетичних та функціональних аспектів упаковки порівняно з чоловіками, із середніми рівнями задоволеності упаковкою 4,5 та 3,8 відповідно ($p < 0,05$). Також було виявлено, що споживачі з вищим рівнем доходу частіше обирають продукти з преміум-упаковкою та додатковими перевагами. Висновки підкреслюють необхідність адаптації маркетингових стратегій для задоволення специфічних потреб різних демографічних груп, що сприятиме підвищенню конкурентоспроможності харчових підприємств на ринку. Це дослідження надає цінну інформацію для виробників харчової продукції, допомагаючи їм краще розуміти споживачів та адаптувати свої продукти відповідно до їх потреб

▸ **Ключові слова:** демографічні характеристики; якість продукції; задоволеність споживачів; оцінка продуктів; ринкова стратегія; фактори вибору

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