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Improving business processes in the agricultural sector considering economic security, digitalization, risks, and artificial intelligence

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► **Abstract.** The study aimed to address ways to improve the efficiency of agribusiness through the introduction of modern technologies and innovative approaches. The methods of quantitative and qualitative analysis of financial indicators, analytical reviews, and specific examples of technology implementation were used to achieve this goal. The study emphasises the impact of digitalisation of the agricultural sector on improving economic security, efficiency and competitiveness. The introduction of digital technologies, such as the Internet of Things, process automation and precision farming, is helping to optimise production processes, reduce costs and improve product quality. The study results show that the concept of smart farming significantly increases the efficiency of agribusiness. The use of Big Data, blockchain technologies, drones and satellite technologies provides better management of agribusiness, while artificial intelligence helps to predict yields and optimise agricultural processes. Risk management in the agricultural sector, including insurance and financial instruments to hedge price fluctuations, is a key factor in enhancing economic stability. The experience of leading global companies such as John Deere, Agricultural Bank of China, Fruition Sciences, TE-FOOD and FieldView has shown the effectiveness of digital technologies and innovations in improving efficiency

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and sustainable development. Particular attention is devoted to the problems and prospects for the introduction of modern technologies in the agricultural sector of Ukraine on the example of Myronivsky Hliboproduct. An integrated model for improving the business processes of Myronivsky Hliboproduct is proposed, including the digitalisation of production processes, the introduction of blockchain technologies, the use of AI and risk management. Necessary steps to overcome existing challenges, such as insufficient funding for innovation, infrastructure constraints, staff training and cybersecurity, were determined. The implementation of the proposed measures will allow the company to become a leader in the implementation of innovations in the agricultural sector of Ukraine, increase competitiveness and ensure sustainable development in the future

► **Keywords:** agriculture; innovative technologies; precision farming; cybersecurity; competitiveness

► Introduction

The agricultural sector plays a key role in ensuring food security and economic development. Ensuring the economic security of agricultural enterprises is becoming increasingly important in the context of global challenges such as climate change and population growth. The introduction of modern digital technologies and artificial intelligence (AI) provides new opportunities to optimise business processes, reduce costs and increase productivity. Digital technologies, such as the Internet of Things (IoT), blockchain and Big Data, allow farmers to obtain accurate information to make informed decisions, which helps them to increase efficiency and competitiveness in the global market. The introduction of AI in the agricultural sector allows for analysing large amounts of data, forecasting crops and optimising the use of resources, which is critical to improving productivity and product quality. At the same time, the digitalisation of agribusiness helps to manage risks, improve transparency and ensure cybersecurity. As a result, agricultural enterprises that actively implement the latest technologies can reduce losses, increase efficiency and remain competitive in the global market. This study aims to identify ways to improve business processes in the agricultural sector of Ukraine through the integration of digital technologies, which will ensure sustainable development and economic security of enterprises.

To determine the trends and challenges in improving business processes in the agricultural sector, it is necessary to address the research and conclusions of leading scholars and practitioners in this area. M. Khanna (2021) pointed out the importance of digital transformation in the agricultural sector, emphasising that the introduction of digital technologies can significantly improve the efficiency of resource management. A study by A. Strizhkova *et al.* (2020), in turn, shows that the use of drones and sensor systems to monitor crops can reduce fertiliser and irrigation costs. R. Ben Ayed & M. Hanana (2021) addressed the role of AI in yield forecasting. According to them, machine learning algorithms can analyse large amounts of historical data and make accurate forecasts, which helps farmers plan their actions and minimise the risks associated with unpredictable weather conditions. A.S.A.F. Alam *et al.* (2020), in turn, proposed to introduce crop insurance systems that cover losses from natural disasters. M. Alkahtani *et al.* (2021) and A. Kolodiy *et al.* (2022) studied the impact of digital platforms on the interaction of agricultural enterprises and suppliers. Their research suggests that the use of blockchain technologies for supply chain management provides transparency and increases trust between market participants. S.A. Bhat &

N.F. Huang (2021) studied the use of big data for management decision-making in the agricultural sector. A study by O. Hrynevych *et al.* (2022) demonstrated that analysing data on weather conditions, soils and markets allows farmers to plan production more accurately and reduce the risk of overproduction or shortages. K. Rijswijk *et al.* (2021) addressed the importance of cybersecurity in the context of the digital transformation of the agricultural sector. They stressed that the growing number of internet-connected devices in agriculture increases the risk of cyber threats. M. Carmela Annosi *et al.* (2020) studied the issues of sustainable development in the agricultural sector. They argued that the introduction of environmentally friendly technologies and practices not only reduces the negative impact on the environment but also contributes to the economic sustainability of enterprises.

In general, the analysis of the works of these authors emphasises the importance of a comprehensive approach to improving business processes in the agricultural sector, which includes digitalisation, risk management, economic security and the introduction of innovative technologies. These studies provide valuable information for agricultural enterprises seeking to improve their efficiency and sustainability in the face of rapid technological and economic change. However, the relationship between digitalisation, cybersecurity and the economic sustainability of agricultural enterprises in the face of global challenges and rapid market changes remains insufficiently researched.

The study aimed to develop a comprehensive model for improving business processes in the agricultural sector by integrating digital technologies, AI, and risk management strategies. The objectives of the study were to determine the impact of digital technologies on the efficiency of business processes in the agricultural sector, to study methods of ensuring the economic security of agricultural enterprises in the context of digital transformation, to study strategies for managing risks associated with cybersecurity in the agricultural sector.

► Materials and methods

The research on this topic included quantitative and qualitative analysis of financial indicators, analytical reviews, as well as specific examples of the use of technology in the agricultural sector. International organisations such as the International Finance Corporation (IFC) (Agribusiness & Forestry, n.d.) and the Europe: Turning the recovery into enduring growth (2024) were analysed. The annual financial reports of agricultural enterprises were used to analyse the financial condition of companies, including Myronivsky Hliboproduct (MHP) (Investor Relations &

Corporate Governance. Annual reports, n.d.), 2023 Annual Report (2023), and the Annual Reports (n.d.). The reports of Fruition Sciences (n.d.), TE-FOOD (n.d.) and Field-View – the driving force behind your farm's future (n.d.) were also analysed. These companies are engaged in the introduction of advanced technologies in the agricultural sector, and their reporting provides information on the financial efficiency of the implemented technologies. Data on financial indicators such as revenue, profit, production costs, loan servicing, labour costs and other expenses were collected and analysed. This analysis included identifying trends and fluctuations in financial performance from 2019 to 2023. In addition, the comparison of financial indicators between different companies was used to determine the impact of the introduction of digital technologies on their financial condition.

The study analysed the state of digital technologies in the agricultural sector of Ukraine and assessed the level of their use and spread among agricultural enterprises. The availability and effectiveness of the implementation of modern technologies, such as monitoring and control systems, process automation, IoT, blockchain technologies, AI, and others, are investigated. The availability of infrastructure for the implementation of digital solutions, the level of technological equipment of agricultural enterprises, and the readiness of staff to use the latest technologies were analysed.

The financial indicators were analysed using quantitative analysis, identifying the main trends in changes in revenues, expenses and profits of companies from 2019 to 2023. The financial performance of different companies was compared to identify patterns in the use of digital technologies and their impact on financial results. This included analysing information on specific examples of the implementation of these technologies in various agricultural companies, as well as assessing their impact on production processes and economic efficiency.

Specific examples of IoT, process automation and precision farming in agricultural enterprises were investigated to assess the effectiveness of these technologies in increasing productivity, reducing costs and improving product quality. Particular attention was devoted to the role of blockchain technologies in ensuring transparency and traceability of supply chains, including an analysis of blockchain projects for farmers' lending, product tracking and risk management. In addition, the use of AI to optimise agricultural processes, resource management, weather and risk forecasting was explored. Methods and tools for risk management in the agricultural sector, including insurance, financial instruments to hedge price fluctuations and the development of business plans to identify and manage risks, were also explored. Approaches to ensuring cybersecurity in the face of growing volumes of digital systems and data were analysed. These methods and materials were used to conduct a comprehensive analysis of the economic security of agricultural enterprises and develop an integrated model for improving the business processes of Myronivsky Hliboproduct through the introduction of modern technologies. The company is one of the largest agricultural enterprises in Ukraine engaged in the production and sale of agricultural products and has a major impact on the country's economy.

► Results

Economic security is critical for the sustainability and success of agricultural enterprises in the face of market instability and changing economic conditions. It is critical for the sustainability of agricultural enterprises and their success in the face of market volatility and changing economic conditions. Economic security covers a wide range of measures and approaches aimed at protecting the financial interests of an enterprise, preventing financial losses and ensuring sustainable development (Nhemachena *et al.*, 2020). Financial planning and control are key components of ensuring the economic security of agricultural enterprises. These processes include a detailed analysis of cash flows, crop costs, loan servicing, labour costs and other expenses. It is necessary to control the receipt and expenditure of funds to ensure the stability of the financial position of the enterprise (Abbasi *et al.*, 2022). For instance, regular monitoring and analysis of financial flows allow us to identify deviations from the plan, such as overspending on fertiliser purchases or a decrease in revenue from product sales and take prompt corrective action.

Analysis of financial flows was used to identify threats and respond to them on time. If a company detects a decline in prices for its products on the market, it may decide to change its sales strategy or look for new markets to avoid financial losses. Planning and controlling the cost of seeds, fertilisers, crop protection products and other inputs is necessary for the reduction of costs and profitability increase. The introduction of precision farming was used to optimise the use of fertilisers and pesticides, which reduces their consumption and improves yields. Agribusinesses often depend on credit to finance their operations; therefore, it is necessary to develop effective debt management strategies to avoid excessive financial burdens and maintain creditworthiness. For instance, the use of financial instruments such as hedging can help agricultural enterprises protect themselves from the risk of rising interest rates on loans (Misra *et al.*, 2020). In addition, regular analysis of the company's financial position can be used to promptly identify liquidity problems and take measures to resolve them, for example, by restructuring debt or raising additional funding.

Labour costs are a significant item of expenditure for agricultural enterprises. Optimisation of these costs through process automation and the use of modern technologies can significantly improve production efficiency. For instance, the use of automated harvesting systems or drones to monitor crops can reduce the need for manual labour, which reduces labour costs and increases productivity (Garg *et al.*, 2022). The implementation of Farm Management Systems provides more efficient planning and control of production processes, which also helps to optimise costs. Particular attention should be devoted to the management of financial risks that may affect the stability and development of an agricultural enterprise. The main financial risks include fluctuations in commodity prices, changes in foreign exchange rates, legislative changes and climatic conditions. Changes in agricultural commodity prices can have a significant impact on the income of agricultural enterprises. A drop in grain prices or an increase in the cost of meat can change the

economic environment of a business (Eli-Chukwu, 2019). According to the International Monetary Fund, the impact of changes in agricultural prices can account for up to 20% of changes in the income of agricultural enterprises in different regions of the world. The use of financial instruments such as futures contracts and options help to hedge price risks and ensure revenue stability. According to the International Finance Corporation, up to 70% of large agricultural enterprises in the United States use futures contracts to mitigate price risks (Europe: Turning the recovery into..., 2024).

Agricultural enterprises that export products or depend on imported inputs are exposed to currency risks. Currency hedging reduces the impact of currency fluctuations on the company's financial results. According to a study by the International Monetary Fund, up to 60% of businesses in the European Union use currency hedging to protect themselves from currency risks. Changes in legislation, such as new tax rates, regulation of agricultural activities, or changes in the rules of export-import operations, can affect the financial stability of a business (Europe: Turning the recovery into..., 2024). It is necessary to keep abreast of legislative changes and adapt business strategies to the new environment. Weather disasters, such as droughts, floods or other natural events, can seriously affect the yields and financial performance of agricultural enterprises (Javaid *et al.*, 2023). Crop insurance and the use of agrometeorological data for risk forecasting help minimise the negative impact of climate change. A key aspect of improving the efficiency of agricultural enterprises is the introduction of modern digital technologies, such as AI, Big Data, drones and satellite technologies. These technologies help to optimise

production processes, reduce costs and increase productivity. For example, AI can analyse large amounts of data to predict yields and optimise resource use, which can reduce costs and increase efficiency (Fathi *et al.*, 2022). The use of digital technologies also helps agricultural enterprises adapt to market changes, increasing their competitiveness in the global market.

John Deere, one of the world's leading agricultural machinery manufacturers, is known for its innovations in digital technology and AI. The company is actively implementing technologies that automate agricultural processes, increasing efficiency and reducing costs. Their tractors and harvesters are equipped with sensors, GPS systems and intelligent algorithms that allow them to optimise the operation of their machinery in real-time. One of the company's key products is the John Deere Operations Centre platform, which enables farmers to monitor and analyse data from their fields. This platform is used by farmers to receive accurate data on yields, soil conditions and weather conditions. The introduction of such technologies has reduced fertiliser and fuel costs by up to 15% and increased yields by 20% through precise application of fertilisers and plant protection products. 2023 Annual Report (2023) is also working with leading technology companies such as NVIDIA to develop AI in agriculture. For instance, their autonomous tractors can independently determine the best routes and ploughing depth using sensor data and machine learning algorithms. This not only reduces fuel costs but also reduces the negative impact on the soil, which is important for sustainable farming. This technology helped the company to increase its revenues and net profit significantly from 2019 to 2023 (Fig. 1).

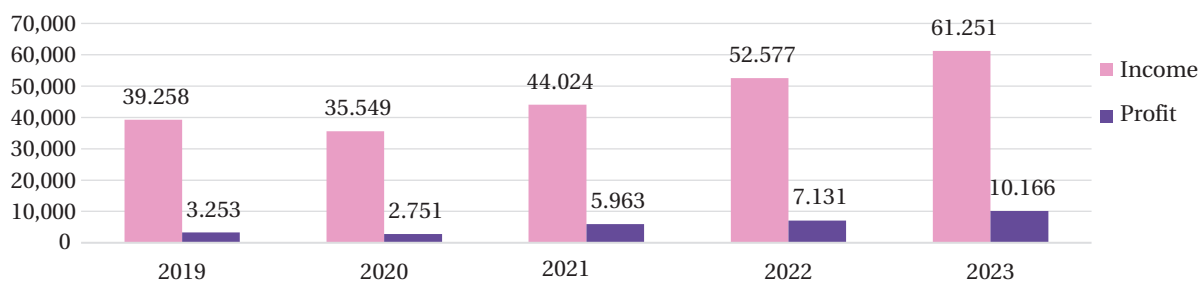


Figure 1. Financial performance of John Deere from 2019 to 2023, USD million

Source: compiled based on data from 2023 Annual Report (2023)

The table shows that John Deere has shown a steady upward trend in revenues and profits over the past five years. From 2019 to 2023, the company's revenue increased by almost 56%, reaching \$61.3 billion in 2023. This demonstrates the success of the company's business processes and its ability to adapt to changes in the market.

Agricultural Bank of China, one of the largest banks in China, is actively implementing blockchain technologies to improve transparency and efficiency in the agricultural sector. The use of blockchain provides full traceability of supply chains and increased trust between all market participants. One of the bank's most successful projects is the introduction of a blockchain platform for lending to farmers. Through this platform, farmers can receive loans

secured by future harvests. The blockchain ensures transparency of all transactions and ensures that collateral and crop data cannot be altered or falsified. This significantly reduces the risks for banks and allows farmers to receive financing on more favourable terms. In 2022, the Annual Reports (n.d.) successfully tested a blockchain system for lending to farmers in Guangdong province. During the first six months of using the system, more than 3,000 loans were issued, totalling more than 300 million RMB (approximately 45 million USD). Blockchain technology reduced the processing time for loan applications from several weeks to a few days, allowing farmers to receive the necessary funds for agricultural work more quickly. Figure 2 shows the company's key financial indicators.

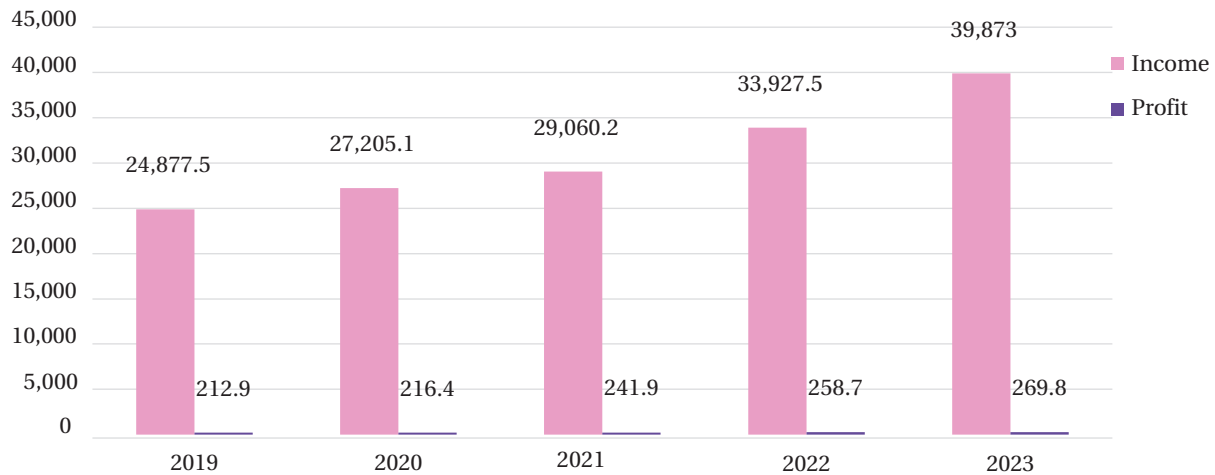


Figure 2. Financial performance of Agricultural Bank of China from 2019 to 2023, billion yuan

Source: compiled based on annual reports of the Annual Reports (n.d.)

The Agricultural Bank of China also shows a steady upward trend in revenues and profits. Between 2019 and 2023, the company's revenue increased by 60%, reaching 39.9 trillion yuan in 2023, which is a testament to the successful use of technology.

Fruition Sciences, with offices in France and the US, is a pioneer in the use of digital technology and AI for vineyard management. The company specialises in integrating IoT and analytical algorithms to monitor and optimise irrigation processes. Their system uses numerous sensors that measure soil moisture, temperature, solar radiation and other critical parameters. The received data is transferred to the cloud platform, where it is analysed using AI algorithms. This allows growers to receive precise recommendations on the optimal time and volume of irrigation, reducing water consumption and improving the quality of the grapes. For instance, one study showed that using the Fruition Sciences system reduced water consumption by 20% while improving grape yields and quality (Fruition Sciences, n.d.).

TE-FOOD is a Vietnamese company that is actively implementing blockchain to ensure transparency and traceability of food supply chains. The company is working with local farmers, manufacturers and retailers to implement a system that allows them to track food from farm to table. Using the TE-FOOD blockchain platform, all product information, including the place of cultivation, production methods, transportation and storage conditions, is stored unchanged and available to all participants in the supply chain. This provides consumers with detailed information about the origin of products and increases their trust in food quality. One of the company's successful projects is cooperation with pork producers in Vietnam. As a result of the implementation of the blockchain system, the supply chain tracking time was reduced by 50%, which significantly reduced the risks of fraud and counterfeiting (TE-FOOD, n.d.). In addition, consumers were able to check all product information using QR codes, which increased the level of trust in local producers.

FieldView, a product of Bayer Germany, uses advanced digital technology and AI to manage farmland.

The platform combines data from various sources, including sensors, drones and satellite imagery, to create comprehensive field maps and analytical reports. FieldView enables farmers to monitor crop health in real-time, analyse soil and weather data, and receive recommendations for optimising crops, fertilisation and irrigation. AI algorithms are used in the platform to accurately determine the water and nutrient needs of plants, which reduces costs and increases yields. For instance, using FieldView increased corn yields by 10% and reduced fertiliser costs by 15% on a farm in Germany (FieldView – the driving force..., n.d.). With accurate data analysis and crop management recommendations, farmers can make more informed decisions and achieve better results.

The previous examples demonstrate how various agricultural enterprises around the world are using modern technology to increase efficiency, reduce costs and ensure the sustainability of their operations. The introduction of digital technologies, blockchain and AI opens new opportunities for agribusiness and contributes to its development in the face of rapidly changing economic and climate conditions. As one of the largest agricultural countries in Europe, Ukraine is gradually introducing modern technologies to improve the efficiency of agricultural production. The use of digital technologies, blockchain and AI is becoming more widespread, although there are certain challenges and limitations. Ukrainian agricultural enterprises are actively implementing digital technologies to optimise production processes. The use of sensors, drones and satellite imagery allows farmers to obtain accurate data on field conditions, yields, soil moisture and other important parameters. For instance, precision farming platforms such as eFarmer and AgroOnline allow farmers to manage their fields through mobile apps and web interfaces (Ihnatko, 2021). These platforms collect and analyse data in real-time, enabling informed decisions on fertilisation, irrigation and crop protection. The use of drones to monitor fields is becoming more and more common. Drones provide detailed images of fields, allowing farmers to identify problem areas, assess the condition of crops and plan agronomic measures. This increased yields and reduced resource costs.

Blockchain technologies are still at the stage of experimental implementation in the Ukrainian agricultural sector but already have the potential to significantly improve the transparency and efficiency of supply chains. One of the first projects in this area is Agrocontrol, a blockchain platform for tracking supply chains. The introduction of AI in Ukraine's agricultural sector is slower, but there are already examples of successful use of this technology. AI is used to analyse large amounts of data to optimise various aspects of agricultural production. For example, IMK uses machine learning algorithms to predict yields and plan crops. This improves the accuracy of forecasts and optimises the use of resources. AI is also used to analyse sensor data and satellite imagery, which identifies problems in the fields and takes timely action. Another example is the Agrieye platform, which uses AI to analyse satellite imagery and weather data, allowing farmers to plan agronomic activities and optimise the use of fertilisers and pesticides.

Although the introduction of digital technologies, blockchain and AI in the Ukrainian agricultural sector is still at an early stage, there are already positive examples of successful use of these technologies. The gradual digitalisation of the agricultural sector is helping to improve production efficiency, reduce costs and ensure transparency in supply chains. However, further development requires addressing challenges such as insufficient funding, lack of proper infrastructure and the need for training.

Investor Relations & Corporate. Annual reports (n.d.) is one of the largest agricultural holdings in Ukraine, known for its vertically integrated structure, which includes all stages of production from growing grains and oilseeds to producing meat and food products. MHP has a significant market share and plays a key role in the country's agricultural sector, making it a good example for analysing the introduction of modern technologies. Figure 3 shows the key financial indicators of MHP from 2019 to 2023.

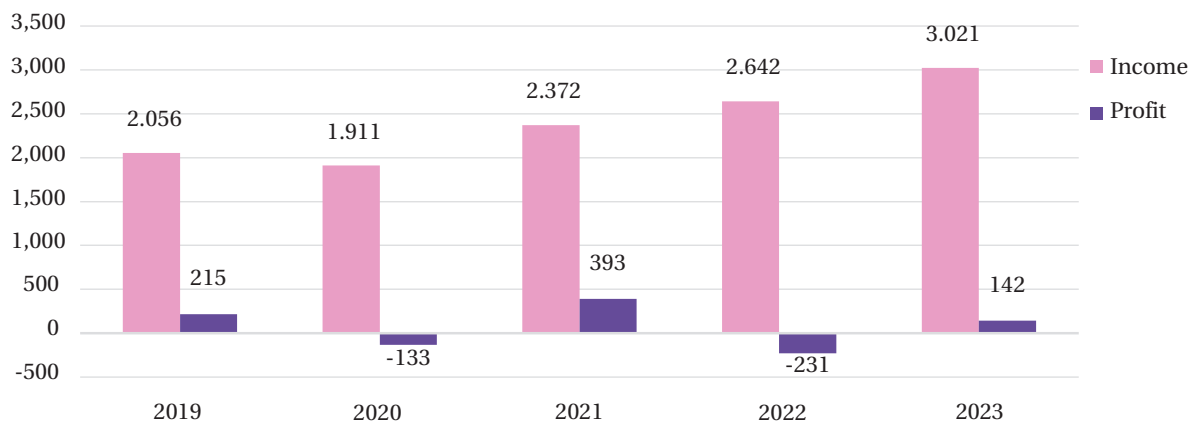


Figure 3. MHP's financial performance from 2019 to 2023, USD million

Source: compiled based on Investor Relations & Corporate Governance. Annual reports (n.d.)

The company showed a significant increase in revenues, which indicates its stability and potential for development. However, fluctuations in profit levels indicate difficulties faced by an enterprise in different economic conditions. The sustainability and effectiveness of management strategies that allow a company to adapt to changes in the market and achieve positive financial results in the medium term are important. MHP faces several problems and challenges. One of the main problems is insufficient funding for innovation. The high costs of implementing modern technologies can be an obstacle to full-scale innovative solutions. For instance, the installation of soil monitoring sensors, drones for field surveys and satellite systems requires significant financial investment.

Infrastructure constraints also pose challenges, especially in remote agricultural regions and in areas affected by the war in Ukraine. They may not have the right infrastructure to support digital technologies. For instance, the effective use of IoT sensors and other digital tools requires a stable and fast internet connection, which may be unstable or non-existent. This complicates the implementation of digitalisation projects and reduces the effectiveness of the implemented technologies. Staff training is critical to the successful implementation

of new technologies. In many cases, employees of agricultural enterprises do not have sufficient knowledge and skills to work with modern technologies. To use precision farming systems effectively, workers need to be trained to recognise and respond to the data provided by these systems. This requires a significant investment in training and development, which can be a significant financial and organisational hurdle for a company. As the number of digital systems and data volumes increase, the risks of cyberattacks increase, which can have serious consequences for MHP. The use of digital technologies involves the storage and transmission of a large amount of confidential data, including information on yields, crop plans, financial data, and more. Vulnerability to cyber threats can lead to data leakage, information loss, or even production processes stopping.

Despite the existing problems, MHP has significant prospects for further development through the introduction of modern technologies. The integration of digital technologies, blockchain technologies, AI, and effective risk management can significantly improve MHP business processes (Fig. 4). To implement this integrated model, it is necessary to address the existing problems and challenges faced by the company, as well as to take into account the overall state of digitalisation in Ukraine.

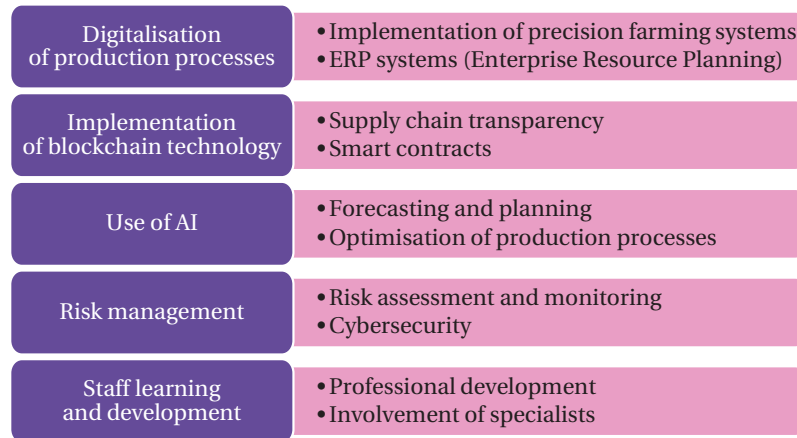


Figure 4. An integrated model for improving business processes at “Myronivsky Hliboproduct”

Source: compiled by the authors

The main components of the integrated model include the digitalisation of production processes, the introduction of blockchain technologies, the use of AI and risk management. The first step is the digitalisation of production processes. The introduction of precision farming systems will allow the installation of sensors to monitor soil, moisture, temperature and other parameters. The use of drones and satellites to regularly inspect fields and collect data, as well as software to analyse the collected data, will allow us to provide recommendations on optimising fertilisation, irrigation and other agronomic measures. Integration of ERP systems to manage all aspects of production, from the purchase of raw materials to the sale of finished products, will automate management processes, reducing costs and increasing efficiency (Duong *et al.*, 2019).

The introduction of blockchain technologies will ensure the transparency of supply chains. The development and implementation of a blockchain platform for tracking products from the field to the end consumer will ensure transparency at all stages of production, increasing the trust of consumers and partners. The use of smart contracts to automate contractual relationships with suppliers and partners minimises the risk of counterfeiting and fraud due to the immutability of blockchain data. The use of AI will improve forecasting and planning. Analysis of large amounts of data using AI can be used to predict yields, plan crops and optimise resource use. The development and implementation of machine learning algorithms to identify patterns and improve decision-making will help optimise production processes. The use of AI for real-time monitoring and adjustment of production processes, as well as automatic detection and resolution of production problems, will increase operational efficiency.

Risk management is an important aspect of the integrated model. Implementation of specialised systems to assess and monitor risks related to production, supply and financial aspects of the company's operations will allow for effective risk management. The employment of AI to predict potential risks based on historical data analysis minimises potential threats. Cyber security is also an important element. Implementation of modern means of protecting data and information systems from cyberattacks, as well as regular training of personnel on

cybersecurity and development of strategies for responding to cyberattacks, will ensure that the company is protected from cyber threats. Staff training and development is critical to the successful implementation of new technologies. Developing and implementing advanced training programmes for employees focused on mastering new technologies and working methods, as well as organising practical training and seminars to teach staff how to work with new digital tools and systems, will help ensure the required level of competence. Engaging experts in digital technologies, blockchain and AI, as well as establishing cooperation with universities and research institutes to train highly qualified specialists, will contribute to the successful implementation of the integrated model (Komarek *et al.*, 2020).

The integration of digital technologies, blockchain, AI and effective risk management can significantly improve the efficiency of MHP business processes. Addressing existing problems and challenges, such as insufficient funding for innovation, infrastructure constraints, staff training and cybersecurity, is critical to the successful implementation of this integrated model. Implementation of the proposed measures will allow the company to become a leader in innovation in the Ukrainian agricultural sector, increase competitiveness and ensure sustainable development in the future.

► Discussion

The results of the study underline the critical importance of economic security for the stability and success of agricultural enterprises in the face of market instability and changing economic conditions. The key aspects of ensuring economic security include financial planning and control, diversification of products and markets, and the introduction of modern digital technologies. These measures reduce financial risks, optimise the use of resources and ensure the stability of the company's financial position.

O. Solosich *et al.* (2021) addressed the role of state support in ensuring the economic security of agricultural enterprises. In their paper, they argue that government subsidies and soft loans play a crucial role in maintaining the financial stability of agricultural companies. D. Pan *et al.* (2020), in turn, showed that enterprises that receive

state support are less dependent on market fluctuations and have more stable financial performance. This confirms the findings of the current study on the importance of financial planning, although its focus was more on internal strategies of enterprises rather than external support. Financial planning and control are key components of economic security. Agricultural enterprises must carefully analyse their financial flows, considering the costs of growing crops, servicing loans, labour and other expenses. It is also necessary to identify and manage financial risks that may arise from fluctuations in commodity prices, changes in exchange rates, changes in legislation or climatic conditions. Effective financial planning allows businesses to minimise risks and ensure a stable financial position even in the face of uncertainty.

Diversification of products and markets is another important aspect of economic security (Nunes & Sytnychenko, 2024). Expanding the range of products helps to reduce the risk of losses in the event of changes in market demand or price changes. The development of new sales markets, including export markets, helps to reduce dependence on the domestic market and expand the audience of consumers (Abdullayev *et al.*, 2024). This reduces the risks associated with fluctuations in individual markets and increases the company's resilience to external shocks. A.A. Adenle *et al.* (2019) addressed the importance of international markets for the economic security of agricultural enterprises. They investigated how export strategies affect revenue stability and risk mitigation. S. Fan & C. Rue (2020) showed that enterprises that actively develop exports are less vulnerable to domestic market fluctuations. These findings are in line with current findings on market diversification as an important aspect of economic security. However, the focus was more on product diversification, while the authors examined international trade in detail.

The digitalisation of the agricultural sector is a key factor in improving its economic security, efficiency and competitiveness in the face of current challenges (Buka *et al.*, 2023). The introduction of digital technologies helps to optimise production processes, reduce costs and improve product quality. One of the main elements of this transformation is the concept of smart farming, which includes the use of IoT, process automation and precision farming. These technologies can be used to collect and analyse data on the condition of crops, soils and climatic conditions, which contributes to more efficient resource management. M.A. Dayioğlu & U. Turker (2021) analysed the impact of digital technologies on the efficiency of agricultural production. Their findings indicate that the introduction of automated farm management systems contributes to a significant reduction in costs and an increase in productivity. J. Clapp & S.L. Ruder (2020), in turn, focused on the use of unmanned aerial vehicles for field monitoring, which coincides with current findings on the use of drones and satellite technology. However, the authors' research is more focused on the technical aspects of implementing these technologies, while there is a need to consider economic and managerial aspects.

The use of Big Data and blockchain technologies has significant potential for agribusiness. Big data collects, stores and analyses huge amounts of information to make informed management decisions. Blockchain provides

transparency of all transactions and operations, which contributes to full transparency and traceability of supply chains (Stender *et al.*, 2024). Drones and satellite technologies provide unique opportunities for monitoring crops and forecasting yields, which allows for accurate planning of agrotechnical measures. J.A. Delgado *et al.* (2019) also studied the role of Big Data in the agricultural sector. They concluded that analysing large amounts of data provides more accurate crop forecasting, optimised resource use, and more efficient management decisions. The current findings on the importance of digitalisation and the use of Big Data are confirmed by the authors' results, but the importance of blockchain technologies for supply chain transparency should also be considered. The introduction of AI in the agricultural sector opens many opportunities to increase the productivity and efficiency of crop cultivation. AI helps to predict crops, optimise resource use, and automate processes, which reduces costs and increases profitability. For instance, AI-powered analytics systems can adapt the use of water, fertilisers, and pesticides to the needs of each specific area of the field.

Effective risk management is an essential component of ensuring the stability and success of agricultural enterprises. The use of insurance, financial instruments such as options and futures, as well as the development and implementation of business plans and risk management strategies, help to minimise the impact of risks on the business (Tanchyk *et al.*, 2024). An important area of risk management is the development of risk mitigation technologies and careful planning and analysis of markets. N.T. Huong *et al.* (2019) studied the impact of climate change on the economic security of agricultural enterprises. They noted that unpredictable weather changes and extreme climatic conditions have a significant impact on the yields and financial stability of agribusiness. N. Möhring *et al.* (2020) proposed the introduction of crop insurance as an effective risk management tool. The current study also mentioned risk management, including insurance, but focused more on digital technologies for monitoring and forecasting crops. This highlights additional approaches to mitigating climate-related risks.

The use of modern technologies by the world's leading agricultural companies, such as John Deere, Agricultural Bank of China, Fruition Sciences, TE-FOOD and others, demonstrates the success of their implementation to increase efficiency and reduce costs. Ukrainian agricultural enterprises are also gradually introducing modern technologies, which allow them to increase production efficiency, reduce costs and ensure transparency of supply chains (Wrzecińska *et al.*, 2023). However, challenges such as insufficient funding, lack of proper infrastructure, and the need for training need to be addressed to further develop. J. Janker *et al.* (2019) focused on the social aspects of the economic security of agricultural enterprises. They studied the impact of HR policies and the level of digital education of employees on production efficiency and economic stability of companies. They found that enterprises that invest in the training and development of their employees have higher productivity and better financial performance. Although the current study focuses more on technological and economic aspects, the authors' findings add to the vision of the importance of human capital for economic security.

The models of successful implementation of modern technologies presented by the world's leading agricultural companies can serve as an example for Ukrainian enterprises. They demonstrate that investments in technology bring tangible results in the form of increased production efficiency, reduced costs and higher yields. Ukraine needs to intensify the process of introducing modern technologies, develop infrastructure and train specialists to ensure the sustainable development of the agricultural sector. An analysis of other authors' studies confirms the complexity and multifaceted nature of approaches to ensuring the economic security of agricultural enterprises. Key aspects such as state support, climate risk management, digitalisation, development of export strategies, use of big data and investment in human capital are proving to be important components of the successful functioning of agricultural enterprises.

► Conclusions

This study provides a comprehensive analysis of the importance of economic security for the stability and success of agricultural enterprises in the face of market volatility and changing economic conditions. The main aspects considered include financial planning and control, product and market diversification, digitalisation of the agricultural sector, use of big data and blockchain technologies, and the introduction of AI.

An analysis of successful examples of digital technologies, such as John Deere, Agricultural Bank of China, Fruition Sciences, TE-FOOD and FieldView, shows the prospects for implementing these innovations in the agricultural sector. John Deere's revenues increased by

56% from 2019 to 2023, reaching \$61.3 billion. And Agricultural Bank of China increased its revenue by 60% from 2019 to 2023, reaching 39.9 trillion yuan. The study also covered the state of the Ukrainian agricultural sector and identified the potential for the introduction of modern technologies in this area. An example of this potential is the analysis of MHP's operations and the identification of problems and challenges that this company faces in the context of innovation. Based on the study, an integrated model was developed to improve MHP's business processes. This model includes five key components: digitalisation of production processes, implementation of blockchain technologies, application of AI, effective management risk, and training and development of personnel. These components are aimed at ensuring transparency, optimising production processes, and reducing risks for the company.

A limitation of this study is the insufficient scope of the topics and examples considered to cover all uses of modern technologies in the agricultural sector. Further research could expand the scope of the technologies considered by examining their impact on various aspects of agricultural production, including environmental and socio-economic aspects. In addition, research could focus on the effectiveness of the implementation of individual technologies in different regions and conditions.

► Acknowledgements

None.

► Conflict of interest

None.

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Покращення бізнес-процесів в аграрному секторі з урахуванням економічної безпеки, цифровізації, ризиків та штучного інтелекту

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► **Анотація.** Дане дослідження було направлене на вивчення шляхів підвищення ефективності агробізнесу через впровадження сучасних технологій та інноваційних підходів. Для досягнення цієї мети було використано методи кількісного і якісного аналізу фінансових показників, аналітичні огляди та розглянуто конкретні приклади впровадження технологій. Основний акцент зроблено на вплив цифровізації аграрного сектора на підвищення його економічної безпеки, ефективності та конкурентоспроможності. Запровадження цифрових технологій, таких як Інтернет речей, автоматизація процесів та точне землеробство, дозволяє оптимізувати виробничі процеси, знижувати витрати та покращувати якість продукції. Результати дослідження показують, що концепція «розумного фермерства» значно підвищує ефективність агробізнесу. Використання Big Data, блокчейн-технологій, дронів та супутникових технологій дозволяє краще управляти агробізнесом, тоді як штучний інтелект допомагає прогнозувати врожайність та оптимізувати агротехнічні процеси. Управління ризиками в аграрному секторі, включаючи страхування та фінансові інструменти для хеджування цінних коливань, є ключовим фактором для підвищення економічної стабільності. Досвід провідних світових компаній, таких як John Deere, Agricultural Bank of China, Fruition Sciences, TE-FOOD та FieldView, показав ефективність впровадження цифрових технологій та інновацій для підвищення ефективності та сталого розвитку. Особливу увагу приділено проблемам і перспективам впровадження сучасних технологій в аграрному секторі України на прикладі компанії «Миронівський Хлібопродукт». Запропонована інтегрована модель покращення бізнес-процесів «Миронівського Хлібопродукту», включає цифровізацію виробничих процесів, впровадження блокчейн-технологій, використання ІІІ та управління ризиками. Для подолання існуючих проблем, таких як недостатнє фінансування інновацій, інфраструктурні обмеження, навчання персоналу та забезпечення кібербезпеки, визначено необхідні кроки. Реалізація запропонованих заходів дозволить компанії стати лідером у впровадженні інновацій в аграрному секторі України, підвищити конкурентоспроможність та забезпечити сталий розвиток у майбутньому

► **Ключові слова:** сільське господарство; інноваційні технології; точне землеробство; кібербезпека; конкурентоспроможність



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Global changes in the development of the export potential of the grain sub-complex of the agrarian sector of Ukraine

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► **Abstract.** In modern conditions, the export of agricultural products is one of the main sources of income for the agricultural sector of Ukraine. Thus, conducting multi-faceted studies of foreign trade in this sector is relevant. The purpose of the study was to develop estimates of the possibility of developing grain exports in Ukraine based on the analysis of current data on the development of this sector, and individual global trends. The paper investigated global changes in the development of the export potential of the grain and food sub-complex of the agricultural sector of Ukraine. It is proved that the decomposition of the export potential of the grain sub-complex according to the sectoral system of the agrarian sector allows forming a step-by-step methodical assessment of its quantitative and qualitative indicators to determine the compositional integrity of the effective value of the object under study. A comprehensive functional-resource analysis of the parameters of the export potential of the grain sub-complex, which are grouped according to the process approach for calculating the food security of the export chain of grain production entities, is presented. The procedure for assessing the state of food security of the grain sub-complex of the state through the resource component allows diagnosing the export capabilities of subjects of foreign trade operations in the presence of numerous risks. The actual dependence of the gross domestic product of Ukraine on the export of products of the grain sub-complex was determined and its forecast value for a five-year period was calculated. A pessimistic-

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optimistic scenario of the growth (reduction) of Ukraine's gross domestic product at the lower and upper limits of realisation of the export potential of the grain sub-complex is given. The conclusions obtained in the framework of the study can be used to form a policy in the agricultural sector of Ukraine

► **Keywords:** industry system; military invasion impacts; war period trends; market integration difficulties; international trade

► Introduction

The agricultural sector now plays a huge role in the development of the Ukrainian economy. It has a significant impact on gross domestic product (GDP), promotes the attraction of foreign currency, and allows for more effective achievement of food security and the fight against hunger on the international stage (Jindo *et al.*, 2020; Pawlak & Kolodziejczak, 2020). In turn, grain production is one of the strategic directions in the structure of the agrarian sector. The reason for this is the growing demand for grain on the global market, which is compounded by growing food security problems around the world (Anghinoni *et al.*, 2021; Constantin *et al.*, 2023). This is happening in the context of the existing potential to increase grain production in Ukraine due to fertile soils, favourable natural and climatic conditions, the presence of seaports, and the constant modernisation of the existing warehouse, production and trade infrastructure in Ukraine.

Currently, Ukrainian grain producers face significant challenges in the European market due to high competition, political instability, and economic pressure increased by Russia's military aggression. This conflict disrupted the regulation of the agricultural market, weakened global logistics, and threatened Ukraine's food security (Penkova & Kharenko, 2023). Overcoming problems requires constant efforts on the part of the state and entrepreneurs to restore the consequences that arose during the war. Therefore, the export potential of the grain sector of Ukraine also remains insufficiently realised. War hinders the development of effective tools for development. The conflict also limited the use of national policies to increase grain exports and protect Ukrainian producers, since state tools in war conditions do not always work effectively due to, in fact, military actions (Yaheliuk *et al.*, 2024). To solve this problem, it is necessary to update the production infrastructure and introduce technological innovations, improve crop rotation, use better fertilisers and seeds, increase yields, and eliminate price imbalances. Given the role of agricultural exports for the country and for the world (in the context of ensuring food security), it is very important to promote its development (Skydan *et al.*, 2024). This can be achieved through new economic reforms that create functional links between agricultural and industrial enterprises to ensure reliable grain supplies.

In general, recognising and understanding the micro-level obstacles faced by exporters is the first step in creating effective export promotion strategies. The main barriers now consist of problems related to duties and quotas, and non-tariff restrictions, for example, the policy on value added tax (VAT) and currency control (Kutkowska & Szuk, 2020; Wang *et al.*, 2022). Agricultural enterprises that actively interact with international trade are key in this context, and their success largely depends on the business environment and the current regulatory framework (Králík *et al.*, 2023). It is important to consider that

the export potential of Ukraine is affected by various foreign economic barriers determined by political, economic, and social factors. These factors shape the structure and nature of export activities at the level of individual countries, regions, and industries.

The organisational and economic and other principles of the functioning and regulation of the development of foreign economic activity, the production and export potential of the agrarian sector were investigated by: N. Trusova *et al.* (2022). However, the continuous evolution of the international concrete environment, coexistence with unique features of internal socio-economic and socio-political conditions, and continuous changes in the activities of enterprises that export grain, introduce additional internal and some external restrictions. This requires a review of the export potential of the grain complex of Ukraine at the global level. It is particularly important to ensure a systematic, integrated, step-by-step and targeted state policy in this area.

The purpose of the study was to assess the possibilities of introducing economic tools to increase the export potential of Ukraine's grain by identifying its components in the agricultural sector. This allowed predicting new elements and characterise methodological approaches to assessing global economic opportunities for grain producers.

► Materials and methods

The study used statistical data taken from relevant internet sources, such as United States Department of Agriculture (USDA significantly increased..., 2022) (export volumes of major wheat producers, the level of export growth of these products, Ukrainian wheat exports), Sown areas of crops by type (n.d.) (share of exports of grain products of Ukraine in the structure of export-import operations of the European Union countries), the Agriculture, forestry, and fishing, value added (% of GDP) – Ukraine (n.d.). Statistical data were evaluated over different time periods depending on the data type, but in general, the time interval was between 2012 and 2024. Graphs and charts were used to visualise the data and analysis results, which helped to better understand the dependencies and existing trends between the data. Conclusions in the framework of the study were developed using analysis, which allowed evaluating the obtained quantitative and qualitative data.

An important method used in the study was the correlation-regression approach, which determined the degree of relationship between two variables, simulated it and predicted the future development of events. Correlation measured the strength and direction of a linear relationship between two variables. The most commonly used correlation coefficient was the Pearson correlation coefficient, which is denoted as r , and is within $[-1; 1]$. Correlation analysis, in turn, involved determining the relationship between a dependent variable (response variable)

and one or more independent variables (predictor variables). A common approach was to form a regression using a line (linear regression), which was used in the work. Excel software and its tools for calculating and constructing data of this kind were used to perform these estimates.

The study also used the calculation of indicators such as variance and standard deviation. If variance is a measure of the scattering of data around their mean and shows the mean square of the deviation of each value from the mean, the standard deviation is the square root of the variance, is also a measure of data scattering, but is expressed in the same units of measurement as the data itself, which makes it more intuitive. The equation (2) for calculating the standard deviation is as follows:

$$\sigma = \frac{\sqrt{\sum(\text{Ex}_{if} - \text{Ex}_{ic})^2}}{N}, \quad (1)$$

where σ – standard deviation; Ex_{if} – actual export volume of products of the grain group from Ukraine in the i -th year; Ex_{ic} – forecast value of growth (reduction) in the volume of GDP from foreign economic trade of subjects of the grain sub-complex of Ukraine in the i -th year; N – the number of observations.

Another indicator, “deviation from the forecast”, was calculated as shown in equation (2):

$$D = \sqrt{1 - R^2} + \sigma. \quad (2)$$

That is, the deviation of the model dependence of GDP on foreign economic trade of subjects of the grain sub-complex of Ukraine amounts to USD 505.43 million. The upper and lower limits of the forecast values were determined by equation (3):

$$\text{UL}_i = \text{Ex}_{ic} + D; \text{LL}_i = \text{Ex}_{ic} - D, \quad (3)$$

where UL_i , LL_i – upper and lower limits of the forecast.

As part of the study, based on the data analysis performed, a regression equation was constructed using the least squares method. The equation in the study was of the third degree, in which the dependent variable was the volume of exports, and the independent variable was the

level of GDP (gross domestic product); the equation where the dependent variable was under the logarithm was also used. These methods of constructing the equation were chosen due to the fact that they had the highest value of R^2 (percentage of variation of the dependent variable). However, the general view of this method was as follows (4):

$$y = \beta_0 + \beta_1 x_1 + \dots + \beta_n x_n, \quad (4)$$

where y – dependent variable; x_n – independent variables; β_n – indicator for an independent variable.

All calculations were performed using Microsoft Excel software suite.

► Results

In the period before the war, the development of the export potential of the grain sub-sector within the sectoral system of the state agricultural sector was determined by various factors that contributed to the growth of this industry. Among these factors, the following can be distinguished: the ability to achieve competitive positions in the most profitable global agricultural markets, an increase in the number of marketing actions of grain producers from Ukraine, a reduction of the risks that consisted in dependence on the domestic market, development and expansion of logistics opportunities, introduction of innovative modernizations, and a change of approach from excessive dependence on raw materials through the development of integrated grain clusters (Lin & Zhang, 2020; Khan *et al.*, 2021).

In Ukraine, the grain sector has a great potential for the development of foreign trade. In 2021, wheat became the main export product in this industry. In the period from 2019 to 2021, Ukraine ranked third among the main exporters to the EU countries, second only to the United States (USD 12.3 billion) and Brazil (USD 11.7 billion). Exports of agricultural products from Ukraine to the EU countries in 2019 amounted to USD 7.3 billion, which indicates a positive trend in international trade relations. An important indicator is the growing role of EU countries in bilateral trade in grain products, which occurs not only in the export, but also in the import of these goods. More information is presented in Figure 1.

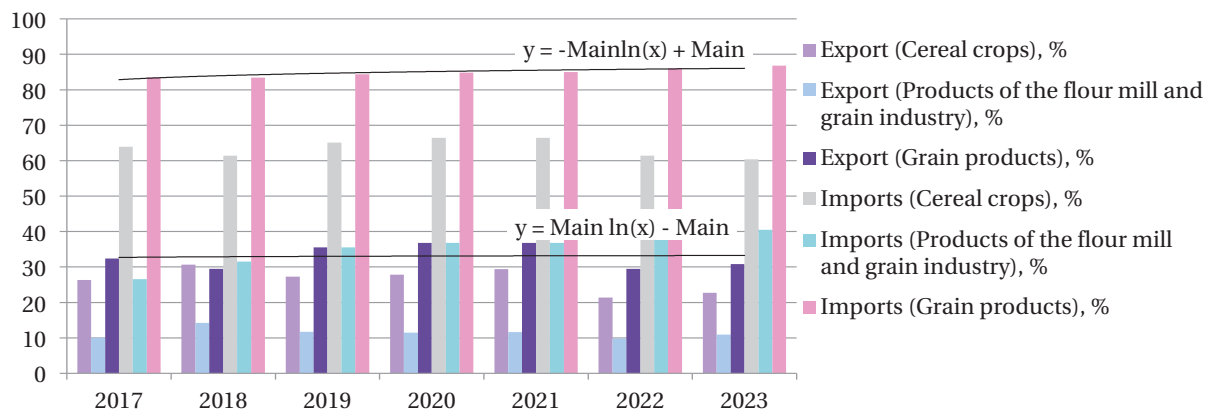


Figure 1. Share of exports of grain sub-complex products of Ukraine in the structure of export and import operations of EU countries for 2017-2023, %

Source: compiled by the authors based on Sown areas of crops by type (n.d.)

EU countries are interesting for exports because of their great strength and financial stability. In addition, their high standards of competition, emphasis on food quality and safety, and increasing the competitiveness of the Ukrainian grain industry make them attractive markets.

In 2023, Ukraine exported 3.9 million tonnes of grain and leguminous crops abroad, which is 17% less than in

2022, when exports amounted to 4.7 million tonnes. Despite this decline, the constant volume of exports in the range of 3.5-4.0 million tonnes per month allowed Ukraine to fully realise the export potential of the grain sector within the agricultural sector. In total, in the period from July 1, 2022 to June 30, 2023, Ukraine exported 48.9 million tonnes of grain and leguminous crops. This data can also be seen in Figure 2.

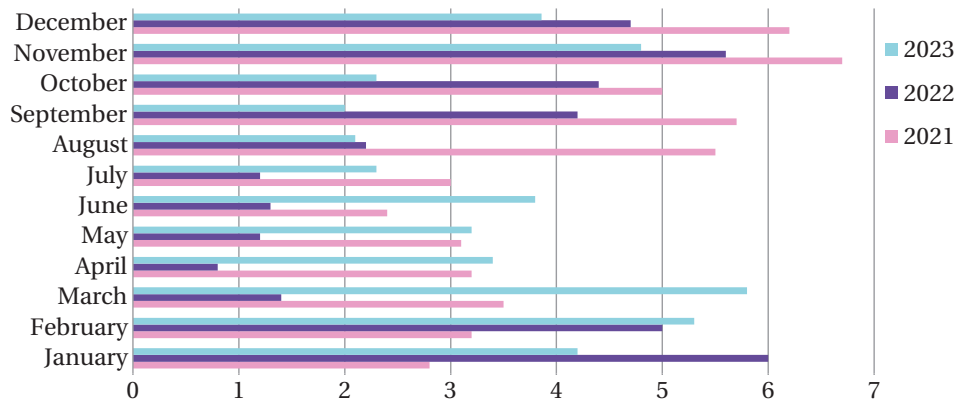


Figure 2. Monthly transit of export shipments of grain sub-complex products to Ukraine for 2021-2023, million tonnes

Source: compiled by the authors based on M. Samoiliuk & Y. Levchenko (2024)

In 2023, Ukraine faced problems in grain exports due to disruptions caused by the Russian invasion, including the destruction of the Kakhovka Hydroelectric Power Plant and logistics blockades. Despite these obstacles, Ukraine introduced a new sea route along the eastern coast of the Black Sea, which allowed Ukraine to successfully export 99.8 million tonnes of goods, including increasing the export of metal and semi-finished products by 40%, rolled steel – by 45.3%.

The value of grain exports from the country decreased by 18.7% to USD 35.8 billion, which reflects an overall decrease in foreign trade turnover by 1.4% to USD 98 billion compared to 2022. However, total sea exports in 2023 increased by 1 million tonnes. Container exports increased by 86% by rail and 36% by road, especially value-added products. But due to the blockade of Polish borders, grain exports by road decreased by 18.3%, although the overall decline was only 0.7% year-on-year

Revenue from corn exports also declined, despite a 5% increase in physical volumes, falling by 16.8%. This was influenced not only by the global drop in prices, but also by logistical problems and the redistribution of profits to neighbouring countries, where Ukrainian grain is often resold. Imports rose to USD 62.2 billion, with notable imports including fuel, medicines, and agricultural products such as fertilisers. Forecasts indicate stable wheat production in Ukraine at the level of 19.5 million tonnes with an increase in exports to 11 million tonnes. Corn production and exports are expected to grow significantly: production will grow by 5 million tonnes to 30 million tonnes, while exports will increase by 3.5 million tonnes to 12.5 million tonnes. Worldwide wheat production reached record levels, mainly due to growth in Russia, Australia, and China, while India and EU countries experienced some declines. Wheat consumption and trade also increased, especially in Australia, with a slight decline in stocks around the world. These data are shown in Figures 3, 4.

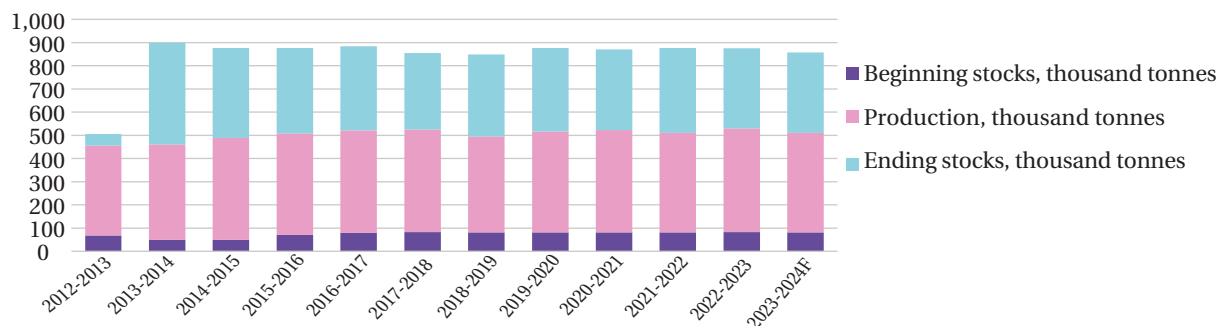


Figure 3. Wheat supply in major eight* exporting countries for 2012-2024F (forecast), thousand tonnes

Note: the eight largest wheat exporters in 2022 were Australia, the United States, Canada, France, Russia, Argentina, Ukraine, Germany, India, and Romania

Source: compiled by the authors based on USDA significantly increased its forecast for Ukraine's corn production and exports in 2022/2023 MY (2022)

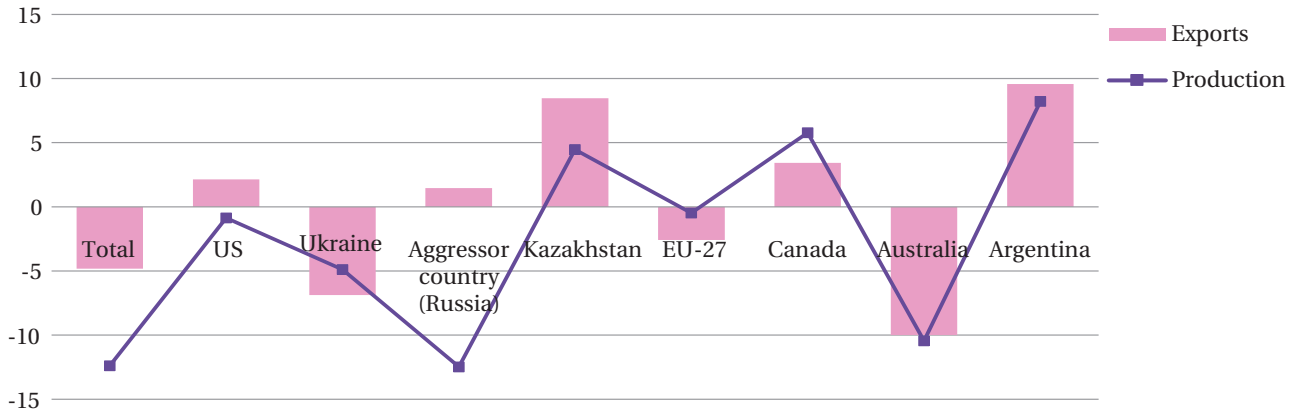


Figure 4. Projected year-on-year changes in wheat production and exports (2023-2024F to 2022-2023), thousand tonnes

Source: compiled by the authors based on USDA significantly increased its forecast for Ukraine’s corn production and exports in 2022/2023 MY (2022)

Global corn production declined by 6.3 million tonnes from 2018 to 2022, with a marked decline in the US and EU countries partially offset by growth in Ukraine, Malawi, and Turkey. Forecasts point to a potential decline in wheat production for major exporters such as Australia and Ukraine, while growth is expected in Argentina, the EU, and Canada. Dry weather conditions, including droughts in Australia and Canada, could further negatively affect global wheat production. Wheat exports from Ukraine may also decrease, although current wheat crops are increasing, estimated production is 16-17 million

tonnes, and exports are 8-10 million tonnes, mainly by sea. Ukraine can export more than 6 million tonnes of wheat to Europe each season, but restrictions on wheat imports from neighbouring countries due to EU policies may persist as European countries start the new season with sufficient reserves of the previous crop. This leaves Ukrainian grain producers primarily as transit intermediaries to these countries, although with limited export volumes. The main demand for Ukrainian wheat comes from Asia and North Africa, but their purchases decreased in 2022-2023 (Fig. 5, 6).

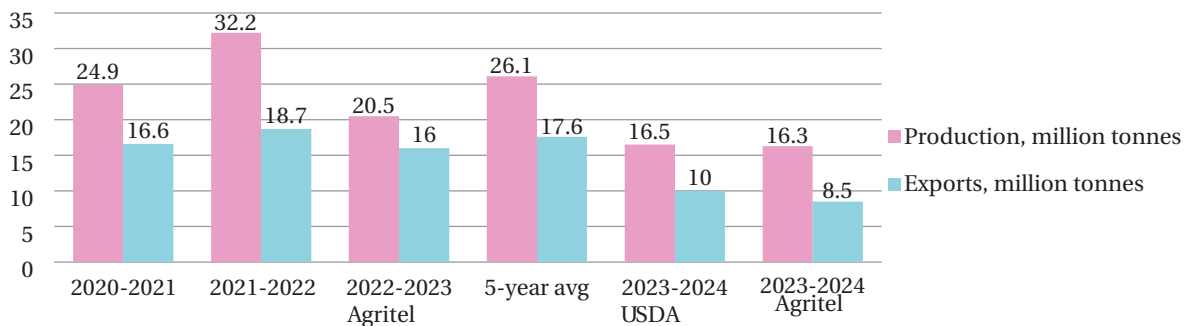


Figure 5. Ukraine wheat production and exports, million tonnes

Source: compiled by the authors based on USDA significantly increased its forecast for Ukraine’s corn production and exports in 2022/2023 MY (2022)

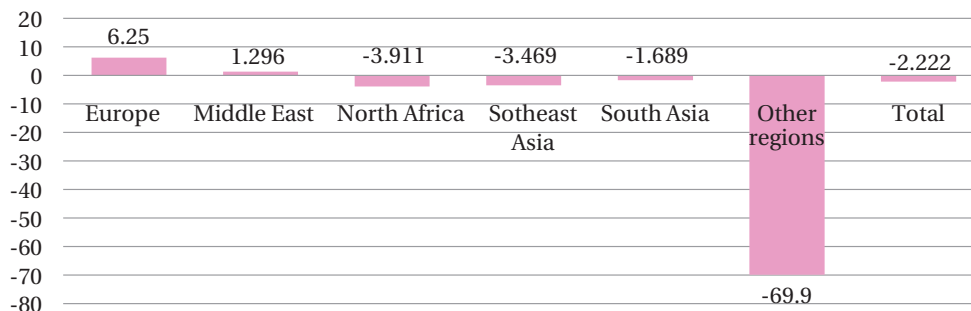


Figure 6. Difference between Ukraine wheat exports in 2022-2023 and 2020-2021, thousand tonnes

Source: compiled by the authors based on USDA significantly increased its forecast for Ukraine’s corn production and exports in 2022/2023 MY (2022)

During 2022-2023, several countries in Asia and North Africa shifted their wheat purchases to alternative suppliers such as Russia, France, and Australia, reducing their dependence on Ukrainian wheat. For example, Egypt, Pakistan, and Morocco, increased purchases from France and Russia, and Indonesia – from Australia. However, these countries remain open to buying Ukrainian wheat if certain conditions are met, in particular, the price and reliable

sea exports. In terms of corn trade, Ukraine, along with Serbia and Zambia, saw an increase in exports, while the EU and the US experienced a decline. In 2023-2024, there are different prospects for exporting Ukrainian wheat to different regions, depending on factors such as demand, local production, quality, and competition from other suppliers. Remaining export stocks of corn in 2022-2023 decreased by 6.2 million tonnes to 306.7 million tonnes (Fig. 7).

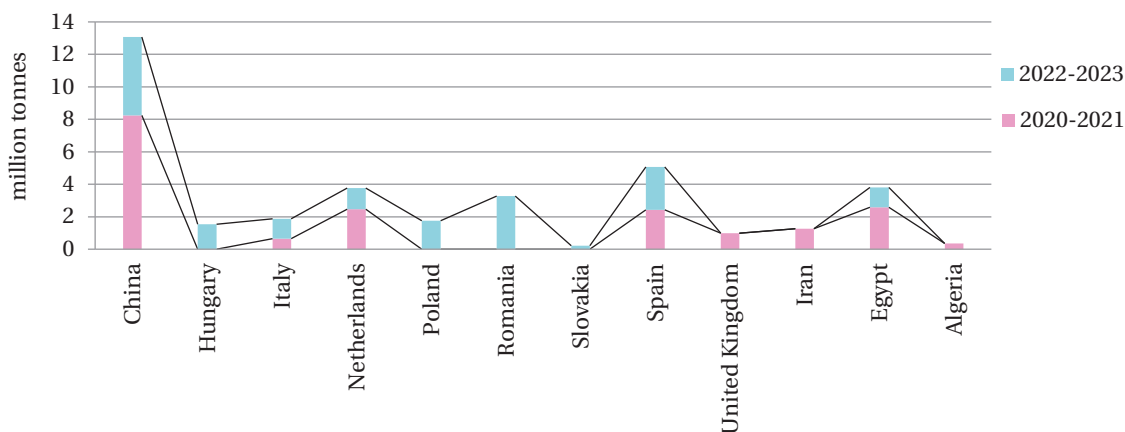


Figure 7. Export of corn in Ukraine for 2020-2023, million tonnes

Source: compiled by the authors based on USDA significantly increased its forecast for Ukraine’s corn production and exports in 2022/2023 MY (2022)

In Ukraine, corn production may decrease due to a decrease in acreage. However, if there are no problems with yield, producers can expect a harvest of approximately 22-23 million tonnes (Fig. 8-9). The available production estimates, together with significant reserves, allow predicting

the export of approximately 19 million tonnes of corn during the 2023-24 season. It is also worth noting that corn exports largely depend on sea routes, since in 2023 70% of the export volume was carried out through deep-sea transportation.

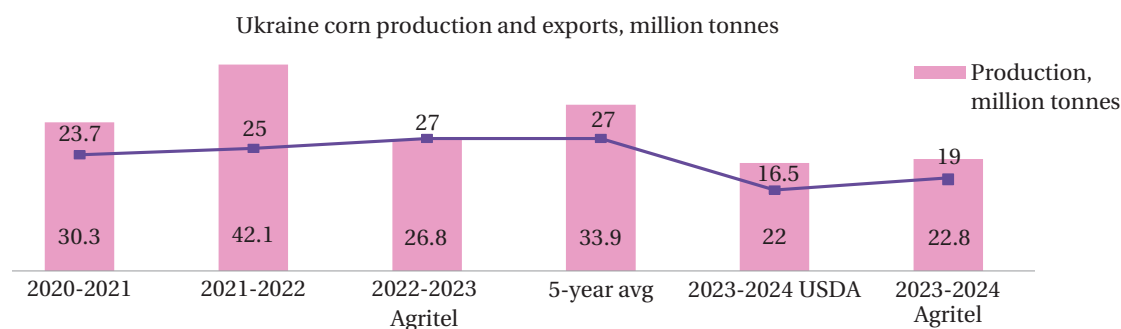


Figure 8. Production and exports of corn in Ukraine, million tonnes

Source: compiled by the authors based on USDA significantly increased its forecast for Ukraine’s corn production and exports in 2022/2023 MY (2022)

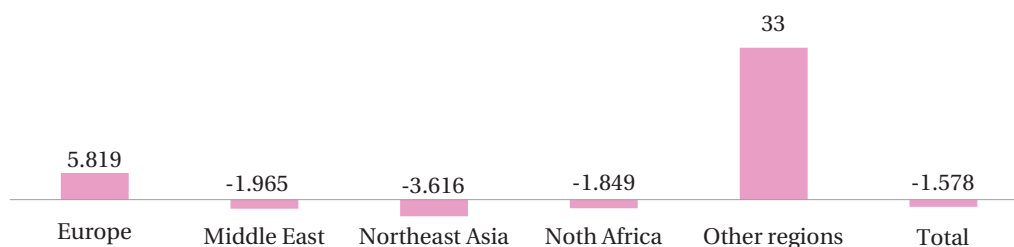


Figure 9. Difference between Ukraine corn exports in 2022-2023 and 2020-2021, thousand tonnes

Source: compiled by the authors based on USDA significantly increased its forecast for Ukraine’s corn production and exports in 2022/2023 MY (2022)

Corn exports to Europe will become more problematic in 2024. Given the forecast of production of more than 12 million tonnes, EU demand for this crop is likely to decrease. This is compounded by a ban on exports to five neighbouring countries and intense competition between corn-producing countries around the world due to the large supply volume (Seok & Moon, 2021). In Europe, Ukraine competes with Brazil. The only possible advantage for Ukraine may be that China opens its own market for Brazilian corn, since China most often buys corn from Brazil. However, Ukrainian corn has competitive advantages both in China and in the world due to the absence of genetically modified impurities. Thus, the prospects for

2024 indicate that the EU-27 should remain a major buyer, although demand could be lower due to a sharp expected rebound in local production by 12 million tonnes. Additionally, there will be rising competition from Brazil in China, alongside record US production and a sharp rise in Argentinean corn output. Sustainable seaborne exports will be crucial to maintaining Ukraine's position in the global market.

Ukrainian barley will continue to lose its position on the world market, and this is due to a decrease in the volume of production of this crop. The export potential of the grain sub-complex of Ukraine for this product in 2024 is forecasted at the level of only 1 million tonnes (Fig. 10).

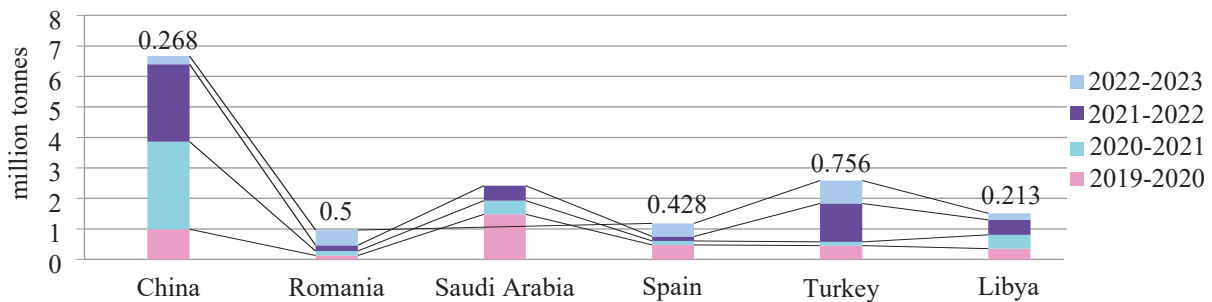


Figure 10. Export of barley in Ukraine in 2019-2023, million tonnes

Source: compiled by the authors based on USDA significantly increased its forecast for Ukraine's corn production and exports in 2022/2023 MY (2022)

Ukraine to continue losing its share in global barley market. The prospects for 2023-2024 indicate that the projected barley export potential for 2024 is very limited, making it difficult for Ukraine to regain its position on the global market. Lower demand from major importers is expected as China has started diversifying its barley imports, focusing on France, Canada, and Argentina. Additionally, Australia is set to return to China's market, and Turkey is expected to further reduce barley imports due to rising domestic supply and high import duty. Romania anticipates higher local production, while Saudi Arabia has switched to importing from Australia, the EU, and Russia. There should be some demand from the Middle East, North Africa, and Spain. Such export potential will be easier to implement, especially given that the leading importers of Ukrainian barley (China and Saudi Arabia) have diversified their purchases in 2022-2023 and will be able to do without Ukrainian barley.

Thus, it should be noted that Ukraine is in for a difficult grain season in 2024. The production of the grain group in Ukraine will decrease significantly. Blockage of grain export routes by the aggressor country, and by other world-producing countries, can lead to complete uncertainty and limitation of the Grain Corridor with neighbouring EU countries. Transit shipments and deliveries through Danube ports remain. In addition, in the new season of 2024, Ukraine will have to compete quite hard for the markets that are still left for the country.

A correlation-regression approach was used to develop a predictive model of the development of the export potential of the grain sub-complex according to the sectoral system of the agrarian sector of the economy of Ukraine. It confirms that for 2012-2023, the dependence

of GDP on the export of products of the grain sub-complex in Ukraine has a close relationship (the coefficient of determination $R^2 = 0.7836$) (5):

$$y = 0.001x^3 - 0.4263x^2 + 72.961x - 1903.3, \quad (5)$$

where y – export of subjects of the grain sub-complex; x – GDP.

To estimate the forecast error (Fig. 11), the actual volume of exports of the grain sub-complex of Ukraine was compared with the forecast value of growth (reduction) in the volume of GDP from foreign trade of grain production entities.

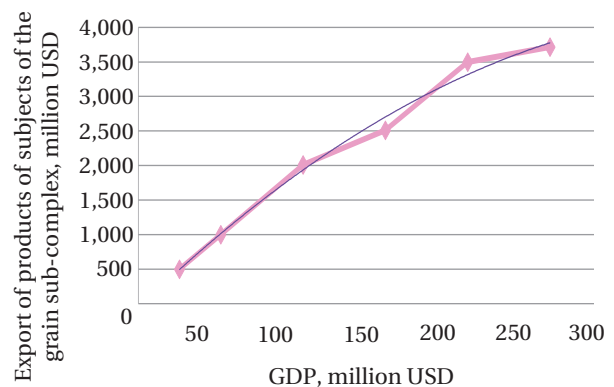


Figure 11. Dependence of GDP on the export of products of the grain sub-complex of Ukraine

Source: compiled by the authors based on Sown areas of crops by type (n.d.); Agriculture, forestry, and fishing, value added (% of GDP) – Ukraine (n.d.)

The deviation of the forecast values is calculated by the (2). That is, the deviation of the model dependence of GDP

on foreign economic trade of subjects of the grain sub-complex of Ukraine amounts to USD 505.43 million (Fig. 12).

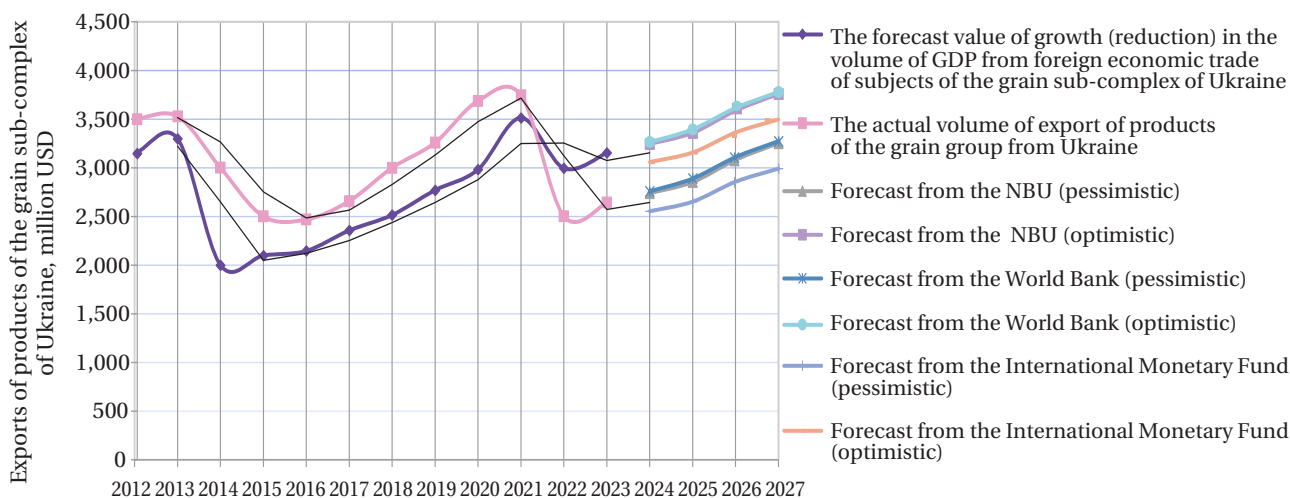


Figure 12. Forecast value of growth (reduction) in the volume of GDP

from foreign economic trade of subjects of the grain sub-complex of Ukraine for 2024-2027, million USD

Source: compiled by the authors based on Sown areas of crops by type (n.d.); Agriculture, forestry, and fishing, value added (% of GDP) – Ukraine (n.d.)

The upper and lower limits of the forecast values are determined by the (3): the National Bank of Ukraine (NBU), World Bank, and International Monetary Fund (IMF) provided varying forecasts for GDP growth from foreign trade in Ukraine's grain sub-complex. The NBU projected growth from 2.9% to 4.8%, the World Bank – from 3.5% to 4.5%, and the IMF – from -3.0% to +4.0%, outlining both pessimistic and optimistic scenarios. The NBU's pessimistic-optimistic forecast for 2024-2027 ranges from USD 2,739.4 million to USD 3,759.02 million. The World Bank's forecast predicts growth from USD 2,758.39 million USD to USD 3,778.56 million during the same period. Meanwhile, the IMF's forecast anticipates growth from USD 2,553.42 million to USD 3,496.39 million for the same period.

Thus, the study showed trends in the export potential of Ukraine in the pre-war period: it was shown that it grew at a significant pace, while in 2021 wheat became the main export product of Ukraine. After the start of Russia's full-scale invasion of Ukraine, the situation changed somewhat, but Ukraine managed to export 48.9 million tonnes of grain and leguminous crops in 2023. In recent years, global wheat production has reached record levels, driven by the development of Asian and North African markets (Wang & Liu, 2023). Corn exports are heavily dependent on sea routes, and forecasts point to possible problems in the coming years regarding trade in this type of product. As for the barley export, it is also likely to continue to decline.

The paper showed that grain exports from Ukraine decreased by 17% in 2023 compared to 2022, but still retained a significant volume of exports. Corn exports also faced a decline due to falling world prices and logistics problems. The reason for this was primarily the naval blockade and other difficulties for exporting products abroad due to the war; despite this, exports of some other types of products increased, in particular, metals and semi-finished products. It is expected that the 2024-2025

grain season will be difficult for Ukraine, with a significant reduction in production and potential blocking of export routes. Nevertheless, Ukrainian farmers should form their long-term development strategies in this way, which would allow them to survive the difficult conditions in which they now operate in a high-quality way.

► Discussion

The implementation of economic tools of the export potential of the grain sub-complex according to the sectoral system of the agrarian sector by identifying its components plays an important role in stimulating economic development and expanding the boundaries of the foreign economic activity of grain production entities, attracting and effectively distributing capital, ensuring the support of their export opportunities in conditions of martial law in country. Due to the state of war in Ukraine, the growth of the following indicators was levelled off: export of products of the grain sub-complex per capita; the ratio of the Ukrainian export of agricultural products to the global export; an indicator of the efficiency of the export possibilities of the grain sub-complex. Meanwhile, in 2022-2023, there were no positive trends of acceleration of such indicators as: the share of grain sub-complex products in the structure of the total export of the agrarian sector; the ratio of grain sub-complex export to GDP; the ratio of the export of products of the grain sub-complex to the volume of production (Maqbool *et al.*, 2020; Mesagan *et al.*, 2021). The lack of significant changes in the dynamics of these indicators is explained by the general recession of the Ukrainian economy. However, in 2023, significant changes took place. GDP from the export of products of the grain sub-complex in the total amount of offers of the agrarian sector grew by 5.3%. Such restorative growth took place after a sharp drop in GDP by 28.8% in 2022. In the 1st quarter of 2023, GDP had downward dynamics. But in the

2nd-4th quarters of 2023, its growth was observed. However, this indicator is a quarter smaller than in 2021. Its growth took place based on low GDP base in relation to 2022. In fact, the economic recovery has stopped. In each quarter of 2023, real GDP from the export of grain sub-complex products was lower than real GDP in the corresponding quarter of 2021 (Sown areas of crops by type, n.d.; List of supplying markets..., n.d.).

At the current stage, the real danger that has arisen in the agrarian sector of Ukraine restrains the development of the export potential of the grain sub-complex, and this, in the future, may lead to irreversible processes and become an obstacle to the post-war recovery of the country. The key issues include low quality management of the grain sub-complex, ignoring innovations in the technological process, and a lack of standardisation of enterprise activity. There is also an insufficient level of funding, despite significant financial assistance from partner countries. The depreciation of fixed assets and a decrease in the degree of material support of the industry, along with an insufficient supply of enterprises with modern production equipment, further exacerbate the problem. The level of innovative development of enterprises is insufficient, and there are unsettled legislative norms regarding joint foreign trade activities with European countries. Additionally, the influence of uncontrollable and unpredictable factors on production results, as well as the imperfection of economic regulators, contribute to these challenges.

European markets are the most attractive for Ukrainian subjects of the grain sub-complex due to geographical proximity and the same sectoral orientation by types of export products (Kryvovyzyuk & Shulha, 2023). However, access to them is complicated by the high level of competition. As practice shows, the inability of the grain sub-complex of Ukraine to overcome the barriers of the European market is connected with the improper adaptability of grain production subjects to its requirements and standards (Kucherenko *et al.*, 2023).

The impact of the war in Ukraine on international trade and economy was also investigated by T. Glauben *et al.* (2022). They noted that the crisis caused by the conflict in Ukraine and aggravated by the COVID-19 pandemic underscores the importance of an open and competitive global market for agricultural products. Import-dependent countries with low per capita incomes are at increased risk of food security. Therefore, to overcome potential food shortages, it is extremely important to maintain open and competitive agricultural markets around the world. Such actions should focus on promoting adaptation, innovation, and efficient use of resources in globally integrated agricultural systems to promote growth and international trade. Researchers suggest that this is the most effective way to achieve this in modern conditions. The current study made similar conclusions: the need to preserve the role of Ukraine in world trade in agriculture and grain in particular was noted. Thus, state representatives should devote as much effort in this area as possible, both in the context of international relations and the internal development of the industry.

The specifics of conducting export policy in the context of exporting products to the EU countries from India were studied by V.R. Renjini *et al.* (2021). They noted that

the export of processed food products to the EU accounts for a significant share of the country's exports, and it is constantly growing. However, due to various kinds of bans and restrictions, there are problems for increasing the volume of imports of products into the country. Researchers compare the situation with China, where it is much easier to increase market share. As part of the current study, attention was also drawn to the fact that in the EU countries there are quite serious standards that complicate the process of importing products to the association. Although the quality of Ukrainian products is generally suitable for such requirements, however, sometimes there are also difficulties for entering the market. This may be partly due to the high competitive advantages of Ukrainian grain in comparison with the products of EU producers. Thus, in order to further deepen cooperation and increase exports, it is necessary to form closer ties with the producers of these countries, and with representatives of state authorities, for a more loyal attitude to imported Ukrainian products (Musayeva *et al.*, 2024).

The impact of agricultural indicators on the concentration of foreign trade and competitiveness of this sector based on data from Romania was investigated by J.V. Andrei *et al.* (2020). They argued that the implementation of appropriate policies in the sector plays an important role for the greater efficiency and competitiveness of the agricultural sector in Romania. In addition, they stressed the importance of assessing the social and economic components of the sector. The researchers also concluded that an increase in agricultural production along with domestic processing can increase exports and replace imports. The current study also concluded that policies aimed at improving the situation in the sector can lead to significantly better results in the sector. Nevertheless, there are doubts about how much Ukraine will be able to pursue such a policy in the context of war.

In turn, the interdependence between economic growth and agricultural exports in the framework of their study was found by S. Udeorah & K. Oluwafemi (2023). The study found a positive association between agricultural exports and economic growth, with each increase in agricultural exports associated with a significant increase in economic growth in the long term. In other words, the results showed the importance of agricultural trade for economic growth and development in countries. Based on this, recommendations were created for the development of more open trade, economic diversification, increased financing and lending schemes for agriculture, and the study of alternative financing options to increase agricultural productivity and stimulate economic growth. As part of the current study, a similar conclusion was also made that agriculture, namely its exports, is causing the rapid development of this sector. In addition, the recommendations provided in the framework of the work are also similar to those described in the paper above. This confirms the results obtained in the current study.

In order to get Ukraine out of the economic recession caused by the Russian invasion, it is advisable to consider the strategy of economic stimulation, in particular, those components that use financial and credit instruments to develop the export potential of the grain sub-complex. First of all, the strategy should determine the target

(priority) areas for the development of the grain sub-complex and should be the basis of development and the driving force behind the stabilisation of the country's economy in post-war recovery.

► Conclusions

The purpose of this study was to assess the development opportunities of the agricultural sector of Ukraine, namely, the grain industry and its export potential. It was concluded that Ukrainian grain exports developed quite rapidly in the past, before the war began: Ukraine became one of the leading exporters to the European Union countries. However, with the start of Russia's full-scale invasion in 2022, the situation changed: Ukraine faced a 17% reduction in grain exports compared to 2022, due to disruptions due to the Russian invasion, infrastructure destruction and logistics blockades. Despite these difficulties, Ukraine managed to maintain export volumes due to new sea routes and increased transportation by rail and road. As part of the study, it was shown that forecasts for wheat and corn production in Ukraine remain optimistic, despite the challenges caused by the war. The paper showed that the expected wheat is at the level of 19.5 million tonnes, and exports – 11 million tonnes, while corn production is expected to grow by 5 million tonnes to 30 million tonnes, and exports – to 12.5 million tonnes. However, it should also be taken into consideration that Ukrainian grain faces tough competition

on the international market: despite this, wheat exports may decline due to production problems and competition from countries such as Russia, France, and Australia. The main demand for Ukrainian wheat is Asia and North Africa, but these regions have diversified their suppliers, reducing their dependence on Ukraine. Similarly, corn exports are under threat due to competition from Brazil and the United States. In addition, Ukrainian barley production and exports are expected to significantly decrease, which will limit Ukraine's ability to regain its global market share. In general, the Ukrainian grain export sector faces a difficult but sustainable future, where market adaptation and diversification are key goals to overcome the difficult conditions that have arisen for Ukraine.

The conclusions help to better understand the prospects for the development of the grain industry in Ukraine, and based on these data to create a strategy for the development of both the state and enterprises. It is important for further study to assess the development opportunities of other sectors of the economy, such as mechanical engineering, information technology, in particular in war conditions.

► Acknowledgements

None.

► Conflict of interest

The authors of this study declare no conflict of interest.

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Глобальні зміни у розвитку експортного потенціалу зернового підкомплексу аграрного сектору України

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► **Анотація.** В сучасних умовах експорт сільськогосподарської продукції є одним з основних джерел доходів для аграрного сектору України. Тому проведення різнобічних досліджень зовнішньої торгівлі в цьому секторі є актуальним. Метою дослідження була розробка оцінки можливостей розвитку експорту зернових в Україні на основі аналізу поточних даних щодо розвитку цього сектору, а також окремих світових тенденцій. У роботі досліджено глобальні зміни у розвитку експортного потенціалу зернопродуктового підкомплексу аграрного сектору України. Доведено, що декомпозиція експортного потенціалу зернопродуктового підкомплексу за галузевою системою аграрного сектору дозволяє сформувати поетапну методичну оцінку його кількісних та якісних показників для визначення композиційної цілісності ефективної вартості досліджуваного об'єкта. Представлено комплексний функціонально-ресурсний аналіз параметрів експортного потенціалу зернопродуктового підкомплексу, які згруповано відповідно до процесного підходу до розрахунку продовольчої безпеки експортного ланцюга суб'єктів зерновиробництва. Методика оцінки стану продовольчої безпеки зернопродуктового підкомплексу держави через ресурсну складову дозволяє діагностувати експортні можливості суб'єктів зовнішньоторговельних операцій в умовах наявності численних ризиків. Визначено фактичну залежність валового внутрішнього продукту України від експорту продукції зернопродуктового підкомплексу та розраховано її прогнозне значення на п'ятирічний період. Наведено песимістично-оптимістичний сценарій зростання (скорочення) валового внутрішнього продукту України за нижньої та верхньої межі реалізації експортного потенціалу зернопродуктового підкомплексу. Висновки, отримані в рамках дослідження, можуть бути використані для формування політики в аграрному секторі України

► **Ключові слова:** галузева система; наслідки військового вторгнення; тенденції воєнного періоду; труднощі ринкової інтеграції; міжнародна торгівля



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Impact of tax policy on the development of agrarian enterprises and organisations

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► **Abstract.** The purpose of this study was to analyse the role of tax policy in the agricultural sector to determine its impact on innovative development, investment decisions, and competitiveness of enterprises in this area. The study performed a comparative analysis of various aspects of tax regulation, review of taxation instruments, consideration of special tax regimes in such countries as the USA, Germany, France, Spain, Poland, and Kyrgyzstan. The study investigated various aspects of tax regulation that have direct and indirect impact on the functioning of the agricultural sector. The role of tax policy in stimulating investment and development in agriculture by providing tax incentives and subsidies for investment in innovative technologies, process mechanisation, and research was examined. Special tax regimes aimed at supporting agricultural enterprises were analysed, and examples of tax policies in different countries, including the USA, the European Union, China, India, and Kyrgyzstan, were provided. The state of agricultural development in Kyrgyzstan was reviewed, and the main challenges, government support measures, and the main land tax rates across the country were identified. The key point was to develop recommendations for improving the tax system to stimulate agricultural development derived from the synthesis method. This involves the introduction of tax exemptions and investment incentives, differentiation of tax rates depending on segments and regions of agriculture, stakeholder consultations, simplification of tax administration, and attraction of foreign

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investment through special tax regimes. Concrete examples were also given of large agricultural enterprises in different countries where improved tax policies can contribute to the development and efficiency of their operations

► **Keywords:** tax regulation; agriculture; state support; tax system; economic stability; investment climate; legislation

► Introduction

Agriculture plays a significant role in economic development and food security. It not only provides food, but also creates jobs, supports rural communities, and contributes to social stability. In the face of contemporary challenges such as climate change, population growth, and global economic instability, the significance of agriculture is increasing, requiring adaptation and increased competitiveness in the global market. However, agrarian enterprises often face challenges related to tax policy. Tax liabilities can substantially affect the financial condition of agricultural organisations, their investment decisions and competitiveness. High tax rates, complex taxation procedures and uncertainty in tax laws may hinder the development of the industry. Specific tax regimes, such as land and property taxation, can create additional pressures without considering the specific features of agricultural businesses. An intelligently designed tax system can have a positive impact on agriculture. It can stimulate investment, increase productivity, and contribute to the modernisation of the industry. Tax incentives and subsidies for investment in modern technology and innovation can help agricultural enterprises improve production processes and use resources efficiently. Understanding the impact of tax policy on agrarian enterprises is critical to ensure sustainable agricultural development. Analysing this impact is essential both for the scientific community and for practical decisions in agriculture and the wider economy.

Some researchers emphasise that tax policy plays a key role in shaping the economic environment for agrarian enterprises. Thus, U. Mirlanbek *et al.* (2023) and J. Spicka *et al.* (2019) note that high tax rates can have a negative impact on investment in agriculture, limiting the opportunities for growth and modernisation of this industry. In the same context, A.P. Barnes *et al.* (2019) discuss that effective taxation can incentivise investment in agricultural technology and productivity improvements that promote sustainable development of the agricultural sector. However, Z. Liu *et al.* (2021), N. Beishenaly & F. Dufays (2023) analysed and concluded that complex tax structures and unclear tax laws can place additional burdens on agrarian enterprises and limit their growth opportunities. S. Acosta-Ormaechea *et al.* (2019) addressed the considerable differences in tax policies between different countries and regions, which can lead to unequal competitive conditions for agricultural enterprises. On the other hand, O.A. Oladipo *et al.* (2019) proposed a model based on the principle of taxation according to the level of income of agrarian enterprises, which they argue can promote more efficient utilisation of tax resources and equitable distribution of tax burden in the agricultural sector. F. Hermans *et al.* (2019) and A. Sridhar *et al.* (2023) also identified the significance of tax incentives in fostering innovation in the agricultural sector. Their findings showed that tax incentives and subsidies can stimulate investment in agricultural research and development. J. Alm (2019) showed that transparent and efficient tax administration can help

reduce administrative costs for businesses and enable them to operate more efficiently.

Overall, the analysis of the cited research findings demonstrates the complexity of the relationship between tax policy and the development of agrarian enterprises. Complex tax structures and unclear tax laws can create additional challenges for agrarian enterprises and limit their growth opportunities. Tax incentives and benefits can promote innovative growth, while transparent and efficient tax administration can reduce administrative costs for enterprises (Omurgazieva, 2024a; 2024b). Despite a considerable number of studies on the impact of tax policy on agrarian enterprises, the following aspects stay unexplored or understudied: the impact of tax reforms on the agrarian sector, including analyses of changes in tax rates, benefits, and subsidies; tax competition between different regions and their impact on the competitiveness of agrarian enterprises; the effectiveness of various tax incentives and benefits for agrarian enterprises in terms of their impact on investment, innovation, and sustainability; and the effectiveness of tax incentives and benefits for agrarian enterprises.

The purpose of this study was to provide a comprehensive analysis of tax policy in the agricultural sector to identify its effectiveness, equity, and implications for the status, investment, innovation, and competitiveness of agricultural organisations. The objectives of the study included analysing the effectiveness of existing tax mechanisms on agrarian enterprises and examining the effectiveness of tax incentives to develop more effective tax regulation strategies in the agricultural sector.

► Materials and methods

This study analysed a wide range of legislation, tax codes, and official documents relating to this industry in countries such as the USA, Germany, France, Spain, Poland, and Kyrgyzstan to examine existing tax policies in agriculture. The analysis was conducted to identify general trends, similarities, and differences between countries in their approach to taxation of agricultural enterprises. For a more comprehensive coverage of the situation in global agriculture, data on tax policies of several countries were examined, including the United States, European Union countries (France, Germany, Spain, and Poland), China, and India (OECD, 2020). The analysis of tax liabilities and incentives in agriculture has revealed the diversity of tax instruments used in different countries and their impact on the economic development of the rural sector. These data provided the basis for further analytical review and drawing conclusions on the role of tax policy in agriculture.

Synthesis and comparative analysis methods were employed to better understand the impact of tax policy on agriculture. The synthesis was employed to draw conclusions on how tax policy can stimulate the development of the agricultural sector and to develop recommendations for governments and other stakeholders to improve tax policy.

A comparative analysis of tax policies applied in different countries has revealed the key principles and objectives that guide these countries in the development of their tax policies in the context of agriculture. Both general strategies and specific measures aimed at stimulating the development of the sector and ensuring its sustainability and competitiveness were explored. Special attention is paid to income tax, land tax, property tax, and value added tax. These tax instruments are the key components of the agricultural tax system and have a direct impact on the financial condition and functioning of agricultural enterprises.

The use of the system analysis method provided a comprehensive review of tax policy, considering its interaction with other factors such as government regulation and economic conditions. The decomposition method made it possible to examine in detail the individual elements of tax systems, identify their features, and evaluate them from the standpoint of their impact on agriculture. For completeness of the analysis of the role of tax policy in agricultural development, the agricultural sector of Kyrgyzstan and its tax policy were also analysed. Official data, including laws and regulations (Tax Code of the..., 2022), statistical reports and data (Finance, n.d.; GDP by types of..., n.d.) provided by relevant national agencies and organisations were used. The analysis covered the period from 2012 to 2023 and was conducted to identify general trends. The analysis of the agrarian sector of Kyrgyzstan and its tax policy helped to identify the specific features of the functioning of this industry in the conditions of the country, as well as to assess the impact of tax measures on its development.

Examples of large agricultural enterprises from various countries were considered, namely Cargill in the USA, Amul in India, and Les Jardins De Creances in France. The US has one of the most developed agricultural economies in the world, and Cargill is one of the largest agribusinesses, allowing for a detailed examination of the impact of tax policy on high-intensity agriculture. India, in turn, is an example of a developing country with a massive agricultural sector, and Amul, one of the largest cooperatives, demonstrates how fiscal policy can support or hinder agricultural development in the face of a growing population and limited resources. France, being one of the leading agricultural producers in Europe, provides an interesting case study to analyse through Les Jardins De Creances. This company illustrates how European fiscal policy and support can contribute to the development of quality and sustainable agriculture.

► Results

The role of tax policy in the development of the agricultural sector is significant and multidimensional. This sector, which plays a key role in food security and socio-economic development, is dependent on tax regulation, which has direct and indirect effects on its functioning. Fiscal policy can stimulate investment and development in the agricultural sector through tax incentives or subsidies for modern technologies, mechanisation and research, which helps to increase productivity and competitiveness of agricultural production (Lencucha *et al.*, 2020). By regulating taxes on exports and imports of agricultural products, the state can influence the price dynamics and incomes

of agricultural enterprises. Special tax regimes, reduced tax rates or exemptions from certain taxes can support SMEs, contributing to their development and reducing inequality in the sector. Tax policies should also ensure that the tax burden is equitably distributed among agrarian enterprises of varied sizes and forms of ownership, thereby contributing to a balanced development of the sector and reducing socio-economic inequalities (Van Kooten *et al.*, 2018). The key tax instruments, such as profit tax on agricultural enterprises, land tax, property tax, and value added tax (VAT), play an essential role in the formation of financial resources of enterprises. These instruments regulate agricultural markets and ensure sustainable rural development. Special tax regimes with reduced tax rates or exemptions aim to support and develop the agricultural sector, increasing its competitiveness and sustainability (MacPherson *et al.*, 2022). Thus, tax policy in agriculture is a complex system of tax obligations and benefits aimed at supporting and developing the agricultural sector. These tax instruments form the financial resources of enterprises, regulate agricultural markets, and ensure sustainable development of rural areas.

The tax system in the agricultural sector of each country is a key instrument of state policy aimed at supporting and developing agriculture. However, there are considerable differences in the tax systems of different countries due to the economic, social, and political characteristics of each country. In the United States, for instance, taxation of the agricultural sector includes taxes on farm profits, land, and property taxes. The US has a progressive income tax system, which means that the amount of tax payments depends on the level of income received. For instance, for income over \$407,000 per year, the tax rate is 40% of the amount earned. A 35% rate applies for income between \$200,000 and \$407,000 and a 33% rate applies for income between \$113,000 and \$200,000. The rate of income tax on agricultural land depends on its productivity, which leads to the calculation of estimated yields for different soil types. It also requires the payment of property taxes, which can be costlier than income taxes in different states (Moravec *et al.*, 2019). For instance, in New York State, a farm of 8 acres (3.24 ha) costs USD 27,000 annually. Meanwhile, a ranch in Texas covering 1,570 acres (635 ha) could be worth USD 70,000 a year without special tax deductions. This taxation system provides the state with considerable revenues that can be used to support agriculture and rural development (Milk taxes: How..., 2017).

Taxation in the agricultural sector of the European Union is a diverse system of tax obligations that reflects the economic, social, and political characteristics of each country. Various taxes are applied in EU countries, such as agricultural income tax, land or property tax, environmental taxes, and VAT. In Germany, for example, agricultural companies can pay corporate tax from 15%. For small farmers with low incomes, there is a simplified procedure for assessing taxable income (flat rate method). They may be entitled to an exemption from a certain part of income tax or to reduced tax rates depending on the volume of production. There is a reduced municipal tax rate for agricultural land: up to 1.2% for agricultural land and 2.4% for other land. Farmers are entitled to a "flat rate" system of value-added tax. They can apply a flat rate of 10.7% to

their sales to compensate them for VAT. Farmers enjoy favourable tax rates on electricity and mineral oils and gases. The agricultural diesel tax refund makes provision for the imposition of a tax of EUR 255.6 on agricultural operations for every 1,000 litres of diesel. The tax on fuel for agricultural purposes is set at a lower level (Jantke *et al.*, 2020). There are no tax incentives for research and development or innovation in Germany.

A comparable situation is observed in France, which has special tax regimes that provide incentives for agricultural enterprises. Business profits of individual farmers or partnerships can be taxed under two tax regimes: under the micro-BA scheme (a form of income smoothing) and using actual revenue. Other partnerships are taxed using actual revenue. Local governments, including departments and municipalities, levy taxes on property acquisitions. These taxes are added to the sale price and paid by the buyer. The applicable rate is set at 5.09%, however, in practice, most local authorities charge an overall tax rate of 5.8%. The purchase of rural structures such as buildings and agricultural land that are leased by farmers is subject to transfer duty at a reduced rate of 0.75% (Facchini, 2024). For agricultural inputs such as fertilisers and phytosanitary products, the standard VAT rate of 20% applies. However, there are reduced rates that apply to certain types of fertilisers and unprocessed products. A reduced rate of EUR 188.2 per 1,000 litres has been set for diesel fuel used in agricultural and construction machinery and public transport. Organic farmers who derive at least 40% of their revenue from organic farming following EU rules have tax benefits. The general tax on polluting activities includes several taxes related to environmental impact and ranges within EUR 0.90-9 per kg. It applies to companies whose activities or products are considered a source of pollution, such as waste, emissions, lubricating oils, detergents, and extraction materials.

Spain and Poland also apply income taxes, property taxes, environmental taxes, and VAT. However, each of these countries has its specific features of tax regulation aimed at ensuring sustainable development of the agricultural sector. In Spain, the state can provide subsidies or loans for the purchase of agricultural machinery and equipment, which helps agricultural enterprises to modernise their operations and increase productivity (Fernández-Rodríguez *et al.*, 2019). In Poland, tax incentives are available for research and development (R&D) to fully offset eligible costs that can be deducted from the tax base. The list of eligible R&D expenditures is extended to include the following: salaries of researchers, purchase of scientific equipment and materials needed for research, as well as patent registration costs and amortisation of fixed assets (Bórawski *et al.*, 2019). In developing countries such as China and India, agricultural taxation plays a significant role in ensuring the financial sustainability of agrarian enterprises and promoting rural development. Unlike previous countries, they do not pay income tax. The Chinese government is actively developing tax incentive and subsidy programmes for agricultural enterprises to promote agricultural development and ensure food security. These programmes may include compensation for agricultural losses, subsidies for the purchase of agricultural equipment and machinery, and preferential

credit terms for agricultural business development (Liu & Mao, 2019). India has various government support programmes for agricultural enterprises, including subsidies on seed, fertiliser and farm equipment, soft loans for agricultural producers, and rural infrastructure development programmes (Bathla *et al.*, 2019).

Agriculture plays a key role in the Kyrgyz economy, accounting for a considerable part of the gross domestic product and providing employment for a large part of the population. Figure 1 shows the share of agriculture in the gross domestic product (GDP) of Kyrgyzstan.

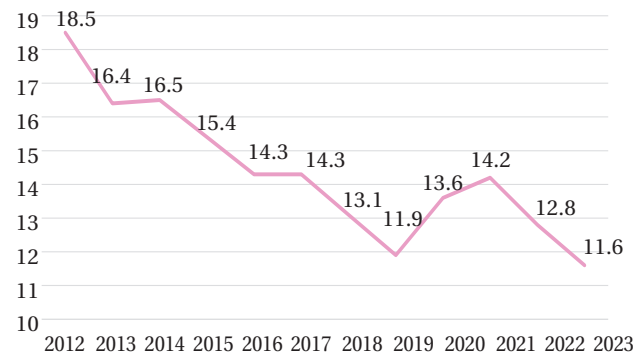


Figure 1. Share of agriculture in Kyrgyzstan's GDP from 2012 to 2023, %
Source: Finance (n.d.)

From 2012 to 2019 as well as from 2021 to 2023, the share of agriculture gradually decreased. However, agriculture is still a significant sector for the Kyrgyz economy and its development could be valuable for food security and sustainable economic growth. There is potential for growth and modernisation of agriculture in the country if relevant measures are taken to improve infrastructure, access to finance and technological innovation. The agricultural sector in this country faces a series of challenges and problems that limit its development. One of the key challenges for agriculture in Kyrgyzstan is the lack of modern technology and infrastructure. Many agricultural enterprises in the country continue to use conventional methods of land cultivation and production, which reduces the productivity and competitiveness of the industry. The problem for agriculture is insufficient funding and access to loans. Many small and medium-sized agricultural enterprises face constraints in obtaining finance to expand production or modernise equipment. Agriculture in Kyrgyzstan is exposed to climatic and natural factors such as climate change, droughts, and floods, which can reduce crop yields and lead to losses for agricultural enterprises. Despite these challenges, Kyrgyzstan's agriculture has the potential for development and modernisation. Taking steps to improve infrastructure, access to finance, and technological innovation can help increase agricultural productivity and efficiency, as well as rural incomes. The creation of an effective and adapted tax policy, considering the specifics of agriculture in Kyrgyzstan, is an integral component of the industry development strategy. It is necessary to ensure a balance between the tax liabilities of agricultural enterprises and their financial capacity, considering both current needs and growth prospects.

The Kyrgyz government provides a variety of support measures for agriculture, including interest rate subsidies and reduced tax liabilities. Under these measures, farmers applying for loans from partner banks for agriculture can avail lower interest rates. Furthermore, farmers are exempted from paying taxes such as value added tax, income tax, and turnover tax. Instead, they are only liable to pay land tax. Kyrgyzstan's agriculture is

characterised by specific taxation features, which are related to natural and climatic conditions, seasonality, as well as low profitability and irregular revenues. Because of this, the agricultural tax system partially accommodates the above features and Kyrgyzstan applies a simplified form of land taxation. Table 1 presents the basic rates of land tax for the use of agricultural land by region in some districts of Kyrgyzstan.

Table 1. Current basic tariffs on land tax for the use of agricultural land in the regions of Kyrgyzstan, KGS/ha

Region and district	Arable land		Perennial plantings	Hayfields	Pastures, fallow lands
	Irrigated land	Dryland			
Batken region					
Batken district	268	41.3	149	–	7.7
Leilek district	268	41.3	149	24.3	7.7
Kadamjai district	275	41.3	150	24.3	12.7
Jalal-Abad region					
Aksy district	306	56.7	193	15.9	13.6
Bazar-Korgon district	414	41.3	220	30.9	15.4
Toguz-Toruu district	223	62.3	–	33	12.9
Chatkal district	194	62.3	–	26.5	12.9
Issyk-Kul region					
Ak-Suu district	373	87.5	173	30.4	10.6
Issyk-Kul district	280	68.8	155	23.8	7.7
Tyup district	379	87.5	174	29.1	15
Naryn region					
At-Bashy district	191	54.3	–	21.7	4.5
Kochkor district	215	37	–	25.1	4.5
Naryn district	196	54.3	–	21.1	5.3
Osh region					
Alai district	232	62.3	–	27.7	5.3
Kara-Suu district	453	41.3	246	27.9	12
Uzgen district	413	62.3	235	33.7	13.9
Talas region					
Bakai-Ata district	318	52.5	164	–	7.4
Aitmatovsky district	350	36.4	165	11.2	4.8
Talas district	297	52.5	164	11	4.8
Chui region					
Alamudun district	400	56.5	209	23.1	10.8
Ysyk-Ata district	400	74.2	213	29.7	10.8
Kemin district	354	80.5	211	29.7	10.8
Chui district	400	74.9	211	32.4	10.8

Source: Tax Code of the Kyrgyz Republic No. 3 (2022)

Analogous basic land tax rates apply to different categories of land, such as household plots, homestead and garden land, as well as settlement and non-agricultural land. However, these rates change periodically depending on various natural, economic, social, and environmental factors. The use of fixed tax rates may create some

difficulties in collecting tax revenues due to lack of customisation to specific land parcels and remoteness from markets. Specifically, such rates do not factor in the quality of land resources and their proximity to potential markets. This results in varying degrees of tax burden on different sectors of the economy, with the lowest in agriculture (Fig. 2).

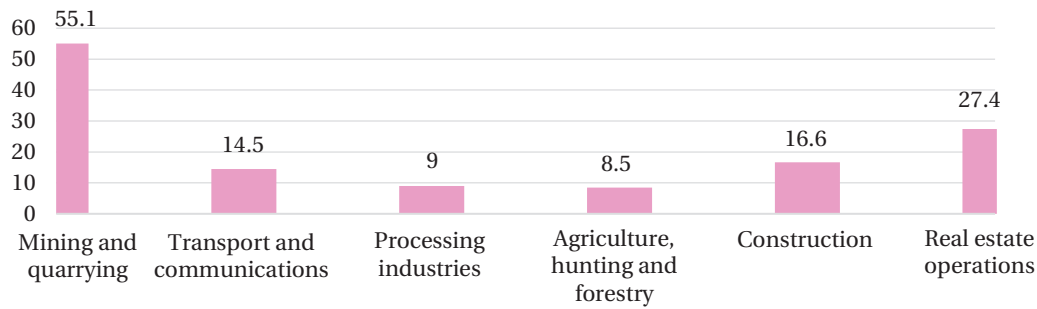


Figure 2. Level of tax burden from total costs by types of economic activity, %

Source: GDP by types of economic activity in current prices (n.d.)

Kyrgyzstan also has a property tax on the purchase of vehicles used in agriculture. The basic tax value for self-propelled machines and mechanisms such as tractors and combines used in agricultural production depends on the period of use. If the service life is up to 15 years, the tax rate is KGS 10 per cm³ of engine displacement. In case of 15 years or more, the tax rate is KGS 5 per cm³ of engine displacement (Tax Code of the..., 2022). Improvement of the tax system plays a significant role in stimulating agricultural development and increasing its efficiency. Several concrete recommendations can be made within the framework of this process. The introduction of tax exemptions and investment incentives for agricultural development is an important measure to attract investment and improve the efficiency of the sector. Providing tax credits for investment in modern technologies can incentivise agricultural enterprises to innovate and increase productivity. Depreciation incentives to replace obsolete equipment will allow agricultural enterprises to renew their production capacity, which will reduce costs and increase competitiveness. Furthermore, subsidies for infrastructure development, such as irrigation and drainage systems, will help agricultural enterprises improve yields and land use efficiency, which contributes to sustainable agricultural development and food security.

To optimise and improve the effectiveness of existing tax benefits and subsidies for agrarian enterprises, it is necessary to revise their conditions and criteria for granting them. It is important to make these benefits more accessible and tailored to the concrete needs of agricultural enterprises. One possible step is to simplify the process of obtaining benefits so that agricultural producers can take advantage of them more quickly and easily. Furthermore, it is vital to revise the terms and conditions of subsidies so that they are better aligned with modern challenges and needs of agriculture, such as the introduction of modern technologies, the development of sustainable agriculture and increased productivity. In addition, transparency and effectiveness of mechanisms for controlling the use of subsidies should be ensured to guarantee their targeted use and minimise the risks of corruption. Improving tax administration and reducing bureaucratic barriers for agricultural enterprises play a significant role in supporting agricultural development. This involves the introduction of measures aimed at simplifying tax reporting procedures, reducing administrative costs, and increasing the transparency of the tax system. One of the key steps could be to revise and simplify the tax filing process for agricultural

producers, making the procedure more accessible and understandable. Furthermore, it is important to reduce administrative barriers, for instance, by reducing the number of required documents and simplifying the process of interaction with tax authorities.

Creating an attractive investment environment for foreign investors in the agricultural sector plays a key role in stimulating the development of this sector and the inflow of capital and innovative technologies. To achieve this goal, it is important to introduce special tax regimes that will provide investors with certain benefits and preferences depending on the volume and duration of investments. It is also necessary to provide investment guarantees that will protect investments and reduce risks for foreign investors. It is essential to provide incentives for capital investment, such as tax credits and subsidies for investment projects in the agricultural sector. Simplification of the procedures for obtaining tax incentives for foreign investors is also a crucial step to create an attractive investment environment. Overall, these measures will attract more foreign investment in the agricultural sector and contribute to its growth and modernisation. Consultation with stakeholders, including agricultural organisations and entrepreneurs, is a key mechanism for identifying needs and proposals for tax system improvements specifically tailored to the needs of the sector. These consultations can gather information on current tax problems faced by agricultural businesses and find potential areas for improvement. Large farms, such as Cargill in the US, can take advantage of tax credits for investments in modern technology and equipment. For instance, tax credits for the purchase of energy efficient equipment can considerably reduce the initial costs of modernisation. This contributes to increased productivity, as new equipment is often faster and more efficient than outdated models. Modern technology can also reduce production costs by saving resources, reducing scrap, and improving product quality. Thus, improved tax conditions allow companies to increase production, expand their product range, and improve their competitiveness in internal and external markets.

Amul, a large agricultural enterprise in India, represents a significant element in the dairy industry. Improved tax policies, such as tax incentives for the purchase of modern equipment for dairy production or property tax reductions, can attract additional investment in infrastructure and technological upgrades. These measures will not only increase the efficiency of milk production, but also contribute to improving product quality and

expanding the product range. Modern equipment allows for more precise control of pasteurisation and packaging processes, which increases the shelf life of products and reduces the risk of losses. As a result, the company strengthens its competitiveness in the dairy products market.

Les Jardins De Creances fruit and berry farm in France is a major player in the fresh fruit and vegetable market. Reducing tax rates on exports can lower financial barriers, which encourages active promotion of products to international markets. This allows the company to set more competitive prices and expand its customer base abroad. Furthermore, providing incentives for the development of irrigation and storage systems can improve the quality and durability of produce. Such measures include tax credits for the installation of drip irrigation and the construction of modern storage facilities, which helps to preserve the freshness of produce and minimise losses during transport. The introduction of tax credits for innovation and sustainable farming practices can further incentivise the adoption of modern technologies such as biological plant protection and organic farming, which improves the environmental sustainability of the enterprise and attracts environmentally conscious consumers.

Overall, improving the tax system to stimulate agricultural development requires a comprehensive approach and careful analysis of existing mechanisms. This can contribute not only to the growth of agricultural production and exports, but also to the improvement of the living standards of rural residents and the overall economic development of the country.

► Discussion

The role of tax policy in the development of the agricultural sector is integral and multifactorial. The sector, which plays a key role in food security and socio-economic development, is highly dependent on tax regulation, which has direct and indirect effects on its functioning. Tax policy can serve as a means of stimulating investment and development in the agricultural sector. The provision of tax incentives or subsidies for investment in new technologies, process mechanisation or research by the government can create favourable conditions for the growth and modernisation of agricultural enterprises. Such measures contribute to increasing the productivity and competitiveness of agricultural production. H. Hu *et al.* (2021), J. Beckman & A.M. Countryman (2021) have emphasised the economic aspects of tax policy in the agricultural sector in their studies. They analysed the impact of changes in tax rates and incentives on the profitability of agricultural enterprises and their investment decisions. The results of the present and the cited studies coincide in that both focus on the economic aspects of tax policy in the agricultural sector and its impact on the profitability of agricultural enterprises. Both studies conclude that supporting investment and reducing the tax burden can boost agricultural production and improve its competitiveness.

The introduction of taxes on exports or imports of agricultural products allows the state to influence price dynamics on both world and internal markets. This can affect output, supply and demand, and farm incomes. One of the key aspects of tax policy in the agricultural sector is the support of small and medium-sized enterprises.

Introduction of special tax regimes, reduction of tax rates or exemption from certain tax obligations can be undertaken to support this category of enterprises. This favours their survival and development and reduces inequalities in the sector. M.H. Ehlers *et al.* (2021) focused on the social aspects of tax policy in the agricultural sector, specifically on its impact on different sectors of society, including small and medium-sized agrarian enterprises and rural residents. D. Varshney *et al.* (2021) analysed what tax measures can influence the level of social inequalities and what tax policy instruments can be used to support small farmers and rural populations. Unlike the present study, which focuses more on general analyses of tax policies in different countries, cited study is more focused on the social consequences of these policies. The researchers considered the accessibility of credit and finance for rural people, and explored what tax measures could help reduce social inequalities in rural communities.

Tax policy should ensure a fair distribution of the tax burden among agrarian enterprises of varied sizes and forms of ownership. Progressive tax rates or tax incentives can contribute to a more balanced development of the sector and reduce socio-economic inequalities. Tax policy in the agricultural sector is a key instrument of state regulation and includes a wide range of tax obligations and benefits aimed at stimulating the development of the industry. The key tax instruments include profit tax on agricultural enterprises, land tax, property tax, and VAT on agricultural products and foodstuffs. Special tax regimes that provide reduced tax rates or exemption from certain tax obligations for agrarian enterprises also play a vital role. U. Shahzad (2020), P. Dupraz & H. Guyomard (2019) focused on the environmental aspects of tax policies in the agricultural sector and investigated which tax measures can help reduce the negative environmental impacts of agriculture and encourage the adoption of sustainable farming practices. The cited study complements the present study by enriching it with an ecological perspective, while the latter concentrates more on the economic aspects of tax policy in the agricultural sector.

There are considerable differences in the tax systems of different countries conditioned by the economic, social, and political characteristics of each country. For instance, in the United States, taxation of the agricultural sector includes taxes on income, land, and property. Whereas in the European Union, taxes can vary from country to country, reflecting its unique characteristics and priorities. In developing countries such as China and India, taxation plays an important role in ensuring the financial sustainability of agrarian enterprises and stimulating rural development. In these countries, tax policies may include tax incentive and subsidy programmes for agrarian enterprises, as well as rural infrastructure programmes. H.C. Tai (2023) conducted a comparative analysis of taxation systems in the agricultural sector of different countries to identify common trends and specific features. The researcher investigated which countries favoured certain types of tax incentives or which countries successfully used tax measures to support the development of the agricultural sector. This approach coincides with the present study by providing a broad overview of how tax policies in the agricultural sector are implemented in different countries and which

methods prove to be most effective. By analysing international experience, best practices can be identified and applied in a country-specific context.

The agricultural sector of Kyrgyzstan also has its specific features in taxation related to natural and climatic conditions, seasonality, and low profitability. The country uses a simplified form of land taxation that accommodates these features and aims to create a fairer tax burden for agricultural enterprises. D. Liu *et al.* (2021) focused on the regional characteristics of tax policy in agriculture. They analysed differences in tax regimes between different regions of the country and studied their impact on the development of the agricultural sector. By analysing regional differences, the researchers find which concrete tax measures have been successful in stimulating agricultural growth in certain areas. The cited study, similar to the present study, recognises the significance of analysing differences in tax policies at the regional level and their impact on the agricultural sector.

Optimising and improving the effectiveness of tax incentives and subsidies for agrarian enterprises requires a comprehensive approach and a careful analysis of existing mechanisms. This can contribute not only to the growth of agricultural production and exports, but also to the improvement of living standards in rural areas and the overall economic development of the country. J. Luo *et al.* (2024) and R.H. Bates (2019) analysed the prospects of agrarian taxation in the context of global challenges such as climate change, demographic change, and globalisation. They considered what fiscal measures could help the agricultural sector adapt to evolving conditions and stimulate sustainable development. Furthermore, innovative approaches to taxation have been proposed that factor in global trends and challenges. The recommendations of the researchers partially coincide with the present findings, especially in terms of stimulating investment in agriculture, supporting small and medium-sized enterprises, and implementing environmentally sustainable practices.

Overall, the role of tax policy in the agricultural sector is multidimensional and key to its sustainable development. The findings of the present study suggest that tax measures can have a substantial impact on various aspects of agriculture, including economic, social, and environmental ones. For successful agricultural development, it is important to consider both global and regional specificities, and to factor in the changing conditions such as climate change and globalisation.

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► Conclusions

The role of tax policy in agricultural development is integral and multidimensional. This study showed that tax measures have a substantial impact on various aspects of agriculture. Tax policy can serve as a means of stimulating investment and development in the agricultural sector. By providing tax incentives or subsidies for investment in modern technologies, process mechanisation or research, the government can create favourable conditions for the growth and modernisation of agribusinesses. Such measures help to increase the productivity and competitiveness of agricultural production.

The study revealed a significant role of tax policy in the development of the agrarian sector of Kyrgyzstan. The share of agriculture in Kyrgyzstan's GDP is gradually falling, but it still occupies a considerable part (11.6% in 2023). The current tax burden and complex taxation procedures reduce investment activity and limit modernisation opportunities. The level of tax burden of total expenditures on agriculture is 8.5%. Low tax support for innovation limits the potential for productivity growth and competitiveness. Recommendations to improve tax policy include reducing the profit tax rate, providing tax incentives and subsidies for investments in modern technologies and scientific research, simplifying tax administration and introducing differentiated tax rates. To create a favourable investment environment for foreign investors, it is important to ensure the stability of tax policy, introduce special tax regimes, and develop public-private partnership mechanisms with tax incentives.

A limitation of this study is the lack of coverage of countries and regions, which may reduce the generalisability of the findings at the global level. For further research, it is recommended that the geographical scope of the study be expanded to include more countries and regions to gain a more comprehensive understanding of tax policy in the agricultural sector. Furthermore, it is advisable to conduct a comprehensive study that considers not only tax aspects but also other factors such as legal regulation, innovation, and infrastructure to better understand the impact on agricultural development.

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► Conflict of interest

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Вплив податкової політики на розвиток аграрних підприємств та організацій

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► **Анотація.** Дослідження було спрямоване на аналіз ролі податкової політики на аграрний сектор з метою визначення її впливу на інноваційний розвиток, інвестиційні рішення та конкурентоспроможність підприємств у цій галузі. У роботі проводився порівняльний аналіз різних аспектів податкового регулювання, вивчення інструментів оподаткування, розгляд спеціальних податкових режимів у таких країнах, як США, Німеччини, Франції, Іспанії, Польщі та Киргизстані. У статті було досліджено різні аспекти податкового регулювання, що справляють прямий і непрямий вплив на функціонування сільськогосподарського сектору. Розглядалася роль податкової політики в стимулюванні інвестицій і розвитку в сільському господарстві шляхом надання податкових пільг і субсидій для інвестицій у нові технології, механізацію процесів і наукові дослідження. Проаналізовано спеціальні податкові режими, спрямовані на підтримку сільськогосподарських підприємств, а також наведено приклади податкової політики в різних країнах, включно зі США, Європейським Союзом, Китаєм, Індією та Киргизстаном. Було розглянуто стан розвитку сільського господарства в Киргизстані, а також визначено основні виклики, заходи підтримки держави та основні тарифи земельного податку по країні. Ключовим моментом є розробка рекомендацій щодо поліпшення податкової системи для стимулювання розвитку сільського господарства, отриманих за допомогою методу синтезу. Це включає в себе запровадження податкових пільг та інвестиційних стимулів, диференціювання податкових ставок залежно від сегментів та регіонів сільського господарства, проведення консультацій із зацікавленими сторонами, спрощення податкового адміністрування та залучення іноземних інвестицій через спеціальні податкові режими. Також було наведено конкретні приклади великих сільськогосподарських підприємств у різних країнах, де поліпшення податкової політики може сприяти розвитку та підвищенню ефективності їхньої діяльності

► **Ключові слова:** податкове регулювання; сільське господарство; державна підтримка; податкова система; економічна стабільність; інвестиційний клімат; законодавство



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The impact of the strategy of socio-economic recovery of rural areas on the management of agricultural enterprises

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► **Abstract.** This study was aimed at analysing the effectiveness of comprehensive recovery strategies in rural areas and their impact on management practices in the agricultural sector. The article considered the socio-economic recovery of rural areas as an important and multifaceted task that is becoming increasingly relevant in the world. The process of recovery includes a set of measures aimed at improving the economic, social and environmental conditions of rural regions. The introduction of modern technologies into production processes increases the productivity and competitiveness of the local economy. The article considered the role of different approaches to recovery, including multi-sectoral, resource-based, innovative, inclusive, ecosystem, political and administrative, and sustainable development approaches. Each of them can be adapted to the specific conditions and needs of rural regions, creating a basis for comprehensive and sustainable recovery. The article analysed the impact of the war in Ukraine on the agricultural sector, which is one of the key components of rural development. As a result, the need for further support and investment in the agricultural sector for its recovery and sustainable development was highlighted. Successful socio-economic rehabilitation of rural areas depends on coordinated actions of various stakeholders, including the state, local authorities, business and civil society. An important component is the development and implementation of strategies that take into account local characteristics and needs, ensuring sustainable development and improving the quality of life in rural areas. Only a comprehensive approach to recovery can ensure long-term and sustainable development that will become the basis for future prosperity in rural areas

► **Keywords:** state policy; territorial development; transport and logistics infrastructure; social initiatives; impact of war

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► Introduction

The relevance of studying the impact of the strategy of socio-economic recovery of rural areas on the management of agricultural enterprises is extremely high, as the agricultural sector plays a key role in the economy of many countries, including Ukraine. Rural areas often face numerous challenges, such as deteriorating infrastructure, demographic challenges, and limited access to financial resources and technology. In such circumstances, developing and implementing effective recovery strategies becomes an important task for both local authorities and businesses. The restoration of rural areas and the development of agricultural enterprises are interrelated processes that have a significant impact on the overall economic situation of the country. The study and analysis of existing strategies, as well as the development of new approaches to their implementation, is an important area of research that will contribute to the sustainable development of rural regions and increase the competitiveness of the agricultural sector.

The works of leading scholars reveal various aspects of the impact of rural renewal strategies on the development of agricultural enterprises. X. Chen (2020) emphasised that effective socio-economic recovery strategies should take into account regional specificities and include the active participation of local communities. V. Shebanin *et al.* (2022), in turn, pointed out that only with the active involvement of the local population can sustainable development be achieved. S. Rotz *et al.* (2019), S. Polishchuk & S. Pyatachenko (2022) studied the impact of innovative technologies on the development of agricultural enterprises. They noted that the introduction of the latest technologies in the production processes of agricultural enterprises not only increases their productivity but also creates new jobs, which helps to reduce unemployment in rural areas. Y. Liu *et al.* (2020), in turn, studied the impact of infrastructure projects on rural development. Their study showed that improving transport and utility infrastructure is a key factor in attracting investment and stimulating the development of agricultural business. H. Long *et al.* (2019) focused on the role of education and vocational training in rural recovery. They argued that the development of human capital through educational programmes and training courses is important for ensuring the development of the agricultural sector. W. Heijman *et al.* (2019) analysed the relationship between socio-economic recovery and environmental sustainability in rural areas. They pointed out that recovery strategies should include environmental protection measures, as environmental degradation can have a negative impact on agriculture. A. Kliuchnyk *et al.* (2023), in turn, considered the role of public policy in supporting rural recovery. O. Nikolyuk *et al.* (2023) argued that effective policies include financial incentives, subsidies, and tax breaks for agricultural enterprises that invest in the development of local communities. Y. Li *et al.* (2019) investigated the impact of global economic trends on the development of rural areas and agricultural enterprises. Globalization and changes in international trade open up new opportunities for agricultural businesses, but also create new challenges.

In general, the authors' research has shown that the strategy of socio-economic recovery of rural areas is complex and includes various aspects such as innovation,

infrastructure, education, environment, and government support. These factors are interconnected and require coordinated efforts to achieve sustainable development of the agricultural sector and improve the quality of life in rural areas. Despite considerable scientific interest in the socio-economic recovery of rural areas, the long-term impact of environmental measures on the sustainability of agricultural enterprises, the integration of local cultural and social characteristics into recovery strategies, and the role of public-private partnerships in this process remain insufficiently researched.

The purpose of the study was to identify the key factors that contribute to the effective development of agricultural enterprises in the context of comprehensive socio-economic recovery of rural regions. The main objectives of the study were: to analyse the factors that influence the success of socio-economic recovery of rural regions; to assess the effectiveness of implemented strategies for socio-economic recovery of rural regions; to determine the optimal approaches to the management of agricultural enterprises in the context of implementing strategies for rural recovery.

► Materials and methods

The study drew on a wide range of sources, including statistical data, academic articles, reports by international organizations, and the experience of successful and unsuccessful recovery projects in Ukraine. The main source of data was official statistics provided by the State Statistics Service of Ukraine. This data included production volumes of major crops and livestock products for the period from 2004 to 2023. The economic accounts of Ukrainian agriculture were also analysed to assess the overall economic situation of the sector and its dynamics during the war. To analyse the impact of the war on the agricultural sector, a comparison was made to assess changes in production volumes before and after the outbreak of the war.

The study of the impact of socio-economic recovery on the development of agricultural enterprises was based on the analysis of specific projects. For this purpose, both successful and unsuccessful examples of project implementation in rural areas of Ukraine were selected. In particular, the projects "Agricultural Receipts" and "Ukrainian Horticulture Business Development Project", which were supported by international donors such as the International Finance Corporation (IFC) and the Government of Canada, were analysed (Tomorrow's harvests fund..., 2019; First financial agricultural..., 2018). The positive impact of these projects on the activities of such agricultural enterprises as Agro-Plus Service and Blagodatna Ferma has been identified (Agro-internship: A Ukrainian project ..., n.d.; Blahodatna farm..., 2018). The analysis of these projects allowed identifying key success factors and reasons for failure, as well as determining the main challenges faced by agricultural enterprises.

Particular attention was paid to the role of local communities in the process of rural recovery. For this purpose, the activities of amalgamated territorial communities (ATCs) in the Khmelnytskyi region were reviewed, which provided qualitative information on their participation in project planning and implementation (Plan of measures..., 2019). It also helped to understand how local

communities influence the effectiveness of recovery efforts and what challenges they face. The Khmelnytskyi region was also chosen because of its active participation in various grant programmes and initiatives aimed at rural development, which creates favourable conditions for researching the effectiveness of such projects.

For quantitative data analysis, statistical methods were used, including regression analysis, which allowed assessing the relationship between various economic indicators and identifying the main factors influencing the development of the agricultural sector. An analysis of the dynamics of agricultural production and economic accounts of agriculture was conducted. This made it possible to assess the impact of the war on the economic situation in the agricultural sector and identify its most vulnerable components. The level of employment in rural areas was analysed to determine the dynamics of changes in the number of jobs and their impact on the socio-economic development of the region. Employment data was available only until 2021, which made it impossible to identify the impact of the war. For the qualitative analysis of the data, a study of various areas of the topic was conducted, which allowed defining the main trends in reports and scientific articles related to the restoration of rural areas, including an analysis of socio-economic development, the impact of environmental factors, as well as the introduction of innovative technologies and support programmes for agricultural enterprises.

The study took into account the role of modern technologies and innovations in the development of the agricultural sector. For this purpose, data on the introduction of new technologies, such as precision farming, drones and biotechnology, were analysed. The study examined how these technologies affect the productivity and environmental sustainability of agricultural enterprises, as well as the economic efficiency and competitiveness of Ukrainian farms in the international market.

► Results

The socio-economic restoration of rural areas is a multifaceted task that is becoming increasingly important in the world. It is a process that includes a range of measures aimed at improving the economic, social and environmental conditions of rural areas. In the economic context, such recovery involves creating new jobs, supporting local businesses, and introducing innovations and modern technologies. Job creation is a key element that contributes to the economic recovery of a region. Increasing the number of jobs in various sectors, such as agriculture, small and medium-sized businesses, and tourism, contributes to higher incomes and lower unemployment (Rao, 2022). Supporting local enterprises through financial and advisory assistance allows them to develop and remain stable even in difficult economic conditions. The introduction of modern technologies and innovations in production processes increases the productivity and competitiveness of the local economy, making it more resilient to external challenges.

The social renewal of rural areas is aimed at improving the quality of life of the population. This includes ensuring access to quality healthcare, education and social services, which is the basis for a healthy and educated society. An essential component of social recovery is social

integration, which involves the active participation of local communities in decision-making and project implementation. This contributes to increased social cohesion and responsibility, as people feel part of a common process (Martens *et al.*, 2021). Education and training play a critical role in human capital development. Education and training programmes produce a skilled workforce that can contribute to the local economy and contribute to its growth. The environmental aspect of socio-economic recovery is also extremely important. The conservation of natural resources and the implementation of measures to preserve and rationally use resources ensure the environmental sustainability of the region. Environmental initiatives aimed at improving the environment, such as ecosystem restoration, pollution control, and green energy development, have a positive impact on the overall environmental condition of the territory. Adaptation to climate change is another important aspect that helps local communities reduce risks to agricultural production and other economic activities (Wang *et al.*, 2019).

Successful socio-economic recovery of rural areas depends on coordinated action by various stakeholders, including the government, local authorities, business and civil society. An important component is the development and implementation of strategies that take into account local characteristics and needs, ensuring sustainable development and improving the quality of life in rural areas. Only a comprehensive approach to recovery can ensure long-term and sustainable development that will form the basis for the prosperity of rural areas in the future. Rural regeneration requires a variety of approaches that consider the unique characteristics and needs of each region. A multisectoral approach involves integrating the efforts of different economic sectors to ensure the integrated development of rural areas. It includes agriculture, industry, tourism, education and other sectors. The multisectoral approach helps to diversify the economy, which reduces dependence on one sector and increases the region's resilience to economic fluctuations (Slavič, 2022). The asset-based approach focuses on using local assets and resources as the basis for recovery. It includes natural resources, cultural heritage, human capital and infrastructure. Using existing assets can reduce the cost of recovery and increase the effectiveness of measures.

A community-based approach involves the active participation of local people in planning, decision-making and project implementation. The community-based approach promotes social cohesion, ownership, and a sense of ownership among local residents. An innovative approach is an important element of rural regeneration. It includes the introduction of new methods of production, management, energy saving and environmental technologies. This increases the productivity, competitiveness, and sustainability of the local economy. The inclusive approach is focused on ensuring equal access to resources and opportunities for all members of the community, including vulnerable groups. This includes women, youth, people with disabilities and other minorities. An inclusive approach promotes social justice and improves the quality of life for all residents of the region (Tiwari, 2022). The ecosystem approach considers the relationship between human activities and natural ecosystems. It involves the conservation

and restoration of ecosystem services such as clean water, fertile land and biodiversity. This approach is aimed at ensuring long-term environmental sustainability and maintaining natural resources. The policy and administrative approach involves the development and implementation of government policies, programmes, and regulations that promote rural development. It also includes financing, subsidies and other forms of state support. The sustainable development approach is based on the principles of economic, social and environmental sustainability. It involves the balanced use of resources, ensuring equal opportunities for all residents and preserving the environment for future generations. This approach is the basis for achieving long-term success in the recovery of rural areas (Adamowicz & Zwolińska-Ligaj, 2020). Each of these approaches can be adapted to the specific conditions and needs of rural areas, creating a framework for comprehensive and sustainable recovery. Integration of different approaches and cooperation between different stakeholders ensure the effectiveness and efficiency of the recovery process.

The socio-economic recovery of rural areas has a direct impact on the agricultural sector, which is one of the key components of rural development. Optimization of the economic environment in rural areas contributes to the prosperity of agriculture by providing it with the necessary resources, markets and highly skilled labour. This recovery is accompanied by improved access to key resources for the agricultural sector, such as land, water, fertilisers, and technology. Improvements in infrastructure and natural resources allow agriculture to operate at a more productive level, increasing yields and product quality. The socio-economic recovery is creating favourable conditions for the development of agritourism and small agricultural enterprises. The development of these sectors helps local farms to earn extra income, contributing to the diversification of their activities and improving the socio-economic status of rural communities. Stimulating local production is another aspect of the impact of the socio-economic recovery on the agricultural sector. The development of small and medium-sized agricultural enterprises helps to reduce dependence on imports, ensuring sustainable local agricultural production. The recovery contributes to the efficiency and competitiveness of the agricultural sector by introducing modern technologies, innovations and best practices in production. This allows farms to compete more successfully in the market and ensures their sustainable growth (Pulubuhu *et al.*, 2020). Improved transport links and access to new markets help to increase the volume and monetization of agricultural production. Access to loans, grants, and other

financial instruments helps the agricultural sector to grow and expand, creating new opportunities for development.

The development of agricultural enterprises in the context of rural recovery is a complex and multifaceted process that affects the economic, social and environmental development of the region. Access to land, water, fertilisers and other resources is a critical factor for the development of agricultural enterprises. The restoration of rural areas should ensure sustainable access to these resources, in particular, by improving land use and irrigation. The development of agricultural enterprises is impossible without adequate infrastructure, including roads, railways, storage facilities and other facilities. Effective regulation and a stable legal framework are important factors for the development of agricultural enterprises, providing transparency, stability and legal certainty (Kyfyak *et al.*, 2022). Rural restoration should facilitate the introduction of new agricultural technologies and stimulate innovative development in agriculture. The restoration of rural areas should contribute to the creation of a stable and predictable market environment for agricultural enterprises. Public-private partnerships play an important role in rural regeneration and agricultural development by combining the resources, knowledge, and expertise of the public and private sectors. Through cooperation, the state can provide the necessary infrastructure, regulatory support and financial incentives, while private companies contribute investments, innovations, and management practices. This partnership contributes to the efficient use of resources, increased competitiveness of the agricultural sector and sustainable development of rural areas, ensuring economic growth and improving the quality of life of local communities (Ciolac *et al.*, 2013).

Ukraine's agricultural sector is one of the key elements of the national economy, demonstrating significant potential for growth and development. Agriculture accounts for approximately 10% of the country's total gross domestic product and is an important source of employment for a large part of the population, especially in rural areas. Ukraine has some of the most fertile soils in the world, in particular black soil, which accounts for about 30% of the world's soil reserves. This ensures high yields for major crops such as wheat, corn, barley, sunflower, and soybeans. In addition, the country is one of the world's leading exporters of grains and oilseeds, which has a significant impact on its trade balance. Ukraine's agricultural sector was expected to grow until 2022 due to the introduction of modern technologies and innovations (Fig. 1). However, due to the war, the state of the agricultural sector in the country has deteriorated somewhat.



Figure 1. Production (gross harvest) of agricultural crops in Ukraine from 2004 to 2023, thousand tonnes

Source: developed by the authors on the basis of the Area, gross harvest and crop yields (n.d.)

The war in Ukraine has had a significant impact on the agricultural sector, causing significant reductions in production of most crops. Despite some recovery in 2023, production levels have not yet reached pre-war levels, indicating the need for further support and recovery of agriculture in the face of ongoing challenges. Table 1 shows the level of livestock production. The analysis of the table shows that the livestock industry in Ukraine has undergone significant changes over the past two decades. The most

significant drops in production volumes occurred after the outbreak of war in 2022. The production of meat, milk, eggs, and wool has declined significantly due to economic difficulties, loss of territories, logistical problems and access to resources. Despite some positive developments in 2023, the overall situation remains challenging, and significant efforts and investments are needed to stabilise and develop the sector. Table 2 presents the economic accounts of agriculture (production account and income account).

Table 1. Production of main types of livestock products in Ukraine from 2004 to 2023

Year	Meat (in slaughter weight), thousand tonnes	Milk, thousand tonnes	Eggs, mln eggs	Wool, t
2004	1,599.6	13,709.5	11,955	3,202
2005	1,597	13,714.4	13,045.9	3,195
2006	1,723.2	13,286.9	14,234.6	3,277
2007	1,911.7	12,262.1	14,062.5	3,449
2008	1,905.9	11,761.3	14,956.5	3,755
2009	1,917.4	11,609.6	15,907.5	4,111
2010	2,059	11,248.5	17,052.3	4,192
2011	2,143.8	1,1086	18,689.8	3,877
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	15505.8	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
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: developed by the authors on the basis of the Production of major livestock products (n.d.)

Table 2. Economic accounts of agriculture in Ukraine, billion UAH

No.	Types/groups of products/activities	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1	Cereals	77.9	107.2	163.9	214.2	226.9	296.6	288.4	309.7	538.9	334.1
2	Industrial crops	52.7	71.4	131.2	170.6	173.8	207.8	189.7	209.9	393.1	294.3
3	Fodder crops	5.5	6	7.3	8	8.6	9.7	9.1	10.4	13.9	11.7
4	Vegetable crops	20.9	22.1	33.9	31.9	33.4	35.7	45.4	49.2	59.7	83.2
5	Potatoes	36.6	41.6	41.1	41.9	53.5	53.3	63.7	60.9	61.2	54.2
6	Fruits, berries, grapes	12.6	12.8	18.4	18.3	23.7	23.5	24.8	26.8	28.8	24.1
7	Other crop products	1.1	1.3	1.9	2.3	2.6	2.7	2.8	3.5	4.6	9.5
8	Crop production in general (1-7)	207.3	262.4	397.6	487.1	522.6	629.2	624	670.4	1,100.2	811.1
9	Animal husbandry (farming)	43.4	48.3	69.1	70.5	87.9	106	108.5	110.4	127.9	136.6
10	Livestock products	48.2	50.4	65.6	67.9	84.3	94.9	92.5	93.6	109.7	107
11	Livestock production in general (9-10)	91.6	98.7	134.6	138.5	172.3	200.9	201	203.9	237.6	243.6
12	Agricultural output (8+11)	299	361.1	532.3	625.6	694.9	830.2	824.9	874.4	1,337.8	1,054.7
13	Output of agricultural services	5.5	7.4	8.3	8.5	9	12.8	13.1	13.5	21.6	14.9
14	Agricultural output (12+13)	304.5	368.5	540.5	634	703.9	842.9	838	887.8	1,359.4	1,069.6

Table 2, Continued

No.	Types/groups of products/activities	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
15	Output of non-agricultural indispensable secondary activities	2.6	2.7	3.7	3.8	3.9	4.7	4.7	5	7.1	4.4
16	Agricultural output (14+15)	307.1	371.2	544.2	637.8	707.8	847.6	842.8	892.9	1,366.5	1,073.9
17	Intermediate consumption	178.6	214.8	311.8	367.4	414.6	500.1	498.7	511.5	789.6	637
18	Gross value added (16-17)	128.5	156.4	22.7	270.4	293.2	347.5	344	381.4	576.8	437

Source: developed by the authors on the basis of the Economic accounts of agriculture (n.d.)

The table shows that Ukraine's agriculture showed steady growth until 2021. However, the war that began in 2022 had a significant impact on production volumes, particularly in the grain and industrial crops sectors. Nevertheless, some sectors, such as vegetables and livestock, have shown resilience and even growth in the face of the crisis. This underlines the need for further support and investment in the agricultural sector to ensure recovery and sustainable development in the future. Agricultural enterprises in Ukraine face numerous challenges, but at the same time have many opportunities for development that can contribute to their sustainability and growth. The war is one of the most serious challenges, as the occupation of part of the country's territory, destruction of infrastructure, mining of fields, destruction of production facilities and logistics chains lead to the loss of land and labour resources and increased risks for investors. Economic instability, such as economic crises, inflation, currency fluctuations, and limited access to finance, also negatively affect the ability of agricultural enterprises to expand and modernise (Poltorak *et al.*, 2023).

Climate change is another significant challenge, as deteriorating climatic conditions, increased droughts and natural disasters threaten the stability of crops and require adaptation to new farming conditions. Land reforms, including an underdeveloped legal framework and unresolved land ownership issues, create barriers to investment and development in the agricultural sector. In addition, technological lag, lack of modern technologies, low level of mechanization and automation of production processes reduce the productivity and competitiveness of agricultural enterprises. The shortage of skilled workers caused by the out-migration of the working population and the ageing of the labour force also leads to a shortage of skilled workers in agriculture. Despite these challenges, there are numerous opportunities for agricultural enterprises to develop.

Deepening cooperation with the European Union opens up new markets, access to European funds and agricultural support programmes, and promotes the implementation of European quality and safety standards. The introduction of modern technologies, such as precision farming, drones, biotechnology and IT solutions, allows for increased production efficiency, reduced costs and improved environmental sustainability (Bovsh *et al.*, 2024). Government support programmes, including subsidies, loans, and grants aimed at modernizing agriculture, can significantly contribute to the development of agricultural enterprises.

The growing demand for organic products opens up new opportunities for the development of organic agriculture, which can generate additional income and improve the environmental situation. Cooperation among small and medium-sized agricultural enterprises in the form of cooperatives can increase their competitiveness, allow them to share resources and equipment, and expand market access (Willer *et al.*, 2024). Ukraine has considerable potential for agricultural exports due to its fertile soils and favourable climatic conditions. Expansion of export markets and product diversification can contribute to the economic growth of agricultural enterprises. Improvements in transport and logistics infrastructure, including the construction of modern warehouses, elevators and processing plants, will help to increase the efficiency of product supply and reduce costs. Thus, despite the serious challenges faced by Ukraine's agricultural enterprises, there are many opportunities for their development. The integration of innovative technologies, development of new markets, government support and international cooperation can significantly increase the competitiveness and sustainability of the agricultural sector. Taking advantage of these opportunities will contribute to further growth and development of agriculture in Ukraine. Table 3 shows rural employment in Ukraine.

Table 3. Employment in rural areas of Ukraine from 2017 to 2021

	2017	2018	2019	2020	2021
Employment, thousand people	5,047	5,082	5,206	4,968	4,877
In % of the total population	54.4	55	48.9	47.1	46.7
Among them:					
Working age, thousand people	4,807	4,871	4,930	4,703	4,605
In % of the population of the corresponding age	61.5	62.9	64.5	62.4	62

Source: developed by the authors on the basis of the Demographic and social statistics/Labour market/Employment and unemployment (n.d.)

Over the period under review, the total number of people employed in rural areas fluctuated, showing an increase from 2017 to 2019, followed by a decline. As a percentage of the total population, employment decreased from 54.4% in 2017 to 46.7% in 2021, indicating a decrease in the share of people employed in rural areas. In terms of working age, the number of employed persons also shows similar dynamics. The share of employed persons among the working-age population remained relatively stable, ranging from 61.5% to 64.5%.

The creation of new jobs in the agricultural sector has a significant impact on poverty reduction, as it provides stable income for the rural population. This helps to improve living standards and reduce migration to cities in search of work. The additional jobs also stimulate the development of local infrastructure and services, which in turn contributes to the socio-economic development of rural communities. In addition, increased employment in the agricultural sector can lead to increased production, improved product quality, and increased export potential for Ukraine. Ukraine has both successful and unsuccessful examples of implementing restoration projects in rural areas. One of the successful examples is the Agricultural Receipts project, which was introduced with the support of international donors such as IFC. This project allowed small and medium-sized farmers to receive financing secured by future harvests, which helped improve their financial capacity and ability to invest in farm development. As a result, many agricultural enterprises have been able to modernise their production and increase their output (Tomorrow's harvests fund..., 2019). For example, the farm Agro-Plus Service from the Zaporizhzhia region, thanks to Agrarian Receipts, raised the necessary funds to upgrade machinery and introduce modern tillage technologies, which significantly increased yields (First financial agricultural..., 2018).

Another example of a successful project is the Ukrainian Horticulture Business Development Project (UHBDP), which is being implemented with the support of the Canadian government. The project aims to increase the competitiveness of small and medium-sized fruit and vegetable producers in the southern regions of Ukraine. Through trainings, consultations and financial support, project participants were able to improve their agricultural skills and expand their markets (Agro-internship: A Ukrainian project ..., n.d.). For example, Blagodatna Ferma, a farm in Vinnytsia Oblast, has implemented an organic berry growing system and organised direct deliveries to supermarkets, which has led to a significant increase in revenues, thanks to its participation in the UHBDP (Blahodatna farm..., 2018). However, there are also unsuccessful projects. One of them is the programme to restore irrigation systems in the southern regions of Ukraine, which was launched in 2013. The aim of the project was to restore and modernise irrigation systems to ensure a stable water supply for agricultural enterprises. However, due to a lack of funding, poor planning and corruption risks, the project failed to achieve its goals. For example, in the Mykolaiv region, many irrigation systems remained in poor condition and farmers continued to face water supply problems. Ineffective management and insufficient coordination between stakeholders led to delays in project

implementation and failure to utilise the potential of irrigated land (Restoring irrigation in..., 2017).

Local communities play a key role in the process of socio-economic recovery of rural areas. Their active involvement in project planning and implementation helps to take into account local needs and specifics, which increases the effectiveness of the measures. For example, in the ATCs of the Khmelnytskyi region, the implementation of cooperative development projects was made possible by the initiative and activity of local residents. They have created several cooperatives that bring farmers together and help them share resources, reduce costs, and improve market access. The role of local governments is also important, as they can attract additional investments, coordinate the activities of different projects, and ensure transparency and accountability in the use of funds. Active cooperation between local authorities, communities and agricultural enterprises contributes to the creation of a favourable business climate and sustainable development of rural areas. Thus, the socio-economic recovery of rural areas in Ukraine has a significant impact on the development of agricultural enterprises. Successful project implementation, active participation of local communities and effective governance are key factors contributing to the achievement of positive results and sustainable development of the agricultural sector.

To improve the efficiency of socio-economic recovery and development of agricultural enterprises in Ukraine, a set of measures should be taken. Firstly, access to financial resources should be expanded by introducing new financial instruments, such as agricultural receipts, leasing, and credit support. It is important to create conditions for attracting investment, in particular, by ensuring transparency and reducing risks for investors. It is also necessary to expand cooperation with international financial organizations and donors, using grants and technical assistance to implement infrastructure projects. Modernization of irrigation systems is critical for increasing the productivity of the agricultural sector. Implementing effective programmes to rehabilitate and modernise irrigation systems, ensuring adequate financing, and introducing modern irrigation technologies such as drip irrigation will help reduce water consumption and increase yields (Havryliuk et al., 2022). In addition, the transport infrastructure needs to be improved by developing transport routes and logistics centres to facilitate the delivery of products to markets. Investments in the storage and processing of agricultural products are also important.

Support for innovation and technology is a key factor in the development of agricultural enterprises. Supporting research and scientific institutions in the development and implementation of new agricultural technologies, encouraging the use of digital solutions such as agrodrones, crop monitoring systems, and farm management software will help to increase production efficiency (Malchenko et al., 2024). It is also important to organise pieces of training and educational programmes for farmers to improve their professional skills, and provide access to advisory services and technical support. Strengthening the role of local communities in the recovery process is essential to achieving sustainable results. The active involvement of local communities in the planning and

implementation of recovery projects, the development of cooperatives and other forms of collective management will help to increase the efficiency of resource use. In addition, the institutional capacity of state institutions dealing with agricultural policy and rural recovery needs to be strengthened, and the legal framework for creating a favourable environment for agricultural sector development needs to be improved. Environmental protection and natural resource management are important aspects of sustainable development of the agricultural sector. Implementation of sustainable farming practices that reduce the negative impact on the environment, development of organic farming and environmentally friendly production, creation of mechanisms for rational use of land and water resources, development of biodiversity conservation programmes and restoration of degraded land will contribute to environmental sustainability.

Finally, improving social protection is critical for rural development. The development of social infrastructure, including access to healthcare, education and cultural services, housing programmes for young people and agricultural workers, the creation of new jobs in rural areas through the development of non-agricultural activities, and vocational reorientation and training programmes for rural residents will help improve living conditions and contribute to the overall socio-economic development of rural areas. The implementation of these recommendations will contribute to the comprehensive socio-economic recovery of rural areas and the development of agricultural enterprises in Ukraine, ensuring sustainable growth and improving the welfare of the population.

► Discussion

The development of rural areas in Ukraine is a complex and multifaceted task that requires an integrated approach and the involvement of various stakeholders. The analysis of the results shows that the socio-economic recovery of rural areas involves not only economic development, but also social integration and environmental sustainability. The economic recovery of rural areas is based on the creation of new jobs, support for local enterprises and the introduction of innovations. The creation of new jobs in various sectors of the economy, such as agriculture, small and medium-sized businesses, and tourism, contributes to the growth of incomes and the reduction of unemployment. Supporting local enterprises through financial and advisory assistance allows them to develop and remain stable even in difficult economic conditions. F. Manzoor *et al.* (2021) studied the impact of financial instruments such as subsidies and soft loans on the development of small and medium-sized businesses in rural areas. They found that financial support is the main factor that stimulates economic growth and job creation. J.M. Pedraza (2021) argued that access to financial resources allows small businesses to expand production, introduce new technologies, and increase the number of employees. The results of the current study also recognise the importance of supporting local enterprises through financial instruments. The studies indicate that financial assistance is critical for stimulating economic growth and business development in rural areas. However, the authors focus mainly on subsidies and loans,

while the current study also emphasises the need for advisory support and innovation that goes beyond financial measures alone.

Social rehabilitation of rural areas is aimed at improving the quality of life of the population. This includes ensuring access to quality healthcare, education and social services, which is the basis for a healthy and educated society. An important component of social recovery is social integration, which involves the active participation of local communities in decision-making and project implementation. This helps to increase social cohesion and responsibility, as people feel part of a common process. A. Calabrese *et al.* (2019) also investigated the importance of social inclusion and local community participation in decision-making. Their study shows that involving citizens in discussions and decision-making contributes to a more efficient use of local resources, increases trust in local authorities, and increases civic engagement. The current study also emphasises the importance of social inclusion and citizen participation in project planning and implementation. Both approaches recognise that without the active participation of local residents, social rehabilitation and regional development can be ineffective.

The environmental aspect of socio-economic recovery is also extremely important. The conservation of natural resources and the implementation of measures to protect and rationally use resources ensure the environmental sustainability of the region. Environmental initiatives aimed at improving the environment, such as ecosystem restoration, pollution control, and green energy development, have a positive impact on the overall environmental condition of the territory (Shahini *et al.*, 2024). Adaptation to climate change is another important aspect that helps local communities reduce risks to agricultural production and other economic activities. G.D. Gann *et al.* (2019) focus on environmental initiatives, in particular the introduction of green technologies and the conservation of natural resources. They believe that sustainable development is impossible without environmental sustainability. The study by Q. Li *et al.* (2022) also highlights the importance of the transition to green energy, the use of renewable energy sources and the protection of ecosystems to ensure the long-term viability of rural regions. This is in line with the approach of the current study, which also recognises the critical role of environmental initiatives in ensuring sustainable development. However, the current findings consider environmental sustainability in the context of not only technological aspects, but also social and economic aspects, to gain a more complete picture of the need for balanced development in rural regions.

Successful socio-economic recovery of rural areas depends on coordinated action by various stakeholders, including government, local authorities, business and civil society (Novak & Dudash, 2023). An important element is the development and implementation of strategies that take into account local characteristics and needs, ensuring sustainable development and improving the quality of life in rural areas. Only a comprehensive approach to recovery can ensure long-term and sustainable development that will form the basis for future prosperity in rural areas. K.M. Johnson & D.T. Lichter (2019) drew

attention in their study to the importance of state support through various mechanisms such as subsidies, development programmes and legal support. They argued that without this effective government intervention, rural recovery may be ineffective or even impossible. The study by B. Dabson & C. Kumar (2021), in turn, demonstrated how support measures can help improve infrastructure, access to finance and other resources, and stimulate entrepreneurship and employment in rural communities. However, there is a need for active multi-stakeholder cooperation, involving not only the government and local authorities, but also businesses, NGOs and local residents. The strategy of the current recovery study recognises the importance of diversity of approaches and the participation of all stakeholders to achieve sustainable rural development.

The socio-economic recovery of rural areas has a direct impact on the agricultural sector, which is one of the key components of rural development. Optimization of the economic environment in rural areas contributes to the prosperity of agriculture by providing it with the necessary inputs, markets and highly skilled labour (Marmul *et al.*, 2023). This recovery is accompanied by improved access to key inputs for the agricultural sector, such as land, water, fertilisers, and technology. P. Prus & M. Sikora (2021) focus on the modernization of infrastructure, in particular transport and irrigation systems, as a key factor for increasing agricultural productivity. Their study confirms that the renewal and modernization of these infrastructure facilities contribute to more efficient use of resources, reduce losses and increase the production capacity of agriculture. The authors' results are consistent with the findings of the current study on the importance of infrastructure investment for productivity. However, other aspects, such as business support strategies and social inclusion, should also be considered. A. Faggian *et al.* (2019) and E.Y. Iis *et al.* (2022) noted in their works the role of education and training as a key factor for human capital development and sustainable economic growth. They emphasised the need for educational programmes and training courses as a means of training qualified personnel. This aspect is consistent with the current research understanding of the critical role of education in producing a skilled workforce, which can be important for sustainable economic development. The interconnectedness between education, economy, social and environmental sectors contributes to a more successful recovery and development of rural areas (Reznik *et al.*, 2021).

Agricultural enterprises face numerous challenges, but at the same time have many opportunities for development that can contribute to their sustainability and growth. In Ukraine, one of the most serious challenges is the war, as the occupation of part of the country's territory, destruction of infrastructure, mining of fields, and destruction of production facilities and logistics chains lead to the loss of land, labour and increased risks for investors. Economic instability, including economic crises, inflation, currency fluctuations and limited access to finance, also negatively affect the ability of agricultural enterprises to expand and modernise. Each of the authors focused on different aspects of such recovery, including

financial support, social inclusion, environmental sustainability, infrastructure modernization, education, and government support. The studies reviewed point to the importance of a comprehensive and integrated approach to rural recovery that takes into account the diverse needs and factors affecting rural development.

► Conclusions

The study found that the socio-economic recovery of rural regions is an important task that is becoming increasingly important in the world. This process includes a set of measures aimed at improving the economic, social and environmental conditions of rural areas.

Economic recovery involves creating new jobs, supporting local businesses and introducing innovative technologies. An important indicator is the decline in employment of the working-age population in rural areas of Ukraine, which fell from 4,807 thousand people in 2017 to 4,605 thousand people in 2021, and the percentage of employed people to the total population decreased from 54.4% to 46.7%. The social rehabilitation of rural areas is aimed at improving the quality of life of the population by providing access to quality healthcare, education and social services, which contributes to the overall well-being and poverty reduction in the regions. The environmental aspect of recovery is key to ensuring the environmental sustainability of the region. The introduction of sustainable farming practices and the protection of natural resources help to maintain the ecological balance that is essential for the long-term development of rural areas.

The socio-economic recovery of rural areas has a direct impact on the agricultural sector, which is a key component of rural development. Support for agricultural enterprises contributes to increased productivity and sustainable growth, which ultimately improves the socio-economic status of rural communities. Successful projects such as Agrarian Receipts and the Ukrainian Horticulture Business Development Project demonstrate the effectiveness of international support and innovative approaches. At the same time, unsuccessful projects, such as the rehabilitation of irrigation systems in the southern regions, highlight the importance of effective management and coordination. Sustainable socio-economic recovery requires increased access to financial resources, modernization of irrigation systems, support for innovation, and strengthening the role of local communities in recovery. Only a comprehensive approach can ensure the sustainable recovery and development of Ukraine's agricultural sector.

A limitation of this study is the limited amount of data and the inability to consider all possible options for rural recovery. Further research could focus on analysing the impact of specific policies and programmes on recovery performance, as well as on the dynamics of change in agriculture and the role of new technologies in this process.

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► Conflict of interest

The authors of this study declare no conflict of interest.

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Вплив стратегії соціально-економічного відновлення сільських територій на управління розвитком аграрних підприємств

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► **Анотація.** Дане дослідження було направлене на аналіз ефективності комплексних відновлювальних стратегій у сільській місцевості та їхній вплив на управлінські практики в агропромисловому секторі. У статті розглянуто соціально-економічне відновлення сільських територій як важливу та багатогранну задачу, що набуває дедалі більшої актуальності в світі. Процес відновлення включає комплекс заходів, спрямованих на поліпшення економічного, соціального та екологічного стану сільських регіонів. Впровадження сучасних технологій у виробничі процеси підвищує продуктивність та конкурентоспроможність місцевої економіки. Розглянуто роль різних підходів до відновлення, включаючи багатосекторний, ресурсно-орієнтований, інноваційний, інклюзивний, екосистемний, політико-адміністративний та підхід до сталого розвитку. Кожен з них може бути адаптований до специфічних умов та потреб сільських регіонів, створюючи основу для комплексного та сталого відновлення. Проаналізовано вплив війни в Україні на аграрний сектор, що є однією з ключових складових розвитку сільських регіонів. Внаслідок чого виділена необхідність подальшої підтримки та інвестицій в аграрний сектор для його відновлення та сталого розвитку. Успішна соціально-економічна реабілітація сільських територій залежить від скоординованих дій різних зацікавлених сторін, включаючи державу, місцеву владу, бізнес та громадянське суспільство. Важливою складовою є розробка та реалізація стратегій, які враховують місцеві особливості та потреби, забезпечуючи сталий розвиток та підвищення якості життя у сільських регіонах. Тільки комплексний підхід до відновлення може забезпечити довгостроковий та стабільний розвиток, який стане основою процвітання сільських територій у майбутньому

► **Ключові слова:** державна політика; територіальний розвиток; транспортна та логістична інфраструктура; соціальні ініціативи; вплив війни



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Economic analysis of the production process of targeted edible fats through post-addition hydrogenation and their market applications

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► **Abstract.** The fat production industry is one of the key and fast-growing components of the food sector of Uzbekistan, and therefore, it is relevant to analyse the economic part of its crucial elements. The purpose of this study was to examine the hydrogenation process from the standpoint of production cost features and pricing issues. The methods employed in the study were descriptive, systematisation, and dialectical. The study showed that the production and utilisation of targeted edible fats play a vital role in the food industry by achieving certain characteristics of other products. However, a hydrogenation procedure is often used to make the fats more efficient. The study described its essence in greater detail and evaluated the economic feasibility of the hydrogenation process. The significance of choosing the correct reactor and catalysts to maximise yield was highlighted, as well as the influence of some other characteristics on it. The study also addressed the disadvantages of the fat hydrogenation process, which has a negative impact on public health. Therefore, activities aimed at mitigating negative impacts in this industry should be carried out more actively. Furthermore, attention has also been paid to assessing the state of the edible fats market in Uzbekistan: the rapid growth rate of the industry has been noted due to the increasing revenues of enterprises engaged in the production of these products. The obtained findings can be applied by enterprises to change the principles of hydrogenation process, as well as by the state authorities to formulate a long-term policy for the development of the industry

► **Keywords:** chemical treatment; cost-effectiveness; hydrogenation reactor; healthcare; industry

► Introduction

As such, dietary fats play a vital role in the health and normal functioning of the human body: they are the most concentrated source of energy among food components (Ahmed *et al.*, 2021; Kolobe *et al.*, 2023). Some fats are part of cell membranes, neurons, and other structural components of the body. They also act as a protective layer for internal organs, which helps them avoid damage during physical impacts, and they also form an insulating layer that helps maintain optimised body temperature during cold weather (Nicholson & Marangoni, 2021). Hydrogenation allows achieving some special characteristics of the fats: it allows solidifying them, thereby increasing their resistance to oxidation, temperature, improving their taste

and aroma (Su *et al.*, 2022). Although the hydrogenation process can produce trans fats, which can be harmful to health if consumed in excess, finding effective approaches to the process is still important. Furthermore, it stays important to assess whether it is still economically feasible to hydrogenate fats, as well as the market characteristics of these products in Uzbekistan.

In the current literature, there are few studies that have evaluated and examined the production of target edible fats in detail, including from the standpoint of economic analysis. D. Rakhimov *et al.* (2024) considered the possibilities of solving the problem of obtaining hydrogenated modified fats by hydrogen treatment with

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catalysts such as nickel, cobalt, and iron. There is a need to switch to health and environmentally safer catalysts, but this part of the problem has not been addressed in detail within the scope of the cited study.

N. Sabirova & M. Sadikova (2023) tried to increase the sustainability of the food industry by expanding the range of shortening fats with new types of fat sources. As a result, it was possible to create shortening fats in plastic, liquid, and granular forms, each designed for a specific food use. In the future, this could be used in practice to make more efficient use of fats in the food industry as a whole. Nevertheless, all the above-mentioned studies did not consider the economic component of food fats production, nor did they mention hydrogenation as one of the types of their processing.

Quite a few scientists have devoted their attention to evaluating different approaches to the processing of dietary fats. Thus, P. Albrand *et al.* (2021) proposed a new model for hydrogenation of sunflower oil using palladium catalyst. They noted that the proposed model should simplify the reaction mechanism based on key assumptions about the composition of sunflower oil. M.S.W. Lim *et al.* (2021) investigated the features of selected catalysts for the hydrogenation process. They proposed some original approaches to fat processing, specifically using catalysts synthesised using ultrasound. The researchers showed that ultrasound treatment altered the selectivity of the product, reducing the production of trans fats compared to catalysts not treated with ultrasound. Notably, the two studies cited above are tremendously important in the context of improving the quality situation of hydrogenation. Nevertheless, there are really few studies in the world that address the economic aspect of the issue of food fat production, which once again indicates the relevance of this study.

Thus, the purpose of this study was to analyse all aspects of hydrogenation from an economic standpoint (assessing the level of profitability of enterprises that are engaged in this type of activity, as well as the current situation in this market). This allowed developing some recommendations for enterprises on the formation of the specific features of conducting their activities from both technical and economic standpoints.

► Materials and methods

The study evaluated the economic feasibility of fat hydrogenation. In other words, opinions were formed on whether it was advantageous to hydrogenate fats in terms of benefits. Nevertheless, there are many difficulties in these assessments. The price of this type of product is not publicly available due to the specificity of the goods needed for the hydrogenation process: therefore, it is difficult to determine a clear market price for it without direct negotiations with manufacturers and suppliers. In this regard, the values assumed within the framework of this study, albeit presumably close to the real values, may differ from the real values obtained by entrepreneurs directly in their work.

Considering the specific features of finding and performing analytics on the information found, many indicators were calculated based on the small amounts of data that could be found, e.g., an approximate estimate of 20 litres of cotton oil based on data on five; an

approximate estimate of the wage of a worker servicing the fat production process based on approximate wage estimates for this kind of specialists. Nevertheless, some indicators were also employed, which are used to assess the financial condition of the enterprise, namely ROI (return on investment), which within the framework of the study was calculated as net profit (before or after tax) in relation to the level of investment in equipment for the production of products. Formula 1 is presented below, which illustrates how the calculation is carried out:

$$ROI = \frac{\text{Profit}}{\text{Investments}} * 100\%, \quad (1)$$

where ROI – the return on investment; Profit – the net profit; Investments – the volume of invested investments.

Therewith, as already noted, the study employed two approaches to estimating ROI: with and without tax deductions, which initially affects Profit, and thus profitability. The study also assessed the overall state of the edible fats industry in the country. For this, some statistical data were used, namely regarding the income received by entrepreneurs in Uzbekistan in this sphere, as well as the level of offline and online sales of edible oil. Thus, data were used from the Oils & Fats – Uzbekistan (n.d.). Notably, it provides data up to 2017 to 2029: accordingly, information from 2024 to 2029 is projected, and while it may provide some information on likely future trends in the industry, it is not entirely reliable.

Certain scientific methods were also employed within the framework of the study. The systematisation of information within the study (regarding the state of the hydrogenated fats market, prices and costs of production) helped to simplify the analysis process, making it more unified and holistic. Abstraction made it possible to analyse certain concepts and variables outside any systems, i.e., in isolation. The dialectical method helped to analyse different sources of information to form a single conclusion on them based on the negative and positive components of each side. Separate approaches to assessing the financial performance of an enterprise were also used.

► Results

Unlike conventional hydrogenation, which leads to the formation of harmful trans fats, step-by-step hydrogenation considerably reduces their content, which is caused by the specific features of the technology, the essence of which is the gradual addition of hydrogen at several stages. Stage-hydrogenated fats also have a better resistance to oxidation, which makes them more resistant to spoilage and extends their shelf life, which is especially significant for food manufacturers, because it allows them to produce products with a long shelf life without the addition of artificial preservatives. The texture quality of such products is also better. Furthermore, the stepwise hydrogenation process can be tuned to produce fats with different properties, namely hardness, plasticity, and stability (Puprasit *et al.*, 2022). This reduces the risk of product spoilage and increases shelf life. All this shows the clear advantages of using the stepwise hydrogenation approach over any other methods.

At the heart of the fat hydrogenation production process is the reactor. It is equipped with a special stirrer,

called a combined gas supply system, which is the basis for carrying out the hydrogenation process. In the hydrogenation reactor, hydrogen is fed to a high-efficiency impeller at the bottom where it is dispersed in tiny gas bubbles (Cho *et al.*, 2021). Additionally, a gas turbine, which has a self-flushing mechanism, circulates unreacted hydrogen, which accumulates in the free space of the reactor, back to the reaction mixture via a hollow shaft. This ensures that there is always enough dissolved hydrogen available for the chemical reaction and provides the appropriate conditions for hydrogenation. The price of this kind of reactors can vary greatly depending on the individual parameters, namely maximum filling volume, design temperature, pressure, as well as some other characteristics.

The price of a reactor can vary considerably depending on what features it has. Moreover, this information is rather non-public, as it is quite difficult to find any data in the public domain regarding how much generators of this kind cost. Their price is formed based on personal agreements between the manufacturer and the potential buyer. Nevertheless, the study still managed to form some price frames, at around USD 10,000 for a 20-litre reactor, considering all possible associated costs. In this case, the hydrogenation process can take 6-24 hours; thus, it is assumed that only one portion of fats that have undergone the hydrogenation procedure can be obtained within one working day (Lee *et al.*, 2021).

However, to carry out this process, other elements are also required, namely the fats themselves (the raw material for hydrogenation), hydrogen (the gas that is added to the reactor to react with the double bonds in the fats) and catalysts (it is to be assumed that the additional equipment that may be needed to carry out the hydrogenation process is already available or was purchased with the purchase of the generator). On one of the Uzbek marketplaces, the price for 5 litres of cotton oil is UZS 92,000, i.e., about USD 7.26; for 20 litres one will have to pay USD 29; the catalyst will cost about the same amount. Therewith, the price of hydrogenated cottonseed per 1 litre is at USD 4.2, i.e., USD 84 for 20 litres. Considering energy costs of about USD 2 per day, as well as a minimum of 1 employee with an average salary of USD 350/month, one obtains a production cost price of about USD 72, while its selling price is USD 12. A net profit per year is USD 4,380 before taxes, which is about 43.8% per annum, with a payback period of 2 years and 4 months, or USD 3,504 at a rate of 20%: in this case the rate of return is 35% per annum, and payback will occur in 2 years and 11 full months.

Notably, the above calculations are rather approximate, and in reality, the yield may turn out to be somewhat higher or lower. A description of the variables affecting possible changes in the profitability of hydrogenated fats production is presented in Table 1.

Table 1. Estimation of the impact of individual variables on the profitability of fat hydrogenation

No.	Variable	Influence
1	Reactor volume	Within the framework of the study, the evaluation was based on a 20-litre reactor. However, better results will be achieved if larger fixtures are used
2	Decrease in reactor cost per litre with volume increase	While a 20-litre reactor may cost around USD 10,000, if the volume of the apparatus to be purchased increases by n times, its price will increase at a comparatively lower rate, resulting in a faster payback period
3	Number of employees	One worker is more than enough to handle a reactor with a capacity of 20 litres. In this regard, when working with a larger sized equipment, e.g., 50 or 100 litres, hiring even an additional 1, 2, or 3 workers (if required) will allow for higher incomes overall
4	Additional costs	Estimates of product delivery, service, and other operating costs were not used as part of the calculations. Still, they should not be so noticeable in terms of their impact on the cost of production at high volumes
5	Catalyst cost	The estimated cost of the catalyst for the hydrogenation process is approximate, and in real conditions may turn out to be both higher and lower

Source: compiled by the authors of this study

Table 1 shows that there are both variables that can actually have both positive and negative effects on the resulting returns. Nevertheless, due to the scalability of this business, it is worthwhile to generally expect more positive results from this type of business due to the economies of scale generated by the purchase of a larger scale reactor.

In Uzbekistan, the oil and fat industry is one of the main industries in the food production sector. It covers oilseed production, vegetable oil processing, and the production of various products such as edible oils, margarines, and industrial fats. With the transition to a market economy, Uzbekistan has made considerable progress in diversifying the processing of oilseeds, especially soya beans, and developing local cultivation of oilseeds such as safflower, sunflower, and sesame. The internal market

for oil and fats products in Uzbekistan is sustainable, fuelled by growing consumption by households, food producers, and a growing population. To better understand the current state of the edible fats market in Uzbekistan, it is worth evaluating the individual data that can describe them. Thus, Figure 1 shows the profits earned by the industry representatives. As Figure 1 shows, the income earned by producers of edible fats in Uzbekistan is constantly increasing. Thus, between 2023 and 2017, revenues increased by 53.5%, which equates to an annual growth rate of 7.4%. The projection of the subsequent change in income presented in Figure 1 also suggests a probable improvement in the subsequent situation. Another characteristic is the sales volumes in the offline and online segments, data which is presented in Figure 2.

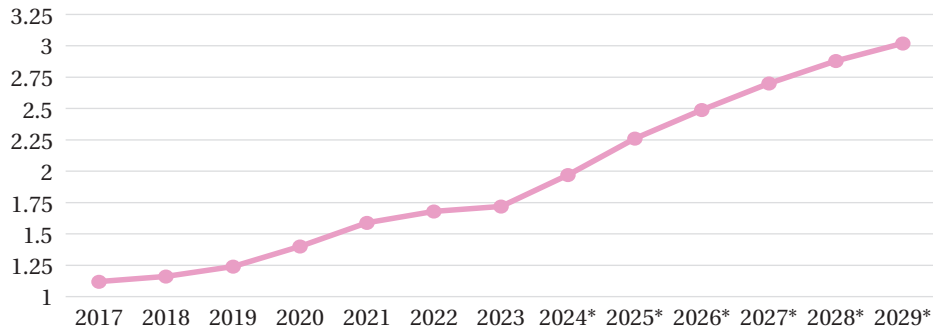


Figure 1. Revenue generated by the edible fats industry in Uzbekistan in 2017-2029, USD mln

Note: * – data from 2024 to 2029 are projections

Source: made by the authors of this study based on data from Oils & Fats – Uzbekistan (n.d.)

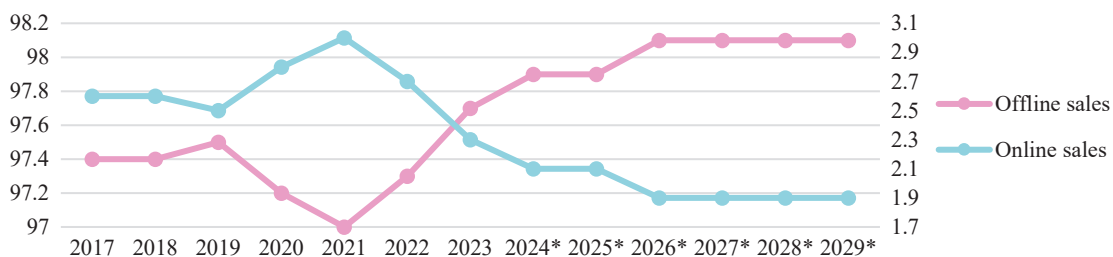


Figure 2. Share of offline and online sales of hydrogenated fats in Uzbekistan from 2017 to 2029, %

Note: * – data from 2024 to 2029 are projections

Source: compiled by the authors of this study based on data from Oils & Fats – Uzbekistan (n.d.)

As Figure 2 shows, the share of offline sales in the country in this sphere is significant: almost all sales take place in this way. The situation stays unchanged and is likely to remain so in the years to come. Nevertheless, it would be more effective to develop specifically online sales as this allows for a considerable increase in sales and therefore has a positive impact on the development of the industry. However, it is challenging to make such an assessment separately for hydrogenated fats. This is caused by the fact that this is a rather niche product, for which it is virtually impossible to find data in the public domain, which means that real niche research is required. Furthermore, such fats are most often used in B2B rather than B2C business models, which also makes it more difficult to collect information and analyse it.

Hydrogenated fats can be utilized in the production of confectionery products such as margarines, candy fillings, biscuits, and pies. They are also used in the bakery industry for baking fats, in the sauce industry, and in the creation of milk substitutes like vegetable creams and cream. Additionally, they serve a role in the creation of feed fats as additives to enrich feed and enhance its nutritional value. Thus, their application is broad yet niche-specific.

In the context of a better understanding of the current state of the market, some additional assumptions can be made about the above assessments of the calculations of the economic viability of fat hydrogenation. Thus, it is worth addressing the specific features of the pricing policy, which can be adopted by the company: in fact, there can be two of them, either based on the market, or based on the formed markup. The study assumed that the

market price of non-hydrogenated fats is at USD 84 per litre. The company is not obliged to set its own price at that level, but above, or below. This affects demand, because if the price is lowered, it is likely to sell more products, and vice versa (Ivashura *et al.*, 2022). In this context, it is worth initially trying to estimate the demand for the product at the market price and then changing the price according to the magnitude of demand. Notably, considering the gradual growth of income received by representatives of the edible fats industry in Uzbekistan, as well as the forecasts that were formed, an increase in demand for products can be anticipated. While this could lead to an increase in price, it should not be very rapid, considering that the increase in demand will be offset, among other things, by an increase in production levels (Yousaf *et al.*, 2022). The company can then either focus on the market price, which will change dynamically, or it can change its rate of return depending on market conditions: for instance, in the valuation exercise, producers should receive approximately 16.7% return for each litre of hydrogenated fat produced. Thus, the generated rate of return may be at the level of 15-16%; however, as market performance changes, it may gradually increase to 18%, 20%, 25%.

Still, hydrogenated fats have their problems, which is why scientists are trying to find other methods of processing fats for later use. The principal reason is trans fats, which have a negative impact on people's health. They cause cardiovascular diseases, can cause diabetes, inflammation of the immune system, adversely affect human growth and development. The fact is that during the hydrogenation process, unsaturated fatty acids

(which have one or more double bonds between carbon atoms) are converted into saturated fatty acids (without double bonds) (Czwartkowski *et al.*, 2022). However, trans-isomers can form when the double bond stays but hydrogen atoms are added to the molecule from opposite sides. Trans-isomers of fats have a different structure from natural fats, which affects their physical and chemical properties (Kopytets & Voloshyn, 2022). They can be more resistant to oxidation, which has a positive effect on the shelf life of products, thus the risk of diseases of all kinds. Apart from the hydrogenation process, trans fats can also be formed in nature, in small amounts, such as during processing of animal products or during fermentation of some foods; however, their concentration is not significant (Sivakanthan & Madhujith, 2020). In this context, legislation is emerging in many countries to regulate the use of trans fats, to minimise their content in products. Thus, in the current environment, it is essential to find new approaches that are aimed at either minimising the occurrence of trans fats in products due to the hydrogenation process or new approaches to fat processing.

► Discussion

The production of target fats in Uzbekistan was considered in a fairly comprehensive manner in the presented study. Nevertheless, there are quite a few difficulties in this area in Uzbekistan despite its significant role for the economic well-being of the state and the industry. Thus, considering the health risks associated with trans fats, it is crucial to implement strict regulations to minimise their presence in food products. The Uzbek authorities should consider reviewing existing legislation to determine whether it is effective in the current context of global trans-fat restrictions. Furthermore, it is still effective to stimulate innovative development to create and implement the latest technologies that could improve the quality of reproducible hydrogenated fats or use a different processing technology (Borsolyuk & Verbytskyi, 2023). Grants, tax incentives, and cooperation with academic institutions and industry experts should be the state's tools for this purpose. This should especially apply to small and medium-sized enterprises, providing them with both technical and financial support.

Work needs to be done on the consumer side as well. Public awareness campaigns, seminars, and educational materials can empower consumers to favour healthier fat options and stimulate demand for trans fat-free products (Tkach *et al.*, 2023). The same applies to the promotion of sustainable practices in the edible fats industry, such as responsible sourcing of raw materials, optimising production processes to minimise waste and emissions, and promoting environmentally friendly packaging, can contribute to a healthier environment and increased consumer confidence (Yemchenko, 2022). Promoting cooperation between industry stakeholders, including producers, manufacturers, and regulators, can facilitate the sharing of best practices, standards, and technological advances. Establishing industry-wide guidelines on fat processing methods, labelling transparency, and quality standards can improve consumer confidence and product integrity (Shahini *et al.*, 2023). By implementing these policy recommendations, Uzbekistan will be able to overcome the challenges of the targeted edible fats industry, address the

public health problems associated with hydrogenated fats, promote innovation and sustainable development, and ultimately improve the well-being of its population. In the present study, the role of fats, their uses, and applications were described in sufficient detail. A. Zbikowska *et al.* (2023) evaluated current trends in fat modification. The researchers described the significance of solid fats in food production and their importance for both practical use and nutritional value. Within the framework of the study, the researchers noted that conventional methods of fat modification, such as partial hydrogenation, are known for reducing nutritional value, therefore suggesting other approaches such as enzymatic transesterification. It was concluded that it is crucial, first of all, to ensure better health levels in countries, to utilise newer methods of fat modification.

F. Troncoso & G. Tonetto (2023) reached analogous conclusions in their economic analysis of sunflower oil hydrogenation. Researchers have pointed out the importance of hydrogenation in modifying fats and oils for various applications including food and non-food industries. However, they also noted that conventional hydrogenation methods using nickel-based catalysts often produce undesirable trans fatty acids, requiring expensive filtration and bleaching processes to remove traces of nickel and ensure product quality. The researchers proposed the use of platinum monolithic catalysts as a solution to reduce processing costs by eliminating filtration stages. In their conclusions, they note the significance of switching to this kind of technology, both to preserve the health of citizens and for environmental and economic reasons. The present study also indicated that there are problems caused primarily by the negative effects of hydrogenated fats on human health, which may make their subsequent use hazardous. Therefore, public authorities should adopt policies that aim to introduce innovative technologies that can reduce the level of harm caused by this process or introduce new types of edible fats processing.

W. Wongjaikham *et al.* (2022) investigated the production of low trans-fat margarine. The researchers pointed out that the importance of fats in the diet is really high. However, conventional hydrogenation methods often result in the formation of trans fatty acids, which is a health hazard. In this regard, the researchers also suggested that the pilot plant could be used to produce low trans-fat margarine. In other words, the implementation of the technology described in this study, or any other technology, will considerably improve the situation in terms of the level of health quality among the citizens of the country. K. Sattarov (2023) reviewed the production of target edible fats in step hydrogenation technology and their utilisation. He pointed out that the quality of the catalyst, activity, durability, and stability in isomer formation during hydrogenation are essential for the efficient performance of this process. The study revealed the problem of trans-isomer formation due to hot temperatures, catalyst specificity, and feedstock composition rich in unsaturated fatty acids. The researcher believes that a critical need in the industry is the development of catalysts: despite considerable progress in this area, the problem is still not fully solved. The present study did not focus so much on issues that address the need for the development of new catalysts. Still,

since it is an approach to harm reduction in terms of harm to public health, it is effective.

F. Mena *et al.* (2013) noted the need to create innovative technologies in this area. The researchers outlined three key strategies to focus on creating healthy edible oils that are low in saturated fatty acids. They recommended the use of fat substitutes for this purpose to mimic the functional and sensory properties of fats while reducing calories, the use of chemical or enzymatic processes in the creation of structured lipids, and the genetic modification of fatty acid composition. However, the researchers also noted the need for more long-term research on this topic to fully assess the impact of all these changes on health outcomes. This study also observed the need for improvement in the context of utilisation of dietary fats to improve the standard of living of the population. Thus, the use of this type of technology is relevant to achieve this goal. Z. Wang (2020) analysed the edible oil market in China. The study described many features of this market in the country. Specifically, it was shown that individual firms attempt to gain competitive advantage by lowering prices below market prices. The researcher generally considers this strategy to be quite effective in attracting new users. In this regard, he recommends more active application of various marketing tools, changing the development strategies of their enterprises to increase the efficiency of their companies. The present study described the specific features of the existence of the edible fats market in Uzbekistan. It was shown that this market is developing quite rapidly in the country, with many opportunities for expansion. In China, the situation is a bit different, with more problems with the competitive situation, among other things. Nevertheless, in the future, the situation in the Uzbek market may come to a state that is currently observed in China. In this regard, these recommendations can also be used in Uzbekistan in the future.

► Conclusions

The study concluded the role of quality production of edible fats for better functioning of the entire food industry. Targeted edible fats are generally designed for specific

uses, whether for margarines, cooking oils, confectionery, or food additives. The hydrogenation process, the key aspect discussed, alters the molecular structure of fats, increasing their stability, shelf life, and suitability for industrial applications. However, this transformation also produces trans fats, which are known for their adverse health effects. In modern environment, regulatory frameworks around the world are evolving to change the way trans fats are regulated to ensure better health outcomes for countries.

The economics of hydrogenation, particularly in Uzbekistan, are highlighted through cost analyses and market trends. The profitability of hydrogenated fats is affected by a range of factors, including production costs, raw material prices, and market demand. The study provided information on profitability calculations with potential income and payback periods. Although the calculation was made with some assumptions, it makes it clear that running such a business in the current environment is still effective in terms of profitability. It costs USD 72 to produce 20 litres of hydrogenated fats in Uzbekistan. Furthermore, the study described selected trends related to the development of this industry in the country. Thus, the evolution of the oil and fat industry of Uzbekistan was presented, demonstrating the achievements in diversifying the processing of oilseeds and meeting the needs of the internal market. Revenues of the oil and fats industry in Uzbekistan totalled USD 514.5 mn in 2023 and are forecast to grow annually by 7.4%.

Nevertheless, the trans fats that arise from the hydrogenation process are still a significant problem for their subsequent increased production. Therefore, it is relevant for future research to propose innovative approaches to reduce health hazards due to the hydrogenation of dietary fats.

► Acknowledgements

None.

► Conflict of interest

None.

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Економічний аналіз процесу виробництва цільових харчових жирів через постадійну гідрогенізацію та їх ринкове застосування

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► **Анотація.** Галузь виробництва жиру є однією з важливих і швидкозростаючих складових харчової сфери Узбекистану, у зв'язку з чим проведення аналізу економічної частини найважливіших її елементів є актуальним. Метою цього дослідження стало розглянути процес гідрогенізації з точки зору особливостей витрат на виробництво та питань ціноутворення. Методами, що застосовувалися в рамках дослідження, стали описовий, систематизація та діалектичний. У рамках дослідження було показано, що виробництво та використання цільових харчових жирів відіграють життєво важливу роль у харчовій промисловості, оскільки дають змогу досягти певних характеристик інших продуктів. Однак, для більш ефективного застосування жирів, часто використовується процедура гідрування. У роботі більш детально було описано її суть, а також проведено економічну оцінку доцільності проведення процесу гідрування. Було підкреслено важливість вибору правильного реактора і каталізаторів для максимізації прибутковості, а також вплив деяких інших характеристик на неї. У рамках дослідження також зверталася увага на недоліки процесу гідрогенізації жирів, який негативно впливає на здоров'я населення. У зв'язку з цим, діяльність, спрямована на зниження негативного впливу в даній галузі, повинна проводитися більш активно. Крім того, увага приділялася й оцінці стану ринку харчових жирів в Узбекистані: було відзначено стрімкі темпи зростання галузі, що було відзначено завдяки збільшенню доходів підприємств, які займаються виробництвом цієї продукції. Отримані результати можуть бути застосовані підприємствами для зміни принципів проведення процесу гідрогенізації, а також державною владою для формування довгострокової політики розвитку галузі

► **Ключові слова:** хімічна обробка; рентабельність; реактор гідрування; охорона здоров'я; промисловість



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Risks of managing financial resources of the agricultural sector of Ukraine in the zone of military conflict: Challenges, threats, ways of counteraction

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► **Abstract.** This study was aimed at identifying the risks that affect financial management in the agro-industrial sector of Ukraine during military operations in order to develop effective countermeasures. The research methodology included an analysis of the main risks, such as exchange rate fluctuations, inflation, disruption of supply chains and political instability, as well as an assessment of strategies to minimise these risks. The main stages of risk management are identified as identification, assessment, and monitoring of risks, as well as development of appropriate strategies, such as investment diversification, insurance, and hedging. The study results showed that the key factors for ensuring stability are the introduction of technological innovations, government support, creation of reserve funds and diversification of funding sources. In particular, the development of modern agricultural technologies, subsidies, soft loans and investments in infrastructure significantly increase the resilience of the agricultural sector to crisis conditions. It is also important to plan cash flows to maintain liquidity and meet financial obligations in a timely manner. The experience of several countries, such as Israel and Georgia, which have faced similar challenges, was reviewed and analysed to see how they managed the financial resources of their agricultural sectors. The experience

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of these countries has shown that successful management of the financial resources of the agricultural sector in the context of military conflict requires a comprehensive approach that includes technological innovation, government support, financial planning and human capital development to ensure sustainable development of the agricultural sector in times of war. This approach allows not only preserving but also developing the agricultural sector, ensuring food security and economic stability of Ukraine

► **Keywords:** risk management; agriculture; instability; investment; exports

► Introduction

Ukraine's agricultural sector faces many challenges, including difficulties in financial management, which have been exacerbated by the ongoing hostilities. Businesses suffer from exchange rate volatility, high inflation, supply chain disruptions and complications in accessing finance. Effective management of financial resources is critical to ensure the survival and development of the agricultural sector in times of war. Studying these aspects will help to develop new approaches to financial planning and risk management.

Many researchers, both in Ukraine and abroad, have been paying attention to the issues of financial management in the agricultural sector. Their research provides valuable information on risks, challenges, and ways to counteract them. M. Khudaykulova *et al.* (2022) studied the impact of the military conflict on the Ukrainian economy, in particular on the agricultural sector, and pointed to a significant increase in financial risks due to the rising cost of credit, exchange rate instability, and logistical problems. S. Williams & R. Karen (2019), in turn, proposed the creation of state support programmes for agricultural enterprises and the development of specialised financial instruments to minimise risks, including those caused by the war. M.V. Soomiyol & O. Fadairo (2020) analysed the cases of agricultural enterprises that were able to adapt to the conditions of military conflict by optimizing costs, diversifying sources of income and introducing new technologies. M. De Rosa *et al.* (2019) pointed out that agribusinesses that implement diversification strategies and actively use risk insurance demonstrate greater resilience to crisis situations. V. Liashenko *et al.* (2022) analysed the role of international organizations in supporting agribusinesses in conflict situations.

A. Faqih *et al.* (2020), in turn, argued that cooperation with international donors and financial institutions can significantly reduce financial risks and contribute to the stabilization of the sector. A. Rijanto (2021) emphasised the importance of introducing modern financial technologies, such as blockchain and financial platforms, to increase transparency and efficiency in financial resource management. M. Hamulczuk *et al.* (2023) studied the impact of military conflicts on global agri-food supply chains. M.A. Arias *et al.* (2019) also noted that international cooperation and support can help reduce the negative impact of conflicts on agricultural markets and ensure the stability of food supplies. K. Brockova *et al.* (2021) drew attention to the importance of innovation and technological development as key factors that allow agribusinesses to remain competitive even in difficult conditions.

The studies of the previous authors provide valuable theoretical and practical material for analysing the risks of financial resource management in the agro-industrial complex of Ukraine. They confirm the importance of an

integrated approach to risk management, cooperation with international institutions, and the introduction of modern technologies to ensure financial sustainability and development of the sector in the context of military conflict. Despite a considerable amount of research, some aspects of financial resource management in the agro-industrial complex in times of war remain insufficiently studied. There is a need to study the adaptation of successful international financial management practices to the specific conditions of the Ukrainian agricultural sector in the context of the conflict.

The purpose of this study was to identify the risks affecting financial management in the Ukrainian agricultural sector during the war in order to identify effective countermeasures. The objectives of the study included: assessing the impact of conflicts on the global financial strategies of Ukrainian agribusinesses; developing and implementing innovative financial instruments to reduce risks and improve management efficiency; and studying the role of government and non-government institutions in maintaining the financial stability of agricultural enterprises during the war.

► Materials and methods

The study is based on data from the State Statistics Service of Ukraine, in particular on economic indicators of the agricultural sector for the period from 2013 to 2023. Data on gross domestic product (GDP), production in agriculture, forestry and fisheries, exports of agricultural products, and capital investments in the agricultural sector are included. The statistics used cover key indicators that affect the financial stability of agricultural enterprises, including the impact of the military conflict on economic activity. The economic accounts of agriculture in Ukraine and the volume of capital investment in agriculture were allocated only until 2022 due to the lack of up-to-date data in the State Statistics Service of Ukraine.

The research methodology includes several key stages: risk identification, risk assessment, consideration of risk management strategies, risk monitoring and control, financial planning in an uncertain environment, innovation and strategic management. The main sources of risks that may threaten the financial stability of agricultural enterprises during military conflict were identified. For this purpose, data and current trends affecting the agricultural sector were analysed.

The identified risks were quantified. A statistical method was used to assess the impact of each factor on the financial performance of agricultural enterprises. For this purpose, the potential losses from negative factors were analysed. Risk management strategies were considered. Different approaches to minimizing or avoiding risks, such as investment diversification, insurance, hedging and other

financial instruments, were considered. The advantages and disadvantages of each approach were analysed, taking into account the specifics of agricultural enterprises.

A system of risk monitoring and control was considered. This included continuous monitoring of risks and the effectiveness of the measures taken. The results of monitoring were analysed to detect changes in the risk environment in a timely manner and adjust management strategies. Financial strategies were explored to help businesses adapt to rapidly changing conditions. This encompasses the creation of reserve funds, diversification of funding sources, adaptation of budgets and cash flow planning. Innovative technologies in production, logistics and management, as well as human resource management, were considered to assess their impact on the sustainability and competitiveness of agricultural enterprises during the crisis.

To assess the impact of various factors on the financial stability of agricultural enterprises, authors analysed key aspects such as agricultural production, production and logistics costs, financial investments in development, and exports. This allowed quantifying the risks and their potential impact on financial results. Statistical methods were used to analyse historical data and identify trends. Data before and after the military conflict were compared to identify changes in the financial performance of agricultural enterprises. This allowed determining the main impacts of the war on economic activity.

Examples of risk management in other countries, such as Israel and Georgia, were studied (Israel: Country file..., n.d.; Georgia: From reformer..., 2018; Countering economic dependence..., 2022). A comparison of risk management strategies applied in Israel and Georgia was conducted. The analysis covered technological innovations, government support, creation of reserve funds and insurance mechanisms.

► Results

Risk management is a key component of financial resource management, especially in times of crisis and military conflicts. Its main goal is to identify, assess and minimise potential risks that may adversely affect the operations of agribusinesses. Risk management helps businesses prepare for possible uncertainties and challenges, ensuring their financial stability and competitiveness even in the most difficult conditions. In the context of the war in Ukraine, risk management is of particular importance as it helps businesses prepare for uncertainties and challenges, ensuring their financial stability and competitiveness even in the most difficult circumstances. The first and most important stage of risk management is risk identification. This process involves identifying possible risk factors that may threaten the financial stability of the enterprise (Bilal & Baig, 2019). In the context of the war in Ukraine, these factors include currency fluctuations, rising inflation, disruption of supply chains, political instability, as well as the destruction of infrastructure and production facilities. For example, sharp changes in the exchange rate can lead to significant losses for businesses with foreign trade contracts. Disruptions in supply chains can complicate the supply of raw materials and sales of finished products, which also affects financial results.

Developing a risk management strategy involves choosing approaches to minimise or avoid risks. Such approaches include investment diversification, insurance, hedging and other financial instruments. In the context of the war in Ukraine, investment diversification may involve the distribution of financial resources between different assets or projects both in the country and abroad, which reduces dependence on one source of income and mitigates risks. Insurance helps to cover potential losses in the event of insured events, such as the destruction of production facilities. Hedging involves the use of financial instruments, such as forward contracts or options, to protect against unfavourable market movements (Robles, 2021). The choice of specific risk management strategies depends on the specifics of the company's activities, its financial condition and market conditions.

Monitoring and controlling risks are the final stage of risk management, which involves constant monitoring of risks and the effectiveness of the measures taken. In Ukraine, during the war, this allows for timely detection of changes in the risk environment and adjustment of management strategies. For example, if there is an increase in inflation, a company may increase its reserves or revise its lending terms. Monitoring and control also include regular risk reports and analysis of the effectiveness of measures, which allows the company's management to make prompt and informed decisions. Monitoring and control also include regular risk reports and analysis of the effectiveness of measures, which allows the company's management to make prompt and informed decisions.

Financial planning in the context of the war in Ukraine is critical to the viability of agricultural enterprises. It includes the development of financial strategies that help businesses adapt to rapidly changing conditions. The main elements of financial planning are aimed at ensuring flexibility, resilience, and efficiency in financial decision-making, which is especially important in the context of economic and political uncertainty caused by the war (Srebro *et al.*, 2021). One of the key elements of financial planning is the creation of reserve funds. In times of war, such reserves can be used to cover operating expenses, pay salaries, purchase necessary resources, or eliminate the consequences of destruction and losses caused by hostilities. Adaptation of budgets is necessary to meet new economic conditions. Regular budget reviews allow businesses to respond quickly to market changes, including cost-cutting and optimizing operations (Onyiriuba *et al.*, 2020). This includes analysing costs and revenues, identifying priority areas for funding, and reducing inefficient costs.

Strategic management in the agricultural sector involves long-term planning and implementation of measures aimed at ensuring the sustainability and competitiveness of enterprises. In the context of military conflict, strategic management is of particular importance, as it allows enterprises to adapt to new challenges and ensure sustainable development. Implementation of innovations is one of the key aspects of strategic management (Saiz-Rubio & Rovira-Más, 2020). In Ukraine, this may include agrotechnologies, digital platforms for financial management, and other innovative solutions that help to adapt to new conditions. For example, the introduction of

automated management systems can optimise production processes, reduce labour costs and improve product quality. Human resource management is also an important element of strategic management. In Ukraine, providing training and support to staff, professional development and introducing incentive programmes helps to retain key personnel and ensure high levels of productivity. Investing in human resource development contributes to improving the quality of products and services, which allows businesses to remain competitive in the market (Baharin *et al.*, 2020).

The war that started in Ukraine in 2014 has become one of the biggest threats to Ukraine's economic development, as it covers all spheres of public life and has a profound impact on macroeconomic indicators, business activity, investment climate, labour markets, and the financial system. The military conflict has taken a toll on GDP. A sharp decline in production, destruction of infrastructure, losses in agriculture and industry, and investment outflows have significantly reduced economic growth. Figure 1 shows the level of GDP and the share of agriculture in GDP.

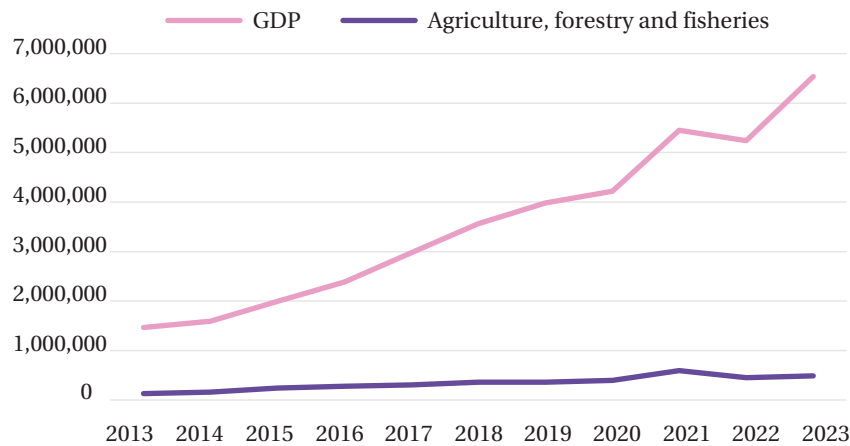


Figure 1. GDP and the share of agriculture in it from 2019 to 2023, million UAH

Source: developed by the authors on the basis of data from the Economic accounts of agriculture (n.d.)

The war affected Ukraine's economy, causing a slight decline in GDP and production in agriculture, forestry, and fisheries in 2022. However, a partial recovery was observed in 2023, indicating that the economy is adapting, and the international community is supporting it. Further development will depend on the stabilization of the situation in the country and the successful implementation of recovery measures.

Ukraine's agricultural sector showed steady growth until 2021. However, the war that started in 2022 had a significant impact on production volumes, especially in the grain and industrial crops sectors. Despite these difficulties, some sectors, such as vegetable and livestock production, have shown resilience and even growth in the face of the crisis. This underscores the importance of supporting and investing in the agricultural sector for its recovery and sustainable development in the future. One of the most catastrophic consequences of the war is the massive destruction of infrastructure. The fighting has destroyed roads, bridges, railways, energy facilities, buildings, and other important infrastructure. Restoration of this

infrastructure will require significant financial resources and time, which puts additional pressure on the state budget and economic development of the country. The war has caused a significant outflow of people from the war zones. Large-scale migration flows have created complex challenges for socio-economic systems. This has led to a shortage of labour, especially skilled workers, which complicates economic recovery and production development. In addition, significant losses among the population, including military personnel, affect the demographic situation in the country (Parkulab & Shikerynets, 2024).

The war has had a negative impact on the investment climate in Ukraine. Instability, risks, and uncertainty associated with the conflict scare away both foreign and domestic investors. Capital outflows, suspension of investment projects and a decline in foreign direct investment significantly limit opportunities for business development and economic modernization. Investors demand guarantees of security and stability, which are difficult to provide in a time of war. Figure 2 shows capital investments in agriculture.

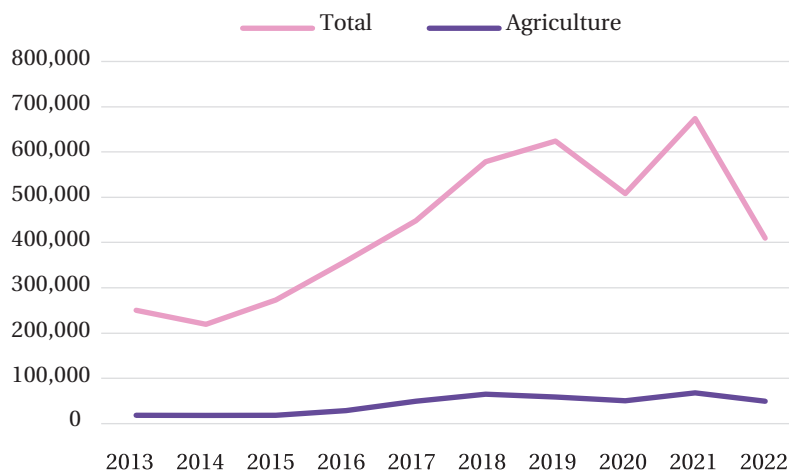


Figure 2. Capital investments in agriculture in Ukraine from 2018 to 2022, million UAH

Source: developed by the authors on the basis of data from the Capital investments (n.d.)

The analysis of the data shows that capital investment in the Ukrainian economy and agriculture in particular has experienced significant fluctuations during the period under review. In 2014, there was a slight decline in investment due to the outbreak of the military conflict. After a period of growth in 2018-2019, the COVID-19 pandemic in 2020 caused a significant decline in investment.

The recovery in 2021 was followed by a sharp drop in 2022 due to the full-scale war, which significantly affected investment activity. This highlights the economy's vulnerability to external shocks and the importance of a stable environment for attracting investment. The war has disrupted logistics chains, while rising energy prices, reduced production, and increased defence spending

have created inflationary pressures. This is leading to higher prices for goods and services, a decline in the purchasing power of the population, and increased social tensions. In addition, the country's financial system is experiencing severe shocks, including rising public debt, budget deficits and currency instability. The war has also affected Ukraine's foreign trade. The blockade of ports, the destruction of transport infrastructure, and the loss of traditional markets and logistics routes have led to a significant decline in exports and imports. This has a negative impact on foreign exchange earnings, trade balance and economic stability of the country. Key industries such as agriculture, metallurgy, and machine building have been particularly affected. Table 1 shows the volume of agricultural exports.

Table 1. Exports of agricultural products from 2019 to 2023, million USD

Products	2019	2020	2021	2022	2023
Live animals, products of animal origin	1.277	1.188	1.345	1.472	1.363
Products of plant origin	12.915	11.883	15.538	13.473	11.717
Fats and oils of animal or vegetable origin	4.732	5.747	7.037	5.949	5.649
Prepared food products	3.220	3.361	3.788	2.497	3.272
All agricultural products	22.144	22.179	27.708	23.391	22.001
All exports	50.055	49.192	68.072	44.136	36.183

Source: developed by the authors on the basis of data from the Economic statistics/Foreign economic activity (n.d.)

The table shows that the war in Ukraine has had a significant negative impact on agricultural exports. Despite some recovery in certain categories in 2023, the overall trend points to a decline in exports due to disruptions in logistics, infrastructure destruction and other military activities. This situation underscores the importance of adapting the agricultural sector to the new environment and finding alternative ways to support exports. Positive changes in Ukraine's position on certain products were mainly driven by the recovery in production and exports, as well as improved access to the European market. In 2022, global market prices for most agricultural products remained high, so the decline in exports in monetary terms was less significant than in physical terms. The share of agricultural exports to European countries increased due to the blockade of ports and changes in logistics routes, which resulted in products being shipped to neighbouring countries first rather than directly to the end consumer. In the marketing year 2022/23, 74.4% of agricultural products were transported by sea, compared to 98% before the war.

In 2022, the demand for credit increased significantly. Farmers needed additional working capital to maintain their operating cycle. This was due to several main factors. Firstly, there was a decline in prices for agricultural products, which had a negative impact on producers' incomes. Second, logistics costs increased due to disruptions in transport chains and changes in logistics routes. Third, there were problems with sales due to restricted access to traditional markets. Additionally, the cost of inputs, including fertilisers and crop protection products (CPPs), increased significantly, which increased the financial burden on farmers. The destruction and damage to agricultural machinery, as well as the need for own transport to ensure the efficient operation of enterprises, have caused an additional need for investment financing. This also applies to the need to implement energy-efficient solutions to help reduce energy costs. In such a difficult situation, the most effective programme for Ukrainian farmers has been the State programme "Affordable loans 5-7-9%". The present programme is in great demand, as it reduces lending costs and provides the necessary financial resources for the stable operation of agricultural enterprises. Thanks to this programme, agrarians such as Myronivsky Hliboproduct, Kernel, Astarta and many others can access affordable financing, which is critical for their survival and development in the face of economic instability and war (Businesses have received..., 2023).

Although the country has faced significant challenges due to the military conflict, certain measures have proved to be quite effective. In particular, the use of state support, the creation of reserve funds, and the introduction of digital financial technologies have helped to ensure a certain level of financial stability in the agricultural sector. State support included concessional loans and subsidies that helped farmers secure the necessary working capital and investments. Electronic payment systems and digital platforms for managing financial flows allowed farmers to respond quickly to market changes and receive the necessary funds quickly. However, there is a need to further improve these strategies and develop new approaches to improve the situation.

Israel has many years of experience in agriculture in the face of constant military confrontation, which can be extremely useful for Ukraine, which also faces military challenges. Israel's experience shows that the agricultural sector can remain stable and productive even in difficult conditions thanks to several key strategies. Firstly, Israel has been actively implementing technological innovations. The use of advanced technologies, such as drip irrigation, hydroponics, and drones for field monitoring, has significantly increased the efficiency and productivity of the country's agricultural sector (Temper, 2009). For Ukraine, which also faces water supply problems, the introduction of such technologies could significantly increase the productivity and sustainability of the agricultural sector. In particular, drip irrigation could help Ukrainian farmers to use water resources more efficiently, while hydroponics could allow them to grow crops in limited areas.

Government support plays a significant role in the sustainability of Israeli agriculture. Agricultural enterprises such as Evogene, Afimilk, Aqua Moaf and others receive significant support from the government through subsidies, soft loans and insurance programmes (Kislev, 2013). There are programmes such as The Green Plan, which provides subsidies for investment in new technologies; the Fund for Encouraging Capital Investment in Agriculture, which provides soft loans for the purchase of agricultural equipment and technologies; and the Agricultural Insurance Fund, which provides protection against losses due to natural disasters, pests, or war (Countering economic dependence..., 2022). State support programmes include compensation for losses from military operations, which helps farmers to rebuild their farms after an emergency. Ukrainian farmers can adopt this approach, as support from the state during wartime is essential to preserve and restore the agricultural sector. Implementation of similar programmes in Ukraine could ensure stability and recovery of agricultural production even in the face of military conflict.

Georgia also has useful experience that can be applied in Ukraine. After the military conflict with Russia in 2008, which significantly affected the Georgian economy and agriculture, the government of Georgia actively invested in agriculture through development programmes. The Agriculture and Rural Development Project programme includes subsidies, soft loans and technical support for farmers. The creation of agricultural cooperatives helps farmers to share resources and increase production capacity (Asmus, 2010). For Ukraine, which is also facing military challenges, the creation of cooperatives could be an effective way to optimise resource use and increase productivity. In addition, Georgia has implemented land ownership reforms that have contributed to more efficient use of land and increased investment in agriculture. Similar reforms in Ukraine could ensure transparency and efficiency in the use of land resources, which is critical for the development of the agricultural sector in a time of war.

These approaches ensure stability, increase efficiency, and allow for quick recovery from crises, which is an important example for Ukraine. The implementation of Israeli strategies in agriculture can help Ukrainian farmers adapt to the conditions of military conflict, maintain

productivity and ensure the country's food security. In the context of the military conflict in Ukraine, it is particularly important to find effective ways to counteract risks and ensure the financial stability of the agricultural sector. To achieve this goal, it is necessary to implement a comprehensive approach that includes technological innovations, government support, creation of reserve funds, diversification of funding sources and development of insurance mechanisms.

One of the main innovative technologies that can be effectively used to manage the financial resources of agricultural enterprises in Ukraine during the war is the introduction of digital financial management platforms. These platforms allow for the automation of financial processes such as accounting, cost management, budgeting and cash flow forecasting. It is recommended to introduce such systems, such as Enterprise Resource Planning (ERP) systems, which integrate all aspects of the enterprise into a single system. This will allow farmers to respond quickly to changes in market conditions, ensure transparency of financial transactions and reduce the risk of financial losses. The introduction of blockchain technologies is also gaining importance in the management of financial resources of agricultural enterprises. The use of blockchain allows ensuring transparency and security of financial transactions, reducing the risk of fraud and increasing trust between counterparties. It is recommended to develop and implement smart contracts for concluding agreements for the supply of agricultural products. This will automate payment and delivery processes, reducing the risk of default and ensuring transparency of financial transactions.

State support is crucial to ensure the stability of the agricultural sector in times of war. Specific measures could include the expansion of subsidy programmes for the purchase of seeds, fertilisers and fuel, as well as concessional lending to farmers. For example, the government could introduce special soft loans with low interest rates for small and medium-sized farmers to help them cover production and modernization costs. The creation of reserve funds is an effective way to ensure financial stability in times of crisis. It is proposed to create both public and private reserve funds that will provide quick access to financial resources in case of emergencies. For example, the state could create a special fund to help farmers affected by military operations to quickly compensate them for their losses. Diversification of funding sources is an important element of a financial stability strategy. Agricultural enterprises should actively attract various types of financing, such as bank loans, investments from international organizations, bonds and private equity. It is recommended to develop cooperation with international financial institutions, such as the World Bank or the European Bank for Reconstruction and Development, to obtain long-term loans on favourable terms. Insurance mechanisms are an important tool for minimizing financial risks in agriculture. Crop and property insurance programmes should be expanded. For example, compulsory crop insurance against hostilities and natural disasters could be introduced to provide farmers with financial protection in the event of unforeseen circumstances.

The war has significantly complicated the logistics of agricultural products due to the blockade of ports and the destruction of transport infrastructure. To mitigate risks, it is recommended to develop alternative logistics routes, for example, through Ukraine's western borders, and to invest in the restoration of damaged infrastructure. Cooperation with international logistics companies could help to address these issues. Training and development of human capital is important for increasing the resilience of the agricultural sector. It is proposed to organise trainings and seminars on the use of modern agricultural technologies, as well as to develop professional development programmes for farmers, agronomists and other specialists. For example, international experts could be engaged to conduct training programmes on the latest agricultural technologies. Countering risks and ensuring the financial stability of Ukraine's agricultural sector during the war requires a comprehensive approach that includes technological innovation, government support, creation of reserve funds, diversification of funding sources, development of insurance mechanisms, optimization of supply chains, innovations in financial planning and human capital training. Such an approach will not only preserve but also develop the agricultural sector, ensuring food security and economic stability of the country.

► Discussion

The results of the study underline the critical importance of risk management for the financial stability of agricultural enterprises in Ukraine, especially in times of crisis and military conflict. Effective risk management involves identifying, assessing and mitigating potential threats to financial sustainability and competitiveness. For agribusinesses in Ukraine, risks can arise from a variety of factors, including currency fluctuations, inflationary surges, supply chain disruptions and political instability. The context of the military conflict in Ukraine exacerbates these risks, highlighting the need for robust risk identification and assessment systems to ensure the sustainability of the agricultural sector.

A. Adelaja & J. George (2019) also focused on the impact of currency fluctuations on agricultural enterprises during military conflicts. Their study emphasises the need to develop financial management strategies that would reduce the risks of such fluctuations. Ö. Akinci & A. Queraltó (2024), in turn, found that sharp currency fluctuations do indeed lead to significant financial losses, especially for enterprises that depend on imported inputs. The paper highlights the importance of implementing hedging and investment diversification mechanisms to reduce exposure to such risks. These results are consistent with the findings of the current study that currency fluctuations are a significant source of risk. The difference is that the authors propose the active use of foreign exchange forward contracts to hedge risks, while the current study focuses on a comprehensive approach, including diversification and insurance.

The development of effective risk management strategies is critical to mitigate the identified threats, especially in the current environment in Ukraine. The main approaches include allocating financial resources through

investment diversification, protecting against risks through insurance, and reducing risks through hedging. Diversification of investments allows distributing capital among different assets or projects, which helps to reduce dependence on a single source of income. Insurance provides protection against specific risks, providing compensation in the event of unfavourable events. Hedging using financial instruments, such as forward contracts or options, protects against negative market movements. The choice of a particular strategy depends on the specifics of the company's business, its financial position and conditions in the domestic and foreign markets of Ukraine. E.D Lioutas & C. Charatsari (2021) examined the role of state support in ensuring the financial stability of agricultural enterprises during the crisis. They conclude that the most effective instruments are direct subsidies and concessional loans. The current study also supports the need for state support, but also puts an emphasis on the importance of creating reserve funds and using modern financial technologies. The authors focus more on traditional methods of state support.

Continuous monitoring and control of risks is critical to adapt to changing conditions during the military conflict in Ukraine. This means regularly tracking risk factors and assessing the effectiveness of mitigation measures. For example, during periods of rising inflation, businesses may need to adjust provisions or revise lending terms to reflect the war. Regular reporting and analysis allow for informed decision-making in a timely manner, which contributes to the effective management of financial risks in times of war. S.A. Khan *et al.* (2022) studied the impact of supply chain disruption on the agricultural sector. They found that the main problems arise from delivery delays and increased transport costs. X. Gao (2019), in turn, suggested creating alternative logistics routes and investing in infrastructure rehabilitation. One of the author's key recommendations was to focus on the introduction of modern technologies to improve the efficiency of logistics processes in the country. The current findings also emphasise the importance of logistics recovery and diversification of supply routes. However, the authors point out the importance of international cooperation for logistics recovery.

In Ukraine, careful financial planning is crucial to ensure the sustainability of agricultural enterprises. Key strategies include the creation of reserve funds, diversification of funding sources, adaptation of budgets and effective cash flow planning. Reserve funds are a financial reserve to cover unforeseen expenses or losses, ensuring the continuity of operations. Diversification of funding sources, such as bank loans, bonds and foreign investment, reduces dependence on a single source and ensures a stable flow of capital. Adapting the budget allows agricultural enterprises to respond quickly to changes in the market, optimizing costs and setting funding priorities. Effective cash flow planning ensures liquidity and timely fulfilment of financial obligations, which is important for maintaining financial stability in an uncertain environment. S.O. Adongo *et al.* (2020) focused on the impact of inflation on the financial planning of agricultural enterprises. They found that the creation of reserve funds and diversification of funding sources are key to protecting

against inflationary risks. Similar to the current study, the importance of reserve funds and diversification is emphasised, but the authors also considered the use of international financial institutions, which makes their approach more global.

H. Friedmann (2021), in turn, highlights the importance of using international financial institutions to obtain additional resources. In the context of Ukraine, where the agricultural sector is facing significant challenges due to the military conflict, this approach can be critical to ensure access to finance and investment needed to support agricultural enterprises. Strategic management focuses on long-term planning and building resilience. In Ukraine's agriculture sector, innovation, infrastructure rehabilitation and human resource development are key. Technological advances in production and logistics can increase efficiency and reduce costs. Investments in human capital through training and incentive programmes are crucial to retain key personnel and ensure high levels of productivity. T.P. Tomich *et al.* (2019) and P. Frankelius *et al.* (2019) investigated the impact of technological innovation in the agricultural sector during military conflicts. Both studies found that process automation and the use of drones were key to maintaining productivity. Their research included case studies of how these technologies have been implemented at various enterprises. The current study also supports the use of innovative technologies, but provides a more general overview of the possibilities, while the authors provide specific examples.

The ongoing conflict in Ukraine has severely affected its economy, including the agricultural sector. The war has resulted in a significant drop in GDP and agricultural production, particularly of grain and industrial crops. However, certain sectors, such as vegetable and livestock production, have shown resilience. Destruction of infrastructure, labour shortages and a negative investment climate are some main consequences of the conflict. Studying the strategies of conflict-affected countries such as Israel and Georgia provides valuable insights. Israel's use of technological innovation, government support and reserve funds has maintained its agricultural stability. Georgia has promoted the creation of agricultural cooperatives that help farmers share resources, reducing costs and increasing production capacity. T. Ben Hassen & H. El Bilali (2022) also analysed the impact of the war on the agricultural sector. They found that the blockade of ports and the destruction of transport infrastructure are key problems. The authors suggest finding alternative markets and developing the domestic market as adaptation strategies. The current study also emphasises the importance of reopening logistics routes, but the author focuses more on finding new markets.

For Ukraine, adopting a comprehensive approach to risk management and financial planning is crucial. This includes attracting technological innovations, securing government support, creating reserve funds, diversifying funding sources and developing insurance mechanisms. Optimizing supply chains, using modern financial planning tools and investing in human capital are also important. Such an integrated strategy would not only reduce risks but also contribute to the recovery and sustainable development of Ukraine's agricultural sector.

In general, the results of studies by various authors confirm the importance of risk management in the agricultural sector during military conflicts, while focusing on different aspects and approaches to addressing these problems. Effective implementation of these strategies can significantly increase the resilience and stability of agribusinesses in conflict situations, ensuring their continued contribution to the economy and food security.

► Conclusions

The study covers a comprehensive analysis of financial risk management in the agricultural sector in the context of military conflict. The study covered the stages of risk management, financial planning and strategic management, as well as an analysis of the impact of the war on Ukraine's economic performance.

The study found that the war in Ukraine has had a significant impact on the country's economy, causing a drop in GDP, a decline in agricultural production and a loss of investment. However, some sectors, such as vegetable and livestock production, have shown resilience to the crisis. This underlines the importance of supporting and investing in the agricultural sector for its recovery and sustainable development. Agricultural output declined from UAH 1,366 billion in 2021 to UAH 1,074 billion in 2022. Capital investment in agriculture also decreased from UAH 67 billion in 2021 to UAH 50 billion in 2022. Exports decreased from UAH 68 billion in 2021 to UAH 36 billion in 2023.

Based on the experience of other countries, such as Israel and Georgia, effective strategies for managing the

agricultural sector in times of conflict were considered. Israel actively introduces technological innovations, provides significant state support and creates reserve funds. State support for the Georgian agricultural sector is mainly focused on financial support, subsidies for farmers and insurance programmes aimed at reducing financial risks in difficult conditions. To ensure the financial stability of Ukraine's agricultural sector during the war, a comprehensive approach should be implemented, including technological innovations, government support, creation of reserve funds, diversification of funding sources and development of insurance mechanisms. This will not only preserve but also develop the agricultural sector, ensuring food security and economic stability of the country.

The main limitation of the study is the lack of access to all necessary data due to limited openness of information and limited resources during the military conflict. Further research could focus on developing specific recommendations for the introduction of new technologies in Ukraine's agricultural sector during the crisis. It is also worth investigating the effectiveness of various financial instruments and state support programmes to ensure the stability of agricultural enterprises.

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► Conflict of interest

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► References

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Ризики управління фінансовими ресурсами аграрного сектору України в зоні військового конфлікту: виклики, загрози, шляхи протидії

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► **Анотація.** Метою цього дослідження було виявлення ризиків, які впливають на управління фінансами в агропромисловому секторі України під час військових дій, з метою розробки ефективних заходів протидії. Методологія дослідження включала аналіз основних ризиків, таких як коливання валютних курсів, інфляція, порушення ланцюгів постачання та політична нестабільність, а також оцінку стратегій мінімізації цих ризиків. Основними етапами управління ризиками визначено ідентифікацію, оцінку та моніторинг ризиків, а також розробку відповідних стратегій, таких як диверсифікація інвестицій, страхування та хеджування. Результати дослідження показали, що ключовими факторами забезпечення стабільності є впровадження технологічних інновацій, державна підтримка, створення резервних фондів та диверсифікація джерел фінансування. Зокрема, розвиток сучасних агротехнологій, субсидії, пільгові кредити та інвестиції в інфраструктуру значно підвищують стійкість аграрного сектору до кризових умов. Важливим також є планування грошових потоків для підтримки ліквідності та своєчасного виконання фінансових зобов'язань. Було розглянуто та проаналізовано досвід декількох країн, таких як Ізраїль та Грузія, які зіткнулися зі схожими викликами, щоб побачити, як вони управляли фінансовими ресурсами своїх аграрних секторів. Досвід цих країн показав, що успішне управління фінансовими ресурсами аграрного сектору в умовах військового конфлікту вимагає комплексного підходу, який включає технологічні інновації, державну підтримку, фінансове планування та розвиток людського капіталу для забезпечення сталого розвитку аграрного сектору в умовах війни. Такий підхід дозволяє не лише зберегти, а й розвивати аграрний сектор, забезпечуючи продовольчу безпеку та економічну стабільність України

► **Ключові слова:** управління ризиками; сільське господарство; нестабільність; інвестиції; експорт

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