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Analysis of the effectiveness of bank credit instruments for agricultural enterprises in Ukraine

Abstract. The purpose of this study was to determine the level of impact of bank credit instruments on the financial stability, profitability, and production efficiency of agricultural enterprises in Ukraine. The study analysed the dynamics of bank lending to the agricultural sector in 2022-2024.

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The total volume of loans provided to agricultural enterprises decreased from UAH 118.9 billion in 2022 to UAH 104.5 billion in 2024. The share of preferential financing under the programme "Affordable Loans 5-7-9%" in 2024 was 46% (UAH 46.9 billion). The study analysed three leading companies – Myronivsky Hliboproduct, Kernel, and Astarta-Kyiv, which actively used bank loans and international financing to stabilise the activities, modernise production and expand export potential. Myronivsky Hliboproduct restored profitability: from a loss of USD 231 million in 2022 to a profit of USD 144 million in 2024. Astarta-Kyiv increased corn yield to 10.35 t/ha, sugar production by 34%, and revenue from agricultural production by 33%. Kernel attracted USD 150 million in syndicated financing, which ensured a 2.3-fold increase in exports in 2024. The study proved that bank loans acted not only as an anti-crisis mechanism, but also as a tool for increasing efficiency, modernisation, and adaptation of enterprises to high-risk conditions. The practical significance of the study laid in substantiating the effectiveness of bank credit instruments as an effective mechanism for supporting the agricultural sector in times of crisis challenges, and in the possibility of using the results obtained to improve state financing programmes

Keywords: financial support; digitalisation; investments; government support; export

INTRODUCTION

The establishment of effective credit support for the agricultural sector is a key factor in ensuring financial stability, modernisation of production and increasing the competitiveness of Ukrainian agricultural enterprises. In the context of increasing external challenges, in particular armed conflict, inflationary pressure and disruption of logistics chains, bank credit instruments are gaining particular importance as a source of mobilising financial resources for seasonal production, updating the technical and technological base, and supporting working capital. Ukrainian agricultural enterprises face a lack of financing of these enterprises, which leads to a high dependence on bank loans. N. Trusova & N. Radchenko (2020) studied the effectiveness of lending taking into account the size of enterprises, the dynamics of loan volumes and revealed the negative impact of the high cost of credit resources on profitability. The authors identified medium-term loans as dominant and also emphasised the importance of cooperation with international financial organisations and the action of the state programme "5-7-9%". Ukraine's agriculture, with a significant share in the structure of gross domestic product and export potential, needs stable external financing. This issue was studied by O. Chyhryn & O. Ivakhnenko (2020), who analysed trends in bank lending to agricultural production, identified the dominance of short-term loans and a low share of long-term loans (only 5%), and also assessed the effectiveness of state support. The authors found that when the level of profitability exceeds the interest rate, enterprises reinvest profits, which stimulates development. Despite the availability of preferential lending programmes, only 7.6% of the bank loan portfolio falls on agriculture, and the level of participation in the programmes remains low.

Agricultural enterprises face difficulties in attracting bank loans due to the unstable economic situation, high risks, and limited access to long-term financing. This topic was studied by S. Andros (2024), who focused on the need to reform approaches to agricultural lending, taking into account its specifics. In the mentioned work, the author analysed the volume of bank financing, pointed out the unevenness of access to loans by region and size of enterprises, and also noted the imperfection of risk management mechanisms. Considerable attention was paid to the development of microfinancing and credit cooperation as tools for expanding access to loan resources, in particular for small forms of business. Access to bank financing for agricultural producers is complicated by high rates, lack of collateral, and uneven lending conditions. I. Tomashuk & L. Volska (2024) analysed the dynamics of attracting loans, pointing to the low share of financing for the agricultural sector and the limited effectiveness of government programmes for small and medium-sized farms. The authors highlighted

information barriers and weak financial readiness of borrowers.

Bank lending to agricultural enterprises is limited by high collateral requirements, a lack of specialised programmes, and low flexibility of banking products. A. Osipova (2020) analysed access to credit, noting the advantage of large enterprises due to the availability of collateral, while small producers face barriers. The author noted that large enterprises have better access to loan capital due to the availability of collateral and financial reporting, while small and medium-sized producers experience difficulties due to the lack of collateral and insufficient credit rating. The insufficient level of availability of financial resources for the agricultural sector hinders the development of enterprises and limits the investment activity. A. Bilochenko (2023) analysed current trends in bank lending, in particular the operation of the "5-7-9%" programmes, emphasising the role of these programmes in reducing the credit burden. The author noted the positive dynamics of agricultural producers' participation in these programmes and the growth in the volume of preferential lending, but pointed out the uneven access between large and small enterprises.

Financial support for agricultural enterprises requires improvement of support mechanisms focused on adaptation to crisis conditions. O. Popelo & A. Zhavoronok (2024) analysed the current state of bank lending in wartime conditions, focusing on limited access to resources and increased risks for creditors. The authors determined that the most effective support instruments were state programmes for compensation of interest rates, which made it possible to maintain credit activity. The complexity of credit support for agricultural enterprises in times of crisis requires the adaptation of financial instruments to modern challenges. N. Tanklevska *et al.* (2023) examined structural changes in the agricultural financing system, focusing on new forms of public-private partnerships, the role of financial institutions, and increased participation of international donors. The authors noted the positive impact of the integration of insurance mechanisms, the digitalisation of risk assessment processes, and the introduction of targeted financing through banking instruments.

The long-term consequences of the credit burden, the effectiveness of the use of loans in different regions, the role of financial literacy and counselling, the impact of innovative banking products and digital solutions, and the need to adapt credit instruments to the needs of small businesses in conditions of economic instability remain insufficiently studied. Behavioural factors, regional differences in access to financing, and the consequences of reduced state support during the war period are also not covered. The purpose of this study was to assess the effectiveness of the use of bank credit instruments in the activities of agricultural enterprises in Ukraine. To achieve this goal, the following tasks were set: to analyse the volumes, conditions, and dynamics of bank lending to the agricultural sector; to identify the relationship between the use of credit resources and the financial results of enterprises.

MATERIALS AND METHODS

This study was practical in nature and covered the period from 2022 to April 2025. It was based on an analysis of the dynamics of bank lending to agricultural enterprises in Ukraine. The total volume of loans provided to the agricultural sector in 2021-2024 was studied using the descriptive method (Ministry of Agrarian Policy and Food of Ukraine, 2022; Landlord, 2023). Particular attention was paid to the programme "Affordable Loans 5-7-9%" PrivatBank (n.d.), which provided the main share of lending to agricultural producers in the period under study. The analysis of the discount rate of the National Bank of Ukraine (n.d.) was carried out in order to assess the impact of monetary policy on the availability of credit resources for the agricultural sector. The availability and conditions of international support programmes for agricultural enterprises were separately analysed using the descriptive method. The impact of the Prostir (n.d.), World Bank Group (n.d.) and Interfax (2023) programmes was studied. The impact of the programmes was assessed using the following criteria: total funding, areas of use of funds, form of support (grants, investments, material resources) and quantitative indicators of coverage. The analysis covered types of funding, targeted allocation of funds, implementation mechanisms and participants.

The case study method was used to analyse three leading agro-industrial companies of Ukraine – Myronivsky Hliboproduct (n.d.), Kernel (n.d.), and Astarta-Kyiv (n.d.). The selection of objects was justified by the scale of economic activity, a high level of availability of financial reporting, as well as the systematic use of bank lending and external financing mechanisms. The analysis of the activities of Myronivsky Hliboproduct (n.d.) considered sources of financing from international financial institutions, in particular IFC (n.d.) and DFC (n.d.), as well as raising funds through the charitable foundation MHP – Gromadi (n.d.). The company's profitability indicators were taken into account separately (Latifundist, 2024a). The analysis of the activities of Kernel (n.d.) involved studying its loan portfolio, including cooperation with international banks, such as ING Bank N.V. (n.d.), Rabobank (n.d.) and BSTDB (n.d.). Additionally, the dynamics of changes in the company's key financial indicators were taken into account (Bizagro, 2025). The analysis of Astarta-Kyiv (n.d.) examined sources of loan financing, in particular cooperation with the Ministry of Finance of Ukraine (n.d.) and the state-owned bank Oschadbank (FRU, 2023). In addition, operational activity indicators were taken into account, in particular production volumes and the seasonal results of agricultural campaigns APK Inform (2024), which are indicators of the efficiency of using the resources involved. The study also took into account the capabilities of digital platforms and fintech solutions in the field of lending to the agricultural sector. The analysis included the three most widely used digital solutions – AgroOnline (n.d.), Soft Farm (n.d.) and Drone UA (n.d.), which were selected according to the criteria of accessibility, level of implementation in agricultural production, integration with banking products and potential for automation of management processes. This stage of the study made it possible to assess the additional capabilities of digital solutions in increasing the efficiency of bank lending to the agricultural sector, which is directly related to achieving the stated goal – assessing the efficiency of using bank credit instruments in the activities of agricultural enterprises in Ukraine. A descriptive method was used to analyse digital platforms, and the results were processed by summarising information from open sources regarding the functionality, scope, and integration with banking services.

RESULTS AND DISCUSSION

Analysis of the volume and structure of bank lending to agricultural enterprises in Ukraine

In 2022-2024, bank lending to the agricultural sector of Ukraine demonstrated a clear trend towards activation, which was made possible by a combination of state support, demand from agricultural enterprises for working capital and investment resources, as well as the adaptation of the banking system to wartime conditions. The largest growth occurred in 2022, and in 2023-2024, high credit dynamics with a stable loan portfolio structure were maintained (National Bank of Ukraine, 2025). In 2022, the total volume of bank loans granted to agricultural enterprises in Ukraine amounted to about UAH 118.9 billion, which is twice the level of 2021, when this indicator was approximately UAH 82.4 billion. The share of agricultural loans in the total bank portfolio reached 15%, which indicated a high level of financial activity in the sector. About 75% of all loans were issued in national currency, mainly for short-term needs – primarily to finance spring field work (Landlord, 2023). A significant factor in the activation of lending was the state programme "Affordable Loans 5-7-9%" PrivatBank (n.d.), within which farmers attracted more than UAH 38.5 billion by June 1, 2022. The total volume of loans under this programme during 2022 exceeded UAH 57 billion (Ministry of Agrarian Policy and Food of Ukraine, 2022).

In 2023, the high level of lending remained – the total volume of loans reached UAH 78.8 billion. About UAH 44.5 billion of loans were issued under the "5-7-9%" programme (PrivatBank, n.d.). During the year, almost 14 thousand agricultural enterprises took advantage of bank loans, of which 10.9 thousand were under the state programme of the Ministry of Agrarian Policy and Food of Ukraine (2024). In the first half of 2023, the high level of the National Bank of Ukraine (NBU) discount rate (25%) made it difficult to access commercial loans, the rates of which sometimes exceeded 20%. However, thanks to fixed rates within the state programme

(from 5% to 9%), farmers retained the opportunity to receive affordable financing (NBU, n.d.).

In 2024, the growth trend continued. During the year, 13,088 agricultural enterprises received bank loans totalling about UAH 104.5 billion, of which UAH 46.9 billion (i.e. about 46%) were under the "5-7-9%" programme. By the middle of the year alone, more than 9,600 loans had been issued in the agricultural sector, of which 8,500 were preferential (Verkhovna Rada of Ukraine, 2025). The NBU discount rate gradually decreased: from 16% at the beginning of the year to about 13% in the second half, which created the prerequisites for cheaper commercial loans, although the rate within the state programme remained stable within a 5-9% of financing range (NBU, n.d.). As of April 2025, in a regional breakdown, the main recipients of funds remained Kyiv (up to UAH 21.7 billion), Dnipropetrovsk (UAH 7.5 billion), Vinnytsia (UAH 7.4 billion), Kirovohrad (UAH 6.9 billion), Odesa (UAH 6.4 billion) and Cherkasy (UAH 6.2 billion) regions. In addition to the preferential rate programme, portfolio guarantees were actively used – in Ivano-Frankivsk region alone the volume reached UAH 782.3 million (Ministry of Agrarian Policy and Food of Ukraine, 2025). Figure 1 illustrates the dynamics of the total volume of bank lending to agricultural enterprises in Ukraine in 2021-2024.

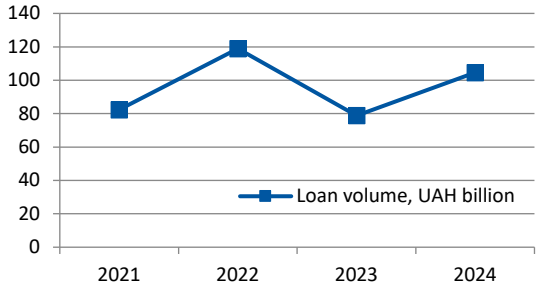

Figure 1. Dynamics of the total volume of bank lending to the agricultural sector of Ukraine in 2021-2024

Source: created by the authors based on Landlord (2023), Ministry of Agrarian Policy and Food of Ukraine (2024), Verkhovna Rada of Ukraine (2025)

Analysis of the graph presented in Figure 1 shows that 2022 became a turning point for the credit provision of the agricultural sector of Ukraine, when, under the influence of state incentives and urgent needs of agricultural producers, bank lending reached a record value. Despite the decline in 2023, a resumption of growth in credit activity is observed in 2024. Such dynamics confirm the importance of financial support programmes and the adaptability of the banking sector to high-risk conditions, which allows agricultural enterprises to stably access financial resources even in crisis periods. Thus, in 2022-2024, bank lending to the agricultural sector of Ukraine became a tool not only for anti-crisis response, but also for stimulating development. Both the absolute volume of lending and the number of enterprises that took advantage of state support programmes increased. The programme "Affordable Loans 5-7-9%" PrivatBank (n.d.) remained the key mechanism through which up to half of all credit financing for the agricultural sector passed. The participation of different types of banks – state, private, and international – ensured flexibility in lending conditions and coverage of a wide range of farms in all regions of Ukraine.

During 2022-2025, state support for the agricultural sector through preferential credit programmes became a key tool for ensuring financial stability and development of agricultural enterprises in conditions of high risks. One of the main forms of such support is the programme "Affordable Loans 5-7-9%", which covers both micro, small and medium-sized agricultural enterprises that meet certain criteria (Ministry of Agrarian Policy and Food of Ukraine, 2025). The participation of agrarian

businesses in this programme has increased significantly in response to military challenges, inflationary pressure and rising resource prices, as well as in view of the need for credit financing for seasonal and investment purposes. The right to participate in the "5-7-9%" programme was open to legal entities or individual entrepreneurs registered in Ukraine and who were its residents. The condition for access is conducting economic activity under the Classification of Economic Activities by KVEDs, assigned to section A "Agriculture", in particular group 01.4 (livestock) and other codes covering crop cultivation, horticulture, viticulture, poultry farming. In addition, the programme allows enterprises engaged in the processing of agricultural products – the production of milk, flour, bakery products, etc. From January 1, 2025, participation in the State Agrarian Register (DAR) is mandatory to receive a preferential loan (Kharkiv Regional Military Administration, 2020).

Financing under the programme covers two key areas: lending for working capital (e.g., purchase of seeds, crop protection products, fuel for the sowing campaign) and investment goals – acquisition and modernisation of machinery, equipment, construction of storage facilities, implementation of development projects. The programme also allowed financing leasing transactions – for example, the purchase of agricultural machinery on lease. Lending rates depended on the type of business: 5% for operating enterprises with an annual turnover of up to UAH 50 million, 7% – for development, 9% – for new projects. The loan was provided in national currency through authorised banks that cooperate with the Entrepreneurship Development Fund (Kharkiv Regional Military Administration, 2020).

In 2024-2025, international financial organisations will play a key role in supporting Ukraine's agricultural sector, directing significant resources to finance, restore, and modernise agricultural production. One of the most active donors is the United States Agency for International Development (USAID). In total, USAID has already invested more than USD 850 million, attracting an additional USD 510 million from the private sector and other donors. One of the key components of this support was the Prostir programme (n.d.), which in 2024-2025, provided for investments of about USD 250 million. It is focused on small and medium-sized farms growing grain and oilseed crops, as well as on developing the export potential of Ukrainian agricultural products. The goal is to increase exports by USD 1.5 billion and attract USD 500 million in private investment. The programme also provides large-scale grant support – about UAH 1.5 billion is provided for the development of innovative solutions and processing, and the grant amounts range from UAH 4 to 198 million. In addition, more than 7 thousand agricultural producers will receive mineral fertilisers (up to 2 tons each) for the spring sowing campaign of 2024 – in total, more than 14 thousand tons of fertilisers will be distributed. USAID also paid significant attention to frontline and de-occupied territories, supporting the restoration and stable activities (Verkhovna Rada of Ukraine, 2023).

The World Bank provided another large-scale area of support through the World Bank Group (n.d.) project – Emergency project to ensure inclusive support for the restoration of agriculture in Ukraine. The total amount of funding reached USD 700 million, of which USD 320 million is provided in the form of grants and USD 230 million in the form of concessional loans, in particular through the Interfax (2023) programme with the support of the Japanese government. The ARISE project aimed to assist more than 90 thousand small and medium-sized farmers through preferential lending, grants, support for horticulture and greenhouse farming. It was expected to mobilise additional working capital of USD 1.5 billion. About USD 50 million in grants will be directed directly to innovative agricultural programmes. A special role in the project was played by the restoration of irrigation systems after the destruction of the Kakhovka Dam – the formation of an irrigation restoration fund according to European standards is one of the priorities. The entire financing system is managed transparently through digital platforms, in particular the State Agrarian Register (DAR) (Interfax, 2025).

Thus, the results of the study indicate the high effectiveness of the combination of state credit support and international financing in ensuring the sustainability of the agricultural sector

of Ukraine in wartime conditions. The resources involved allowed a significant number of agricultural enterprises to maintain production activity, implement investment projects, support exports and modernise infrastructure. In contrast, the study by H. Hamdaoui & M. Cancelo (2024) was of a macroeconomic nature and analysed the relationship between the development of the banking system, GDP growth and commodity prices in France, Spain, and Romania. It was found that the banking sector had a positive impact on economic growth, although excessive debt, inflation and non-performing loans had a restraining effect. Both studies confirmed the key role of banks in stimulating the economy, but differed in scale, methods, and context. The study by J. Wang *et al.* (2024) was devoted to the impact of green lending on the development of agricultural enterprises in China. The authors found that financial support focused on environmental objectives contributed to increased productivity, reduced emissions and the introduction of eco-innovation, especially on large farms. The effectiveness of such loans depended on regional differences and financial accessibility. While that study examined sustainable development, this one examined ensuring financial sustainability through affordable credit, reflecting different strategic approaches to the role of financial instruments in the agricultural sector.

A similar logic to J. Wang *et al.* (2024) was demonstrated by Q. Wang *et al.* (2025), but in a digital context. The study showed that digital financial inclusion – through mobile platforms, online services, etc. – contributed to increasing the productivity of small and medium-sized agricultural producers, especially in regions with low banking infrastructure density. In this case, financing was considered not only as a resource, but also as a tool for overcoming regional inequality. In contrast, this study almost did not cover digital aspects, and the traditional banking system, combined with state support, played a key role. At the same time, both studies pointed out the need for active state participation in ensuring access to credit resources. The importance of systemic solutions in the field of financing was even more underscored by M. Nasir *et al.* (2025), who showed that in developing countries, the main barriers to innovation remained not only limited credit, but also low financial literacy, information asymmetry and lack of trust in financial institutions. In this context, this study was consistent with the approach of M. Nasir *et al.* as it also underlined the need for government intervention, although it focused not on long-term modernisation, but on anti-crisis adaptation.

The study by C. Ngong *et al.* (2023) highlighted a different type of challenge – a deep structural lack of formal credit in rural areas of Cameroon. The authors argued that farmers were unable to realise the production potential due to limited access to credit resources and weak financial infrastructure. In contrast to this study, where government anti-crisis mechanisms played a key role, the work of C. Ngong *et al.* focused on the need to reform the financial ecosystem and improve the knowledge level of farmers. This indicated that access to financing remained a universal condition for effective development, but the ways to ensure it depended on the specifics of institutional barriers and the depth of structural problems.

In 2022-2024, bank lending to the agricultural sector of Ukraine increased significantly, which was due to a combination of state support, in particular through the programme "Affordable Loans 5-7-9%", and the adaptation of the banking system to wartime conditions. Both state and private banks acted as key creditors, which ensured diversification of financing sources. The vast majority of loans were provided in national currency to cover short-term needs, but the share of investment loans gradually increased. Such dynamics indicate the preservation of financial activity of the agricultural sector even in times of crisis.

Assessment of the effectiveness of the use of bank loans by agricultural enterprises

In 2022-2024, Ukrainian agro-industrial companies demonstrated the active use of bank loans as one of the main tools for ensuring stable operational activities, investment development and increasing export potential. An analysis of three leading agricultural enterprises – Myronivsky Hliboproduct (n.d.), Kernel (n.d.), and Astarta-Kyiv (n.d.) – allowed defining the peculiarities of the relationship between

lending volumes and the financial performance of enterprises in crisis economic conditions. In 2022-2024, the financial dynamics of the MHP company demonstrated a close relationship between the effectiveness of credit provision, modernisation of production facilities and the gradual restoration of profitability after the crisis period. In 2022, the company recorded a net loss of USD 231 million, which was caused by significant exchange rate losses, the impact of military operations, and a decrease in export activity (APK Inform, 2023). At the same time, in 2023, the situation significantly improved due to the implementation of anti-crisis financial measures, in particular, the refinancing of part of debt obligations, active attraction of funds from international financial organisations, and the implementation of investment projects to modernise bioenergy complexes. This allowed to increase production efficiency and reduce costs. As a result, MHP received a net profit of USD 142 million (Latifundist, 2024a). In 2024, the company maintained positive dynamics, ending the year with a profit of USD 144 million, which indicated stabilisation after the shock of the previous period (Fig. 2) (Pikalo, 2025).

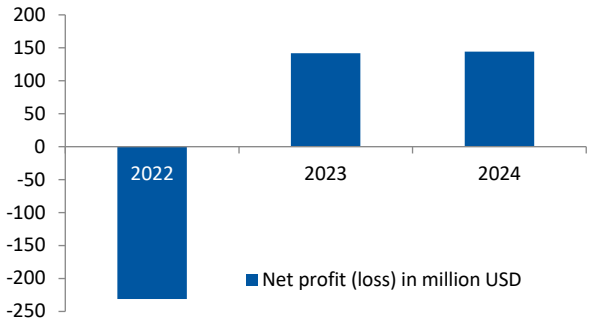

Figure 2. Dynamics of MHP's net profit (loss) in 2022-2024, million USD
Source: created by the authors based on APK Inform (2023), Latifundist (2024a), Pikalo (2025)

The graph in Figure 2 illustrates a clear turning point in MHP's financial results during 2022-2024. After significant losses in 2022, the company managed to quickly restore profitability in 2023 and maintain stable indicators in 2024. Such dynamics indicate effective management of financial risks, effective use of credit resources and gradual strengthening of the company's operational stability against the backdrop of a difficult economic situation. Over the past three years, the debt load has remained high at around USD 1.6 billion. The bulk of it was long-term, while short-term debt, including USD 500 million in Eurobonds due in 2024, was successfully refinanced through new credit lines. Thanks to stable access to international financial institutions, MHP has ensured flexible liquidity management (Agro Portal, 2024). For example, IFC (n.d.) provided USD 30 million for the modernisation of the bioenergy complex and USD 100 million to support financial stability. DFC (n.d.) allocated USD 250 million for infrastructure improvements, including the construction of backup power supply systems. The Ministry of Finance of Ukraine (n.d.) provided the company with USD 100 million in financing with a commitment to introduce eco-technologies and improve management standards. In addition to international sources, MHP took advantage of the state programme to compensate 25% of the cost of Ukrainian-made agricultural machinery in 2024, which allowed it to update its technical base (DIA, 2024).

Despite the significant debt burden, the company demonstrated a gradual improvement in financial results. In 2023, the operating margin (sales profitability) reached 11%, while in 2022 it was 10%. The return on assets in 2023 was about 4.2%, which corresponded to the average level for agroholdings with high capital intensity. This demonstrated the company's ability to effectively use the resources involved to generate profit, despite the difficult macroeconomic situation (Latifundist, 2024a).

In parallel with bank lending, MHP actively attracted grants and implemented social projects through the MHP – Gromadi charitable foundation (n.d.). During 2022-2024, the fund implemented competitions to support small businesses (for example, "Do Your Own Business"), attracted more than 616 business applications from 15 regions, and the total amount of financing reached UAH 1.5 billion. Such initiatives complemented the company's economic activities, strengthening its image as a responsible social investor (Forbes, 2025).

Along with MHP, the Kernel agroholding also actively attracted bank financing in 2022-2024 to stabilise operating activities, support export operations, and modernise infrastructure. In 2024, for the first time since the start of a full-scale war, the company attracted a USD 150 million credit line from a syndicate of European banks, including ING Bank N.V. (n.d.), Rabobank (n.d.), and BSTDB (n.d.). At the same time, internal financing was increased – for example, the credit limit of the Druzhba-Nova enterprise from Oschadbank (n.d.) increased to UAH 1.2 billion, and Kernel's total loan portfolio in this bank exceeded UAH 2.2 billion (Latifundist, 2024b).

The company's financial dynamics during these years were unstable: in 2022, the company suffered losses of USD 41 million, which was a sharp contrast to the profit of USD 513 million in 2021. The main reasons were logistical difficulties and the impact of the war (Latifundist, 2022). However, in the 2023 fiscal year, Kernel restored profitability – net profit amounted to USD 299 million, Earnings Before Interest, Taxes, Depreciation, and Amortisation (EBITDA) – USD 544 million (Share UA Potential, 2023). In the 2024 fiscal year, there was a decline: net income decreased to USD 168-204 million, and EBITDA to USD 381-384 million. At the same time, the company's net debt decreased from USD 453 million to USD 308 million, which strengthened financial stability despite the decline in profitability. However, the increased credit load and the difficult macroeconomic situation caused a decrease in the profitability of assets and equity (Bizagro, 2025). The dynamics of net profit (loss) for 2022-2024 are shown in Figure 3.

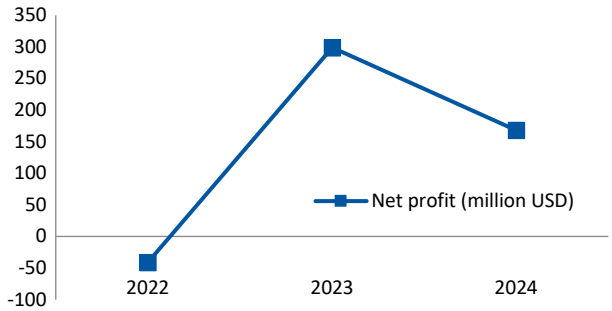

Figure 3. Dynamics of Kernel's net profit (loss) in 2022-2024 (million USD)
Source: created by the authors based on Kernel Holding S.A. (2022), Kernel Holding S.A. (2023), Kernel Holding S.A. (2024)

Figure 3 reflects the clear dynamics of the company's financial recovery: after a loss of USD -41 million in 2022, the company demonstrated a sharp improvement in results and achieved USD 299 million in profit in 2023. In 2024, profit decreased to USD 168 million, but remained at a significantly positive level. This trajectory indicates the efficient use of financial resources, the company's ability to adapt to crisis conditions and the gradual strengthening of its financial stability. In 2022-2023, Kernel negotiated with creditors to defer payments on the principal amount of the debt, but continued to service interest payments on time. In 2023, the company reached agreements to postpone payments of USD 600 million to 2024 and 2027, and in 2024 it successfully repaid Eurobonds for USD 300 million, which indicates the preservation of creditors' trust. Loan funds played an important role in increasing export volumes. In the

first quarter of 2024, exports of grain and processed products increased by 2.3 times, and oilseed processing by 27%. The company increased sales volumes due to the launch of a new oil extraction plant and improved logistics. In the 2023 fiscal year, Kernel exported 4.4 million tons of agricultural products to 70 countries around the world. The raised financing allowed Kernel to maintain stable operating activities, modernise production and expand exports, despite the difficult economic situation (Censor, 2024).

During 2022-2024, Astarta-Kyiv actively attracted credit resources to modernise and expand production capacities, develop the agricultural segment and agro-processing. In 2023, the company repaid loans in the amount of EUR 24 million and had access to unused credit lines in the amount of EUR 42 million as of December 31, 2022. At the same time, the management did not plan new long-term borrowings, focusing on optimising the debt portfolio. In 2024, the financial strategy changed – Astarta-Kyiv concluded a five-year investment agreement with PrivatBank (PrivatBank, n.d.) for USD 10 million, which provided for financing the expansion of agricultural and sugar production. The funds were directed to the development of livestock, crop production, as well as the purchase of new machinery and equipment. In addition, the company agreed with Oschadbank to provide a loan of USD 60 million for the construction of an agro-processing plant. In 2023, financing was attracted from the IFC (USD 40 million) for the construction of a soy protein concentrate production plant, and from the EBRD – USD 30 million to support sustainable investments in agriculture and processing (FRU, 2023).

The total amount of confirmed financing for this period 2022-2024 exceeded USD 140 million. At the same time, most of the credit resources had a clear investment focus – on the development of production, and not on covering operating costs. In the structure of liabilities as of the end of 2022, short-term liabilities amounted to UAH 4.37 billion, long-term – UAH 4.07 billion, that is, the distribution was almost symmetrical. The company did not increase long-term debt in 2023, which indicates a prudent financial approach (Prasad, 2025). The dynamics of net profit for 2022-2024 is shown in Figure 4.

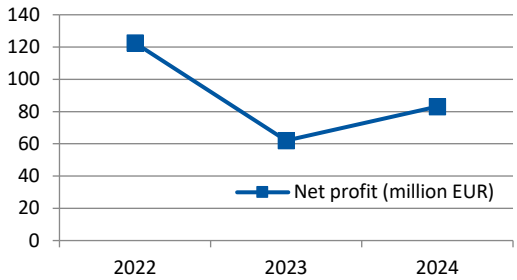

Figure 4. Dynamics of net profit of Astarta-Kyiv in 2022-2024 (million EUR)
Source: created by the authors based on Astarta Holding PLC (2022), Astarta Holding PLC (2023), Astarta Holding PLC (2024)

The graph reflects the dynamics of net profit of the company Astarta-Kyiv in 2022-2024. In 2022, the company demonstrated a high financial result – EUR 122.5 million, however, in 2023, profit significantly decreased to EUR 62 million, which indicates the impact of external risks and changing market conditions. In 2024, there is a partial restoration of financial performance – profit increased to EUR 83 million, which confirms the stabilisation of production activities and effective cost management. According to financial indicators in 2023, Astarta-Kyiv demonstrated stability. The Debt-to-Equity ratio was 0.29, which is an indicator of low debt burden. The Interest Coverage Ratio at 4.6 indicated reliable coverage of debt service from operating income. This created a stable financial basis for growth (Guru Focus, 2025). Credit resources allowed the company to achieve record yields: in 2023, corn yield reached 10.35 t/ha (16.2% more than in 2022),

which provided 200 thousand tons of harvested products. Sugar production volumes increased by 34%, beet processing by 37%. Agricultural revenue increased by 33%, livestock increased by 10%, and milk production by 12% (APK Inform, 2024). Thus, the effective use of credit collateral had a direct positive impact on the company's productivity, profitability, and growth.

A comparative analysis of the three companies demonstrated a common trend – the effective attraction and use of bank loans made it possible to maintain or increase financial performance, implement investment projects, adapt to the risks of the war period and support export activity. All three enterprises ensured debt service, demonstrating responsible financial behaviour. The difference between these enterprises was in the volume of funds raised, debt structures and financial results, but in all cases a positive relationship was observed between the level of lending and indicators of production and financial efficiency. This confirms the feasibility of supporting access to credit resources for agricultural businesses in conditions of macroeconomic instability.

In the work of S. Aziz *et al.* (2024) the main attention was paid to the comparison of bank and fintech lending in Indonesia. As in Ukraine, access to bank loans remained limited for small farmers due to high collateral requirements and low financial capacity. However, unlike Ukraine, Peer-to-Peer (P2P) platforms were actively operating in Indonesia, offering flexible financing conditions, taking into account social factors and even allowing loans to be repaid with products. In this study, such mechanisms were not recorded – here, state support was implemented mainly through traditional banking instruments. A similar trend was observed in the study by R. Njotoprajitno *et al.* (2022), which confirmed that the growth of the share of problem loans (NPL) negatively affected the profitability of banks. In this aspect, both studies agreed: the effectiveness of banking activities in the agricultural sector directly depended on the structure of the loan portfolio. However, the Indonesian work was more macro-financial in nature and did not reveal the specifics of agricultural lending or the participation of the state in the financing process.

In turn, F. Sun (2022) investigated the problems of access to finance for small farmers in China. It stressed the role of information asymmetry, lack of collateral, and low financial literacy – factors that were also relevant to the Ukrainian context. Both studies recognised the critical need for government support. At the same time, the Chinese study focused on the application of digital technologies (scoring, Big Data), while this study was dominated by the analysis of institutional programmes without an emphasis on digital transformation. A deeper exploration of the topic of credit risk was proposed in the work of W. Deng *et al.* (2023), which assessed the effect of farmers' participation in environmental insurance programmes. The authors argued that insurance instruments reduced banks' risks and improved credit access. This approach partly echoed the Ukrainian experience, in which the level of risk also affected the financing structure. However, the Ukrainian study did not include insurance as an element of government policy, focusing on the credit dynamics of enterprises.

In 2022-2024, the leading agricultural companies of Ukraine – Astarta-Kyiv, Kernel and MHP – actively used both the own resources and external financing to ensure stability and development. Despite the difficult macroeconomic situation, these companies attracted significant amounts of credit funds from state and international banks, investing these funds in the modernisation of production, the development of processing and agricultural infrastructure. The attraction of investments was accompanied by a moderate level of debt burden and an increase in operational efficiency. This indicates a high level of companies' adaptive capacity to the challenges of wartime and the strategic orientation towards long-term sustainability.

Prospects for the application of digital solutions and new banking products in lending to the agricultural sector

In conditions of growing uncertainty in the economy and growing risks in agriculture, the digitalisation of financial services and the emergence of new banking products play a key role in transforming approaches to lending to the agricultural sector. Farmers face high price volatility, climate risks, logistical challenges, and limited

access to financial resources, especially during martial law. Therefore, banking institutions focused on cooperation with the agricultural sector are increasingly implementing digital tools that allow these institutions to reduce transaction costs, accelerate the process of making credit decisions, ensure transparency of financial transactions, and adapt products to the individual needs of agricultural enterprises.

One of the main prospects is the development of online lending and mobile banking for farmers. Such services are already being implemented by some state and commercial banks, in particular through the use of integrations with digital agricultural accounting platforms. For example, the Ukrainian platform Soft Farm (n.d.) offers agricultural producers integrated solutions for maintaining electronic agricultural accounting, field cartography, GPS monitoring of equipment and reporting, which can be linked to banking products for automated creditworthiness checks. Similarly, AgroOnline (n.d.) allows forming crop rotations, calculating a financial model of production and forming documents for submission for bank lending. For example, within the framework of the Ok Agro project, teams of agricultural companies studied the needs for digitisation, in particular working with Kernel (n.d.) and AgroOnline (n.d.). The company was tasked with calculating the economy and time for performing operations on the farm in such a way that this information was understandable not only to managers, but also to all employees. As a result, about 80% of the information has been integrated into a digital system, including land bank data, weather data, and agro-technological operations (Kurkul, 2020). In addition, Drone UA (n.d.) provides remote monitoring of crop conditions via drones and satellite data, which allows banks to assess the actual condition of collateral or predict yield as a factor in risk assessment. This data was used to reduce the time for creditworthiness analysis and minimise fraud risks. In the future, full integration of digital agricultural systems with bank CRMs will ensure continuous information exchange and prompt updating of credit limits in accordance with the actual financial condition of the enterprise.

The direction of applying Big Data technologies, artificial intelligence (AI), and machine learning algorithms for automated risk assessment is also rapidly developing. Banks can analyse large volumes of satellite images, climate data, and market trends to predict possible yields and borrowers' solvency. These tools not only increase the accuracy of forecasts, but also make it possible to create new types of financial products with a differentiated approach to insurance and loan portfolio formation. In particular, more active implementation of weather derivatives and parametric insurance is expected as components of new loan programmes for the agricultural sector, which allows the bank to reduce the risk of non-return in the event of adverse weather conditions. In parallel with the development of digital solutions, a transformation of banking products is observed. If previously classic working and investment loans with fixed rates prevailed, now banks are beginning to develop more flexible instruments. For example, banks developed credit lines with seasonal differentiation of the interest rate or with deferral of payments until harvest. The practice of agricultural receipts in digital format, which are integrated into banking processes as collateral, is also spreading. Such products allow attracting financing quickly, with minimal documentary support, provided there is trust in digital platforms and data transparency (Pattnaik *et al*., 2024).

Another direction of future development is the expansion of banking ecosystems, which combine not only financial services, but also additional services for farmers: crop monitoring, agricultural exchanges, price analytics, consulting support. Banks' participation in such ecosystems allows banks not only to better understand customer needs, but also to offer integrated solutions, where lending will be only part of a comprehensive approach to farm management. In the future, such ecosystems may become a platform for placing new financial products, in particular, targeted green loans, microcredit for microfarms, products for young farmers, etc. Special attention should be paid to digital guarantee mechanisms that can reduce risks for banks in unstable conditions. This involves the integration of portfolio guarantee systems administered by the Entrepreneurship Development Fund into banks' digital channels. This allows loans to be provided without collateral or

with partial collateral, automating the process of interaction between the bank and the guarantor. In the future, such mechanisms may be expanded through the participation of international financial institutions (e.g., EBRD or IFC), which will contribute to increasing the availability of credit for small and medium-sized agricultural producers (Javaid *et al*., 2023).

In addition, it is worth expecting the emergence of digital platforms based on open banking, which will provide farmers with full control over the financial profile. In particular, farmers will be able to choose the optimal loan offers from different banks, manage applications, compare rates, and see the lending history in a single digital office. This will increase competition between banks and help improve lending conditions in the agricultural sector. Certain prospects also open up for the introduction of central bank digital currencies (CBDC), which in the future can be used for targeted agricultural payments or control over the use of credit funds. Thanks to smart contracts, it is possible to ensure automated loan write-off only after achieving certain results (for example, purchasing fertilisers, completing the harvest, etc.). This significantly reduces the risk of misuse of resources and facilitates state control over the effectiveness of agricultural support programmes. However, along with the potential of digital solutions, there are also certain limitations. These include low levels of digital literacy among rural populations, weak Information Technology (IT) infrastructure in remote areas, insufficient integration of banking systems with agro-platforms, and cybersecurity risks. For the digitalisation of lending to be effective, government support is needed in the form of grants for digital modernisation of farms, tax incentives for the use of digital solutions, and the development of a single standard for interaction between banks and agro-services (Javaid *et al*., 2023).

A comparison with the study by S. Mushtaq & S. Mushtaq (2023) revealed a common understanding of the positive impact of lending on agricultural production, but with a fundamentally different analytical focus. The authors considered 53 countries at the macroeconomic level, using econometric models to assess the impact of financial variables. At the same time, this study focused on practical mechanisms of bank financing in Ukraine in conditions of military instability. While S. Mushtaq & S. Mushtaq found the contradictory role of government spending and foreign direct investment (FDI), this study, on the contrary, emphasised the importance in stabilising the financial condition of agricultural enterprises. Similarly, in the study of J. Kang & M. Zhao (2022), digital technologies were a key factor influencing access to finance. Fintech platforms and online banking in China became tools for attracting financial resources for rural households. In contrast, in the Ukrainian context, traditional banking mechanisms, as well as state and donor support programmes, played a primary role. Thus, digitalisation became a point of divergence, and the general conclusion about the importance of access to finance was a point of contact.

In turn, the study of C. Hu *et al*. (2023) also supported the thesis about the importance of financial inclusion, but in the context of the impact of digital financial services on farmers' incomes. At that time, this study focused on the prospects for the application of digital solutions. At the same time, both approaches agree that effective lending is the basis for sustainable agricultural development. Similarly, Y. Liu *et al*. (2021) emphasised institutional conditions and the quality of local governance as factors affecting the effectiveness of rural financing. In contrast, this study gave the leading role to state anti-crisis policies and the adaptation of banking systems. At the heart of both studies is increasing efficiency through access to resources, although the tools and implementation environment differed. The work of Z. Ding *et al*. (2024) offered an unconventional view, emphasising the connection between agricultural loans, land transfer and the green transformation of agriculture. The authors proved that adequate financing promotes environmentally friendly innovations. In turn, this study considered lending mainly as a mechanism for ensuring the economic sustainability of enterprises.

In summary, it can be argued that the prospects for the application of digital solutions and new banking products in agricultural lending are extremely promising. These innovations pave the way for deeper financial inclusion, reduced credit risks, increased transparency and

efficiency of agricultural financing. Combining digital innovations with adapted financial instruments will allow agricultural enterprises to better cope with challenges, increase production and strengthen the resilience in the long term. The successful implementation of these solutions depended on the cooperation of the state, the banking sector, digital platforms and farmers, who should become active participants in the new digital agrifinance ecosystem.

CONCLUSIONS

In 2022-2024, bank lending became a key tool for stabilising and developing the agricultural sector of Ukraine, as evidenced by a significant increase in the volume of financing and the number of farms involved. In 2022, UAH 118.9 billion in loans were provided to agricultural enterprises, which almost doubled the level of 2021. In 2023, the volume of lending reached UAH 78.8 billion, and in 2024 – already UAH 104.5 billion. A special role in this process was played by the state programme "Affordable Loans 5-7-9%", within the framework of which UAH 44.5 billion was issued in 2023 alone, and UAH 46.9 billion in 2024. About 75% of all loans were provided in the national currency for the short-term needs of farmers, in particular, spring field work, which indicates a significant adaptation of banks to the needs of the industry.

Financial support covered both large agricultural holdings and small and medium-sized businesses, as evidenced by the increase in the participation of enterprises in the programme – from 10.9 thousand farmers in 2023 to 13,088 in 2024. At the same time, thanks to portfolio guarantees and mandatory participation in the State Agrarian Register, even farms with limited access to collateral were able to attract resources. In 2024, the volume of such guarantees exceeded UAH 782 million in Ivano-Frankivsk region alone. In addition, the participation of international financial institutions (USAID, EBRD, World Bank) provided additional financing channels – the AGRI-Ukraine programme alone attracted more than USD 850 million, and the ARISE project – USD 700 million, of which USD 320 million in the form of grants.

Analysis of leading companies – MHP, Kernel and Astarta-Kyiv – demonstrated the effectiveness of attracting credit funds: for example, MHP managed to restore profitability from a net loss of USD 231 million in 2022 to a profit of USD 144 million in 2024. Kernel, despite a decrease in profit to USD 168-204 million in 2024, strengthened its financial stability, reducing debt to USD 308 million. Astarta-Kyiv demonstrated the lowest level of debt burden (Debt-to-Equity – 0.29), a high level of yield and an increase in production volumes. All companies successfully serviced debts, modernised production capacities and increased exports. It was found that the prospects for the development of agricultural lending in Ukraine are associated with the further digitalisation of financial services, the introduction of flexible banking products and the expansion of ecosystems that combine financing with agricultural services. Big Data, artificial intelligence, and digital collateral tools will play a crucial role in increasing the accessibility and accuracy of credit risk assessment. A limitation of this study was that behavioural factors in smallholder farmers' decision-making regarding lending were not taken into account, and digital aspects of financing were only partially considered. Future research prospects include in-depth study of the effectiveness of digital financial instruments, behavioural economics in the field of agricultural lending, and the impact of regional characteristics on access to banking resources.

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Аналіз ефективності банківських кредитних інструментів для аграрних підприємств України

Анотація. Метою даного дослідження було визначити рівень впливу банківських кредитних інструментів на фінансову стійкість, прибутковість і виробничу результативність сільськогосподарських підприємств України. У межах дослідження проаналізовано динаміку банківського кредитування агросектору у 2022-2024 роках. Загальний обсяг кредитів,

наданих аграрним підприємствам, зменшився із 118,9 млрд грн у 2022-му до 104,5 млрд грн у 2024 році. Частка пільгового фінансування за програмою «Доступні кредити 5-7-9 %» у 2024 році склала 46 % (46,9 млрд грн). У дослідженні здійснено аналіз трьох провідних компаній – «Миронівський хлібопродукт», «Кернел» та «Астарта-Київ», які активно використовували банківські кредити та міжнародне фінансування для стабілізації діяльності, модернізації виробництва та розширення експортного потенціалу. «Миронівський хлібопродукт» відновив прибутковість: від збитку 231 млн дол. у 2022 році до прибутку 144 млн дол. у 2024-му. «Астарта-Київ» збільшила врожайність кукурудзи до 10,35 т/га, виробництво цукру – на 34 %, а виручку з агровиробництва – на 33 %. «Кернел» залучив 150 млн дол. синдикованого фінансування, що забезпечило 2,3-кратне зростання експорту в 2024 році. Дослідження довело, що банківські позики виступили не лише як антикризовий механізм, а й як інструмент зростання ефективності, модернізації та адаптації підприємств до умов високих ризиків. Практичне значення дослідження полягає в обґрунтуванні ефективності банківських кредитних інструментів як дієвого механізму підтримки аграрного сектору в умовах кризових викликів та в можливості використання отриманих результатів для вдосконалення державних програм фінансування

Ключові слова: фінансова підтримка; цифровізація; інвестиції; державна підтримка; експорт

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Budgetary mechanisms for stimulating environmental modernisation of agribusiness in Ukraine

Abstract. The aim of this study was to conduct a comprehensive analysis of the system of budgetary instruments for stimulating environmental transformation of the Ukrainian agricultural sector and to develop scientifically sound recommendations for optimising mechanisms of state financing for sustainable development of agricultural production. The methodological basis was formed by the principles of systematicity, objectivity and historicism, and structural-functional analysis, comparative analysis, content analysis and secondary data analysis were used to study the regulatory and legal framework, official reports and statistical materials for the period from 2024 to early 2025. A multi-level system of budgetary incentives was established with a funding volume of over UAH 24 billion in 2025, covering more than 300,000 beneficiaries through mechanisms ranging from direct grants to tax incentives. while a disproportion was identified between traditional subsidy programmes, which account for 70% of the total volume, and targeted environmental initiatives. A key trend has been the integration of environmental standards into financial programmes under the influence of international partners, as evidenced by the introduction of mandatory environmental and social assessments as part of the preferential lending programme, demonstrating an evolution from reactive support to proactive investment climate formation. The systematisation of European experience revealed Ukraine's strategic dilemma between adapting to the standards of the European Union's Common Agricultural Policy and maintaining the competitiveness of agricultural exports, while the practical results of implementing precision farming, bioenergy and organic production technologies have demonstrated the potential to reduce resource use by 15-25% while maintaining productivity. The main limitations to effectiveness are the fragmentation

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of environmental criteria in traditional support programmes, the difficulty of access to grant funding for small producers due to high co-financing requirements, and the lack of a comprehensive system for monitoring the environmental results of budget expenditures. The study has formed a scientific and methodological basis for improving state policy to stimulate the environmental modernisation of the agricultural sector through the creation of coordination platforms, the introduction of digital environmental monitoring systems, and the development of differentiated approaches to financing different categories of producers

Keywords: state support; financial instruments; grant programmes; subsidies; tax incentives

INTRODUCTION

Modern agricultural activity in Ukraine is characterised by significant anthropogenic pressure on the environment, manifested through excessive use of mineral fertilisers and pesticides, soil depletion and a decline in biodiversity. The agro-industrial sector of Ukraine accounts for a significant share of the country's gross domestic product (GDP), but at the same time poses significant environmental risks, including degradation of agricultural land, soil erosion and high levels of land cultivation. Global climate challenges and European integration processes require Ukrainian agribusiness to transition to sustainable production practices, which raises the issue of developing effective mechanisms for state support for the ecological modernisation of the industry. The scale of environmental problems in the agricultural sector is confirmed by official statistics. According to Minister of Agrarian Policy Vitaliy Koval, Ukraine's agro-industrial sector accounts for approximately 20% of GDP, of which agriculture accounts for about 11% and processing for about 9% (Skoryk, 2024). At the same time, according to the Food and Agriculture Organization (FAO), about 20% of Ukraine's agricultural land suffers from degradation (approximately 6.5 million hectares), and annual soil losses due to erosion volume to 300-600 million tonnes (FAO, 2019). In addition, according to estimates by experts from the National Academy of Agrarian Sciences of Ukraine, the level of land cultivation is one of the highest in the world – 57% of the country's territory and almost 80% of agricultural land (AgroPolit, 2019).

European experience shows the key role of budgetary instruments in the sustainable development of the agricultural sector, while in Ukraine, mechanisms for financial support for the ecological modernisation of agribusiness remain fragmented and focused mainly on traditional production. Limited budgetary funding for the greening of the industry complicates the transition to sustainable development, especially in the context of martial law and future post-conflict recovery. This necessitates the optimisation of the budgetary incentive system, which must take into account the challenges of a transitional economy and the requirements of integration into European standards, requiring a review of approaches to the structuring and distribution of financial resources. The degree of development of the topic is characterised by the availability of a wide range of studies in the field of state support for agricultural production and the ecological transformation of the agricultural sector. In the Ukrainian scientific school, fundamental research on the greening of agricultural production is represented by the works of leading agricultural economists.

The financial support of the agricultural sector's development in the context of global challenges attracts the close attention of contemporary researchers. A thorough analysis of credit mechanisms for supporting agricultural enterprises was carried out by K. Larianova & G. Kapinos (2025), who substantiated the role of financing in achieving sustainable development goals in a state of martial law. The authors examined in detail the specifics of the functioning of credit institutions in conditions of limited access to capital and highlighted the mechanisms for adapting financial instruments to the needs of wartime. At the same time, V. Galkin (2025) focused on the impact of public funding on the activation of innovation processes in agriculture, revealing correlations between the volume of budget allocations and the level of technological modernisation in the industry. The researcher analysed the

effectiveness of various forms of state support and their impact on the introduction of modern technologies in agricultural production. An alternative perspective was presented by A. Yatsun & N. Vdovenko (2024), who focused on modelling financial instruments for sustainable development of the agricultural sector, proposing a comprehensive approach to structuring support mechanisms. The researchers developed a conceptual model for integrating various financial instruments into a single system of support for sustainable agricultural development.

The issue of stimulating environmental transformations at the local level is reflected in works devoted to decentralised mechanisms for supporting sustainable agricultural production. Based on the results of research by Y. Zastavnyi (2021), financial and economic instruments for the development of organic production at the level of amalgamated territorial communities were analysed in detail, revealing the potential of local budgets to stimulate environmental practices. The author systematised the experience of using local budget funds to support organic agricultural production and proposed mechanisms to improve the effectiveness of such programmes. At the same time, Polish researchers R. Rudnicki *et al.* (2023) presented a comprehensive study of the pro-environmental activity of farms within the framework of the European Union's common agricultural policy, demonstrating the effectiveness of a systematic approach to the green modernisation of agriculture. The researchers analysed the results of the implementation of agro-ecological measures in various EU countries and assessed their impact on the productivity and environmental sustainability of agricultural production.

The digital transformation of the agricultural sector and its interconnection with sustainable development policy have become the subject of scientific interest among Swiss economists. According to the conclusions of M. Ehlers *et al.* (2021), the need to adapt agricultural policy to the digital era was justified, emphasising the importance of integrating technological and environmental requirements. The researchers examined the challenges and opportunities associated with the introduction of digital technologies in agricultural production and their potential for improving environmental performance. A comprehensive assessment of the European "Farm to Fork" strategy from the perspective of agricultural economics was carried out by Dutch researcher J. Wesseler (2022), who identified contradictions between ambitious environmental goals and the real possibilities of achieving them through existing financial mechanisms. The author analysed the economic consequences of implementing the strategy for different categories of agricultural producers and proposed ways to optimise policy instruments. A systematic view of ensuring agricultural sustainability through agroforestry was presented by Spanish scientists, in particular J. Santiago-Freijanes *et al.* (2021), who systematised global and European policies to support agroecological practices. The researchers analysed in detail the experience of European Union countries in implementing agroforestry systems and assessed their potential for ensuring the sustainable development of the agricultural sector.

An analysis of the scientific literature shows that most studies focus on specific aspects of state support for agriculture, general issues of greening agricultural production, or the experience of Western European countries in implementing "green" policies. At the same time, the issue of comprehensive optimisation of budgetary mechanisms for stimulating the ecological modernisation of agribusiness, taking into account the specifics of the transformation processes in the Ukrainian economy, remains insufficiently studied. There is a gap in research on the relationship between the structure and volume of budgetary financing of environmental measures in agriculture and the effectiveness of their implementation at the microeconomic level of agricultural enterprises, especially in the context of limited state financial resources and the need to ensure food security.

The aim of the study was to determine the role of the state budget in stimulating the environmental modernisation of Ukraine's agricultural sector by analysing the effectiveness of existing financing instruments and justifying areas for their improvement in order to increase the environmental sustainability of agribusiness. To achieve this aim, the following research objectives were set: to analyse existing budgetary

instruments for financing the environmental modernisation of Ukraine's agricultural sector (subsidies, tax incentives, support programmes) and assess their effectiveness; to systematise foreign experience in the use of budgetary mechanisms to stimulate the sustainable development of the agricultural sector; to develop recommendations for improving budgetary mechanisms for stimulating the environmental modernisation of agribusiness in order to increase the environmental sustainability of the industry.

MATERIALS AND METHODS

The methodological basis of the study was formed by the principles of systematicity, objectivity and historicism, which ensured a scientifically sound approach to the study of budgetary mechanisms for stimulating the ecological modernisation of Ukraine's agricultural sector. The application of the principle of systematicity made it possible to consider budgetary instruments as interrelated elements of a unified system of state support for agribusiness, functioning in the context of the general transformation processes of the Ukrainian economy and European integration challenges. Adherence to the principle of objectivity ensured an unbiased analysis of the effectiveness of existing mechanisms for financing grant support, subsidy programmes, tax incentives and international initiatives, while the principle of historicism made it possible to trace the evolution of the system of state support for the agricultural sector during 2024 – early 2025, taking into account the specific conditions of martial law and European integration.

Structural and functional analysis was used to study the architecture of budgetary mechanisms as an integrated system covering various types of support, from direct grants to tax incentives and preferential lending. This method made it possible to reveal the functional purpose of each financing instrument and their interaction in achieving the goals of environmental modernisation of agribusiness. The financing structure was analysed by type of support, funding volume, access conditions and environmental criteria, which made it possible to systematise various state incentive mechanisms into a single conceptual framework. The functional links between national and international support programmes were examined through the prism of their coordination on the basis of DAR (n.d.) as a single digital platform.

A comparative analysis was used to compare Ukrainian experience with European best practices in the implementation of policies to support the environmental modernisation of agriculture. A comparative study of the principles and mechanisms of the European Union's Common Agricultural Policy was conducted, in particular the system of standards for good agricultural and environmental condition (GAEC) and eco-schemes as instruments for stimulating sustainable farming practices. The structure and volume of funding for national support programmes were compared with international initiatives in Ukraine in terms of environmental focus, beneficiary coverage and intensity of support per participant. The models of agricultural production in Ukraine and EU countries (Poland, Hungary) were compared to identify specific challenges in adapting European standards to the conditions of large-scale agribusiness.

Content analysis was used to systematically study the regulatory framework for state support of Ukraine's agricultural sector and to identify trends in the integration of environmental criteria into financial programmes. The content of the fundamental Law of Ukraine No. 1877-IV "On the Principles of the State Agrarian Policy and the State Rural Development Policy" (2004) and numerous subordinate acts detailing the mechanisms for the distribution of budget funds were analysed. Resolutions of the Cabinet of Ministers of Ukraine regulating the functioning of grant programmes were examined, in particular Resolution of the Cabinet of Ministers of Ukraine No. 130 "On Approval of the Procedure for Using Funds Provided for in the State Budget for Partial Compensation of the Cost of Domestically Produced Agricultural Machinery and Equipment" (2017), Resolution of the Cabinet of Ministers of Ukraine No. 738 "On Some Issues Regarding the Provision of Grants to Businesses" (2022) and Resolution of the Cabinet of Ministers of Ukraine No. 918 "On Approval of the Procedure for Using Funds Provided for in the State Budget to Support Farms and Other Agricultural Producers" (2022).

Secondary data analysis was used to study quantitative indicators of the functioning of budgetary mechanisms and their effectiveness based on published official reports and statistical materials. Data on the total volume of state support for the agricultural sector, presented in reports by BDO (an international auditing and consulting company) in Ukraine on state support for agribusiness during the war and materials on state support for the agricultural sector in 2024 (Verkhovna Rada of Ukraine, 2024; EBA, 2025). Information on the number of programme participants and the distribution of funds, published in materials on grants for farmers and an overview of agricultural sector support programmes (Chaszmin, n.d.; Kovalenko, 2025), was examined. Documented cases of successful implementation of environmental technologies were analysed, including materials on the activities of the organic enterprises "Ekorod" and "Garna Organica" (BrandStory, n.d.).

The source base of the study consisted of Ukrainian regulatory and legal acts in the field of state support for agriculture, reports of international organisations on assistance programmes for the Ukrainian agricultural sector, official materials on the implementation of state support programmes, and European Union documents on the Common Agricultural Policy. EU regulations and directives were used, in particular Regulation of the European Parliament and of the Council No. 1305 "On Support for Strategic Plans to be drawn up by Member States under the Common Agricultural Policy", (2021), which establishes rules for supporting the strategic plans of Member States under the CAP (Common Agricultural Policy), European Commission documents on GAEC standards, and materials on the implementation of the "Farm to Fork" Strategy (European Commission, n.d.; CAP, 2024). Reports from the Food and Agriculture Organisation of the United Nations (United Nations), the United States Agency for International Development, the World Bank, USAID (United States Agency for International Development) and other international donors on programmes to support the Ukrainian agricultural sector were analysed (Landlord, 2023; World Bank Group, 2023; Growhow, 2025). The informational basis also included official announcements regarding the introduction of environmental and social assessment within the preferential lending programme, materials on the initiative "Green Modernisation of the Agro-Industrial Complex 2025", and the draft law on "investment cashback" (BDF, 2025; Dnepragro, 2025; Greenpost, 2025). The comprehensive application of these methods and the diverse source base ensured a thorough study of budgetary mechanisms for stimulating the ecological modernisation of the agricultural sector of Ukraine, taking into account their functional characteristics, effectiveness, and prospects for further improvement.

RESULTS

Characteristics and analysis of existing budgetary instruments for the environmental modernisation of the agricultural sector

The current system of budgetary mechanisms for stimulating the ecological modernisation of agribusiness in Ukraine was formed during 2017-2025 under the influence of European integration processes and in the context of Russian aggression against Ukraine, which began in February 2022. The transformation of state policy to support the agricultural sector is taking place in the context of harmonising domestic legislation with European Union standards, where about 40% of all adaptation procedures relate specifically to the agricultural sector (Agroportal, 2023). The issue of integrating environmental requirements into financial support mechanisms is becoming important in a context where the agro-industrial sector accounts for approximately 20% of Ukraine's gross domestic product, of which agriculture accounts for about 11% and processing for 9% (Skoryk, 2024). The fundamental legal basis for state support for agriculture remains Law of Ukraine No. 1877-IV "On the Principles of the State Agrarian Policy and the State Rural Development Policy" (2004), which creates a regulatory framework for the development and implementation of numerous subordinate acts. The evolution of this legislative foundation is reflected in the resolutions of the Cabinet of Ministers of Ukraine, which detail the mechanisms for the distribution of budget funds and increasingly integrate environmental criteria into the conditions for financing.

The system of direct budget financing for environmental modernisation is based on grant support through digital platforms, as well as traditional subsidy mechanisms. A key innovative component has been the integration of support programmes through the Diia (n.d.) and DAR (n.d.) portals, which function as a single transparent platform for unifying the rules for receiving both state and international aid (European External Action Service, 2024). This digital transformation of the administration system has significantly simplified procedures for farmers and increased the transparency of fund distribution. Grant support through state programmes covers three main areas, each of which has the potential for environmental modernisation. The "Orchard grant" programme (Diia, n.d.) provides funding of up to UAH 400,000 per hectare for the development of horticulture, berry growing and viticulture, with the mandatory condition of co-financing of at least 30% of the project cost by the recipient, as regulated by Resolution of the Cabinet of Ministers of Ukraine No. 738 "On Some Issues Regarding the Provision of Grants to Businesses" (2022). The environmental potential of this programme lies in stimulating the diversification of agricultural production, which contributes to the preservation of biodiversity and increases soil sustainability compared to monocultural farming.

The greenhouse construction grant programme is seen as a tool for intensive environmental modernisation, as it provides the opportunity to control growing conditions and optimise the use of water resources and fertilisers. Funding of up to UAH 7 million for the construction of modular greenhouses with an area of up to 2.5 hectares, with 30% co-financing, creates incentives for the introduction of resource-saving technologies (Chaszmin, n.d.). The adaptability of the greenhouse grant policy is indicative, as the initial requirements for job creation were revised after feedback from the business community, demonstrating the flexibility of state incentive mechanisms (Lawoffice, n.d.). The third area of grant support is aimed at developing processing enterprises with funding of up to UAH 8 million, which is an important element in moving away from a raw materials-based economy (Chaszmin, n.d.). Co-financing conditions are differentiated depending on the order of application submission: for the first thousand applicants, the state covers 70% of the project cost, for the next ones – up to 50%. This mechanism stimulates the creation of high value-added products and can integrate environmentally friendly processing technologies.

Budget subsidies and grants form the second level of direct financing, where the main environmental component is support for land reclamation systems (EBA, 2025). The restoration and construction of land reclamation systems became relevant after the destruction of water infrastructure as a result of military actions, in particular the bombing of the Kakhovka hydroelectric power plant (HPP) by Russian occupation forces on 6 June 2023 at around 2:50 a.m. (NV, 2024). Effective water management through land reclamation is a direct tool for environmental modernisation in the context of climate change and military destruction of critical infrastructure. Subsidies per hectare for small producers cultivating up to 120 hectares of land volume to up to UAH 4,000 per hectare in accordance with Resolution of the Cabinet of Ministers of Ukraine No. 918 "On Approval of the Procedure for Using Funds Provided for in the State Budget to Support Farms and Other Agricultural Producers" (2022). Although these subsidies do not have direct environmental criteria, they create financial stability for the implementation of sustainable farming practices among the largest group of agricultural producers. Partial compensation of the cost of agricultural machinery in the volume of 25% excluding value added tax (VAT), regulated by Resolution of the Cabinet of Ministers of Ukraine No. 130 "On Approval of the Procedure for Using Funds Provided for in the State Budget for Partial Compensation of the Cost of Domestically Produced Agricultural Machinery and Equipment" (2017), has an indirect environmental effect by encouraging the renewal of the technical fleet. Modern equipment is characterised by higher energy efficiency and less negative impact on the soil, which makes this programme a tool for the technological greening of the industry.

The system of indirect budgetary incentives underwent changes in 2024-2025 due to

the integration of environmental standards into the financing conditions. The "Affordable Loans 5-7-9%" programme was transformed from a general support instrument into a targeted environmental incentive mechanism after the introduction of mandatory environmental and social assessment for borrowers on 1 December 2024 (Ministry of Finance of Ukraine, 2024). This shift in preferential lending policy was influenced by international financing through the World Bank as part of the ARISE (Agriculture Recovery Inclusive Support Emergency) project. The environmental and social management system provides for a comprehensive check of compliance with current environmental legislation, the availability of permits, waste management practices and emission reduction measures (BDF, 2025). The identification of high environmental risks leads to a refusal to provide financing, while less critical shortcomings require corrective measures to be implemented during the loan period. This transformation demonstrates how international financial assistance is becoming a powerful lever for changing domestic policy, turning access to capital into a tool for forcing agribusiness to become more environmentally friendly.

Tax incentives represent a long-term systemic approach to environmental modernisation through the "investment cashback" project, which is being prepared for consideration by the Verkhovna Rada. This mechanism proposes to compensate up to 70% of capital investments in the processing industry through tax incentives over a ten-year period from 2026 to 2035. The incentives include exemption from income tax, provided that 90% of income is generated from the sale of own processed products, as well as exemption from VAT and import duties on new equipment. Unlike one-off grants and subsidies, "investment cashback" creates stable and predictable conditions for capital-intensive modernisation projects with investments ranging from EUR 100,000 to EUR 50 million (Greenpost, 2025). This approach demonstrates the evolution of public policy from reactive support to proactive shaping of the investment climate, where environmental modernisation becomes economically attractive due to a reduction in the tax burden.

In 2025, the Ministry of Agrarian Policy launched the large-scale initiative "Green Modernisation of the Agro-Industrial Complex 2025", with a budget of UAH 120 billion for the period 2025-2028, positioning it as the first comprehensive project for the renewal of the agricultural sector since independence (Dnepragro, 2025). This programme is not fundamentally a new financing mechanism but rather a consolidating brand designed to unite existing and announced grant, credit, and subsidy programmes under a single narrative of ecological modernisation. The strategic significance of this initiative lies in creating a coherent and attractive vision for both domestic and international investors, simplifying communication and forming a shared understanding of the future development of the agricultural sector. The programme covers a wide range of environmental technologies, including precision farming using agricultural drones, Global Positioning System (GPS) navigation, and artificial intelligence systems, the development of bioenergy through the production of biofuels from biomass, as well as the preservation of landscape diversity (Dnepragro, 2025). The conceptual value of the "Green Modernisation of the Agro-Industrial Complex 2025" initiative lies in creating a synergistic effect between different support instruments, where individual programmes complement one another in achieving the common goal of ecological transformation. This enables agricultural enterprises to plan comprehensive modernisation projects by using various sources of financing within a single strategic framework. An analysis of the structure and functional characteristics of the existing budgetary mechanisms makes it possible to systematise them according to types of support, volumes of financing, conditions of access, and environmental criteria, thereby creating a basis for assessing their potential in stimulating the sustainable development of the agricultural sector. A comprehensive overview of these instruments demonstrates an evolution from traditional subsidy mechanisms to integrated support systems that combine economic incentives with environmental requirements, as reflected in Table 1.

Table 1. Systematisation of budgetary mechanisms for stimulating the ecological modernisation of the agricultural sector of Ukraine (2024 – early 2025)

Financing mechanism	Type of support	Maximum amount	Co-financing conditions	Environmental criteria	Target group	Regulatory framework
Orchard grant	Direct grant	UAH 400,000 per hectare	30% from the recipient	Production diversification	All categories of producers	CMU Resolution No. 738-2022
Greenhouse grant	Direct grant	UAH 7 million	30% from the recipient	Resource conservation	Small and medium-sized farms	CMU Resolution No. 738-2022
Processing grant	Direct grant	UAH 8 million	30-50% from the recipient	Creation of added value	Processing enterprises	CMU Resolution No. 738-2022
Per-hectare subsidies	Direct subsidy	UAH 4,000 per hectare	None	Support for small-scale production	Farms up to 120 hectares	CMU Resolution No. 918-2022
Machinery compensation	Direct compensation	25% of the cost	Registration in the SAR	Technological modernisation	Registered in the SAR	CMU Resolution No. 130-2017
Irrigation and drainage systems	Targeted support	Varies	Varies	Water-saving technologies	All categories	Sectoral programmes
Affordable loans at 5-7-9%	Preferential lending	Varies	Own funds + ESMA	Mandatory ESMA from December 2024	SMEs	EDF + ARISE project
Investment cashback	Tax incentives	70% of investments	EUR 100 thousand – 50 million	Processing as environmental modernisation	Processing enterprises	Draft law (2026-2035)

Note: SAR – State Agrarian Register; ESMA – Environmental and Social Management/Assessment; SMEs – Small and Medium-sized Enterprises; EDF – Entrepreneurship Development Fund; CMU – Cabinet of Ministers of Ukraine; ARISE – World Bank project "Agriculture Recovery, Inclusive Support for Emergency"
Source: created by the authors based on Resolution of the Cabinet of Ministers of Ukraine No. 130 (2017), Resolution of the Cabinet of Ministers of Ukraine No. 738 (2022), Resolution of the Cabinet of Ministers of Ukraine No. 918 (2022), Ministry of Finance of Ukraine (2024), BDF (2025), Greenpost (2025), Dnepragro (2025)

The presented systematisation of budgetary mechanisms confirms the formation of a multi-level system for stimulating environmental modernisation, which combines traditional instruments of direct support with innovative mechanisms of environmental regulation. An important trend is the integration of environmental criteria into programmes that were not originally focused on environmental protection, demonstrating a systemic transformation of approaches to state support for the agricultural sector. At the same time, the diversity of access conditions and co-financing requirements creates opportunities for a differentiated approach to different categories of producers, although it requires further improvement in terms of simplifying administrative procedures and increasing the transparency of environmental performance criteria.

Assessment of the effectiveness of existing budgetary mechanisms and the role of international support

Analysing the effectiveness of budgetary mechanisms for stimulating the environmental modernisation of the agricultural sector requires a comprehensive approach that combines a quantitative assessment of funding volumes with a qualitative analysis of the environmental effects of programme implementation. State support for Ukraine's agro-industrial complex in 2024-2025 is characterised by significant structural changes caused by the need to adapt to martial law conditions and the simultaneous desire

for European integration (EBA, 2025). The total budgetary funding for the agricultural sector in 2024 amounted to approximately UAH 18.4 billion, of which programmes with direct or indirect environmental effects accounted for approximately 35-40% of the total support (Verkhovna Rada of Ukraine, 2024). A quantitative analysis of the distribution of budget funds shows the dominance of traditional subsidy mechanisms over targeted environmental programmes. Subsidies per hectare for small agricultural producers remain the largest item of expenditure, covering more than 280,000 farms and amounting to approximately UAH 6.5 billion in 2024 (Kovalenko, 2025). At the same time, grant programmes with a more pronounced environmental focus receive significantly less funding: the "Orchard grant" programme received UAH 1.2 billion, the "Greenhouse grant" programme received UAH 800 million, and support for processing enterprises received UAH 1.5 billion (Chaszmin, n.d.). The share of expenditure on land reclamation systems and water management is about UAH 2.1 billion, reflecting the increased attention to water-saving technologies after the destruction of the Kakhovka hydroelectric power plant (HPP) (EBA, 2025).

A qualitative analysis of programme effectiveness shows mixed results depending on the type of incentive and target group. Grant support programmes are characterised by a high level of selectivity and strict selection criteria, which ensures that resources are concentrated on the most promising projects, but at the same time limits accessibility for small producers. The average grant for horticulture development is UAH 280,000 per hectare, which covers about 65-70% of the actual costs of establishing intensive orchards. Greenhouse projects demonstrate higher efficiency in terms of resource use, as they allow savings of up to 40% in water and 30% in fertilisers compared to open ground, but require significant initial investment and technological support (Chaszmin, n.d.). Compensation for the cost of agricultural machinery proved to be one of the most popular mechanisms among agricultural producers, covering more than 15,000 enterprises in 2024 (Ministry of Economy of Ukraine, 2025). The environmental impact of this programme is reflected in the renewal of the technical fleet with the latest equipment models, which are characterised by increased fuel efficiency and reduced emissions. At the same time, the criteria for selecting equipment do not include specific environmental requirements, which limits the programme's potential to promote green technologies.

The practical application of budgetary mechanisms demonstrates varying levels of effectiveness depending on the type of support and the specifics of the enterprise. According to the Ukrainian Cabinet of Ministers, over the course of a year and a half, UAH 723 million in grant funds were invested in horticulture and greenhouse farming under the eRobota programme, with the state covering 70% of the project cost on condition that a sufficient number of jobs were created (Cabinet of Ministers of Ukraine, 2024). Carbominer received a grant from the Climate Innovation Vouchers programme and successfully developed an innovative technology for capturing CO_2 from the atmosphere to fertilise greenhouse crops, which accelerated the growth of tomatoes and cucumbers using environmentally friendly technologies (EBRD, 2024). According to information from the Food and Agriculture Organization of the United Nations and the European Union Support Programme, 237 Ukrainian agricultural producers from the Lviv, Zakarpattia, Ivano-Frankivsk and Chernivtsi regions received USD 2.8 million in funding, enabling them to invest in critical tools, green technologies and infrastructure to modernise production (European External Action Service, 2024).

An analysis of successful practices in the implementation of environmental technologies demonstrates the commercial viability of sustainable agricultural production. The organic enterprise "Ekorod", founded in 2004 in the Zhytomyr region, specialises in the production of organic cereals and oil from 12,000 hectares of certified land, demonstrating stable growth in exports to the European Union (EU) and achieving sales of over UAH 150 million in 2023 thanks to the introduction of biological plant protection methods, which reduced pesticide costs by 100% while maintaining yields at 85-90% of conventional production. The company "Garna Organica", cultivating 3,500 hectares in Odesa region since 2018, has successfully integrated into

international organic supply chains, exporting sunflower oil, wheat, and maize to 15 countries worldwide and demonstrating profitability at the level of 18-22% due to a price premium for organic products of 15-30% compared with conventional equivalents. At the same time, the enterprise reduced agrochemical costs by 40% and increased soil organic matter content from 2.1% to 2.8% over five years of certified organic production (BrandStory, n.d.). These examples illustrate that organic production can be economically attractive provided there is access to premium markets and appropriate government support during the certification and transition period. An indicative example is the experience of Mykola Mysnyk's 280-hectare farm in the Chernihiv region, where the introduction of organic technologies over five years has led to a measurable improvement in soil quality through the use of crop rotation with legumes, composting plant residues and abandoning synthetic fertilisers and pesticides. Research conducted by the Oleksandr Sokolovsky Institute of Soil Science and Agrochemistry of the National Academy of Agrarian Sciences of Ukraine (NAAS of Ukraine) recorded an increase in phosphorus content by 15%, potassium by 12%, nitrogen by 8%, and humus by 0.3 absolute percent, which increased the water-holding capacity of the soil by 20% and increased the population of beneficial microorganisms by 2.5 times (Suspilne Chernihiv, 2021). These indicators testify to the restoration of natural soil fertility and the long-term sustainability of the production system, which are key indicators of successful environmental modernisation.

International support plays a catalytic role in the transformation of the Ukrainian agricultural sector, providing not only financial resources but also the transfer of advanced technologies and standards. The Food and Agriculture Organisation of the United Nations (FAO) has launched a two-year, USD 150 million support programme aimed at restoring agricultural land and supporting affected farms (Growhow, 2025). The programme includes demining agricultural land, restoring irrigation systems and supporting seed production, which is important for the ecological restoration of land after military operations. The US Agency for International Development (USAID), through its AGRO programme (2019-2026), provides grants for the development of agricultural processing ranging from UAH 8 to UAH 40 million, and also funds pilot projects to modernise irrigation systems (Landlord, 2023). A distinctive feature of the USAID programme is its focus on the introduction of energy-efficient technologies and drip irrigation systems, which can save up to 50% of water resources compared to traditional irrigation methods. Mercy Corps, funded by the Howard G. Buffett Foundation, focuses on supporting smallholder farms in war-affected regions by providing financial assistance ranging from UAH 50,000 to UAH 200,000 per household (UASP, n.d.; Arhirova & Stepanenko, 2025).

The standardising influence of international donors is manifested through the introduction of ESCOs into Ukrainian financial programmes. Starting in December 2024, all borrowers under the "Affordable Loans 5-7-9%" programme must undergo a mandatory environmental and social assessment, which is a result of the World Bank's requirements under the Agriculture Recovery, Inclusive Support for Emergency (ARISE) project (World Bank Group, 2023; Ministry of Finance of Ukraine, 2024; BDF, 2025). This requirement has radically changed the logic of providing preferential loans, transforming them from a tool for general economic support into a mechanism for stimulating environmentally responsible business. The coordination of international aid through DAR as a single digital platform has increased the efficiency of resource allocation and reduced programme duplication (European External Action Service, 2024). DAR integrates applications for both national and international support, allowing farmers to combine different sources of funding to implement comprehensive modernisation projects. DAR statistics show that about 30% of international grant recipients also use state support programmes, which creates a synergistic effect for the implementation of environmental technologies (Cabinet of Ministers of Ukraine, 2022; Ministry of Agrarian Policy and Food of Ukraine, 2022).

Despite positive developments, existing budgetary mechanisms are characterised by a number of systemic constraints that reduce their effectiveness in stimulating environmental

modernisation. The fragmentation of programmes is manifested in the absence of a unified strategy for integrating environmental criteria into all state support instruments. Most traditional subsidy programmes do not include environmental performance requirements, which leads to a situation where the mechanisms with the largest funding have the least environmental impact (EBA, 2025). The insufficient integration of environmental criteria is most pronounced in support programmes for small agricultural producers, which cover the largest number of beneficiaries. Subsidies per hectare are provided without taking into account farming methods, which does not create incentives for the transition to sustainable practices. The lack of a system for monitoring environmental outcomes makes it impossible to assess the real impact of budget expenditures on the state of the environment and the efficient use of natural resources. The complexity of accessing support programmes remains a significant barrier for small producers, despite the digitisation of procedures through the Diia (n.d.) and DAR (n.d.) portals. Co-financing requirements of 30-50% of project costs are unaffordable for most farms cultivating up to 50 hectares of land. The complexity of preparing business plans and technical documentation requires the involvement of professional consultants, which further increases the cost of participating in grant programmes. Only about 15-20% of grant applications submitted meet all formal requirements, indicating a need to simplify procedures and strengthen advisory support (Chaszmin, n.d.). A structural analysis of budget financing and international assistance allows for the systematisation of the main sources of funding for the ecological modernisation of the agricultural sector, their targeting and effectiveness (Tables 2, 3).

Table 2. Structure of budget financing for the environmental modernisation of Ukraine's agricultural sector (2024 – early 2025)

Funding area	Volume 2024 (billion UAH)	Volume 2025 (billion UAH)	Number of beneficiaries	Environmental potential	Main results
Per-hectare subsidies	6.5	7.2	280,000	Low	Financial stabilisation
Orchard grant	1.2	1.8	2,800	High	Production diversification
Greenhouse grant	0.8	1.2	450	High	Resource conservation
Processing grant	1.5	2.1	680	Medium	Creation of added value
Machinery compensation	2.3	2.8	15,200	Medium	Technological modernisation
Irrigation and drainage systems	2.1	3.5	1,200	High	Water conservation
Affordable loans 5-7-9%	4.2	5.8	8,500	Medium	ESMA from December 2024
Total	**18.6**	**24.4**	**308,830**	–	**Comprehensive support**

Source: created by the authors based on Verkhovna Rada of Ukraine (2024), European External Action Service (2024), Growhow (2024), EBA (2025), Landlord (2025)

International support is characterised by a more concentrated approach to financing, with an emphasis on technologically complex projects and strict environmental selection criteria (Table 3).

Table 3. Structure of international assistance to Ukraine's agricultural sector (2024 – early 2025)

Donor/ Programme	Volume of funding	Number of beneficiaries	Environmental criteria	Main results	Implementation mechanism
FAO of the United Nations	USD 150 million	450 farms	Land rehabilitation	Demining and restoration	Direct grants
USAID AGRO	UAH 8-40 million	85 projects	Energy efficiency	Processing and irrigation	Competitive grants
Mercy Corps	UAH 50,000-200,000	12,000 households	Sustainable practices	Household support	Targeted assistance
World Bank	Credit lines	8,500 borrowers	Mandatory ESMA	ESMA standards	Through the EDF
EU grants	Up to USD 150,000	280 producers	Organic production	Aggregation models	Through the SAR
Total	**Approximately UAH 6-8 billion equivalent**	**~21,315**	**High standards**	**Technological modernisation**	**Various mechanisms**

Source: created by the authors based on World Bank Group (2023), European External Action Service (2024), EBRD (2024), Landlord (2025)

A comparative analysis of the data in Tables 2 and 3 demonstrates a fundamental difference in the approaches to national and international financing of environmental modernisation in the agricultural sector. National programmes are characterised by larger funding volumes (UAH 24.4 billion in 2025) and a broad scale of coverage (over 308,000 beneficiaries), but their environmental potential varies from low to high depending on the specifics of the programme. At the same time, international assistance, despite its smaller absolute volumes (equivalent to about UAH 6-8 billion), demonstrates a more targeted approach to environmental criteria and covers approximately 21,300 beneficiaries. The ratio of the number of projects to the volume of funding is indicative: while national programmes provide an average support of about UAH 79,000 per beneficiary, international programmes provide from UAH 400,000 to UAH 11 million per project, reflecting their focus on technologically complex and capital-intensive initiatives with high environmental potential.

A comparative analysis of national and international support programmes shows that international assistance is characterised by stricter environmental criteria and a higher level of technical support, but covers significantly fewer beneficiaries than national programmes. National funding ensures scale and stability of funding, but requires a radical strengthening of the environmental component to achieve sustainable development goals. The data in the tables show that the ratio between national and international funding is approximately 3:1, with international aid focusing on high-tech and innovative projects with clear environmental criteria. National programmes cover more than 300,000 beneficiaries, while international initiatives support about 13,000 projects, demonstrating the complementarity of these approaches. The synergy between national and international mechanisms creates the potential for a comprehensive system of incentives for environmental modernisation, but requires further improvement in coordination and unification of environmental performance standards.

European experience and strategic challenges of European integration

The process of Ukraine's European integration in the agricultural sector is taking place in the context of a fundamental transformation of the European Union's Common Agricultural Policy itself, which has evolved from a mechanism for ensuring food security to an instrument for realising the bloc's climate ambitions. This transformation poses unique challenges for Ukraine, as the country must simultaneously adapt to complex environmental standards and maintain its role as a global exporter of agricultural products in a state of martial law. The strategic dilemma lies in the need to balance access to European markets and financial support on the

one hand, and maintaining the competitiveness of Ukrainian agricultural exports on the other (Landlord, 2024).

The current architecture of the EU's Common Agricultural Policy is based on two fundamental principles: ensuring farmers' incomes through direct payments and stimulating sustainable development in rural areas through development programmes. The CAP budget for the period 2021-2027 amounts to EUR 386.6 billion, which is 31% of the total EU budget, of which EUR 291.1 billion is allocated to direct payments and market measures, and EUR 95.5 billion to rural development. A key innovation of the new programming period is the introduction of national strategic plans, which allow each member country to adapt pan-European objectives to local conditions while maintaining the unity of standards and principles (CAP, 2024).

The Good Agricultural and Environmental Condition (GAEC) standards form the regulatory framework for receiving support under the CAP and represent the minimum requirements for farming that ensure environmental conservation and climate resilience. The GAEC system comprises nine basic standards grouped into three thematic areas: soil and organic matter conservation (GAEC 1-3), water protection (GAEC 4-5) and biodiversity and landscape conservation (GAEC 6-9) (Regulation of the European Parliament and of the Council No. 1305 "On Support for Strategic Plans to be drawn up by Member States under the Common Agricultural Policy", 2021; Agroportal, 2025). GAEC 1 requires the preservation of permanent pastures with high environmental value, preventing their ploughing and promoting carbon sequestration in the soil. GAEC 2 protects carbon-rich soils, including peatlands and wetlands, from drainage, which is critical to achieving climate neutrality goals. GAEC 6 establishes minimum soil cover to prevent erosion and nutrient loss, which is particularly relevant for sloping land (European Commission, n.d.).

The practical application of European standards is demonstrated by successful adaptation cases in Central and Eastern European countries. The Polish agricultural enterprise "Organic Farma Zdrowia", covering an area of 850 hectares in the Masovian Voivodeship, implemented GAEC standards between 2019 and 2023, achieving a 45% reduction in soil erosion through the use of cover crops in accordance with GAEC 6 and an increase in carbon sequestration of 2.3 tonnes of CO_2 per hectare due to the preservation of permanent grasslands under GAEC 1 (Rudnicki *et al.*, 2023). The Hungarian farm "EcoVölgy Kft" in the Bács-Kiskun region receives annual eco-payments of EUR 180 per hectare for implementing agroforestry and diversified crop rotations. This approach allowed the farm to increase biodiversity by 60% and reduce pesticide use by 70% while maintaining profitability at the level of 15-18% (Santiago-Freijanes *et al.*, 2021).

The integration of the CAP with the European Green Deal has transformed agricultural policy into a key instrument for achieving EU climate neutrality by 2050. The "Farm to Fork" Strategy sets ambitious targets: a 50% reduction in pesticide use by 2030, a 20% reduction in fertiliser use, an increase in organic farming to 25% of agricultural land, and the restoration of 10% of agricultural land with high biological value (Cuadros-Casanova *et al.*, 2023). Achieving these goals will require a radical change in production practices, which will require significant investment in new technologies, retraining of farmers, and restructuring of supply chains (Wesseler, 2022). The financial architecture of the CAP in the context of the green transition is characterised by a stronger link between receiving support and complying with environmental requirements. The principle of cross-compliance has been replaced by stricter conditions, which include the mandatory allocation of at least 25% of funds to climate measures under direct payments and 35% in rural development programmes (Guyomard *et al.*, 2023). The new eco-schemes system provides for additional payments to farmers for implementing practices that exceed basic environmental requirements, including precision farming, agroforestry, organic production and biodiversity conservation.

For Ukraine, adapting to CAP standards means a radical transformation of traditional approaches to agriculture. The Ukrainian model of agricultural production, based on large latifundia with intensive use of resources, differs significantly from the European model of family farms with diversified production (Nivievskyi, 2024).

The average size of an agricultural enterprise in Ukraine is over 2,000 hectares, while in the EU it is about 17 hectares, which creates fundamentally different conditions for the implementation of environmental practices and monitoring of their compliance. Strategic dilemmas regarding adaptation to European standards have emerged in discussions about the conditions for Ukraine's future membership in the EU. Reports of Ukraine's possible willingness to give up CAP subsidies in exchange for a relaxation of the European Green Deal requirements have caused a wide resonance in European political and expert circles (Landlord, 2024). The potential volume of support that Ukraine could give up is estimated at approximately EUR 96.5 billion over a seven-year budget cycle, which is 25% of the total CAP budget. This position reflects the recognition that excessive regulatory burdens could significantly reduce the competitiveness of Ukrainian agricultural exports in global markets.

The arguments in favour of abandoning CAP subsidies are based on the experience of countries that demonstrate high agricultural productivity without significant state support. The New Zealand model, where subsidies were abolished in the 1980s, has shown that reducing state intervention can stimulate innovation and increase the efficiency of the industry (Landlord, 2024). However, critics of this approach point to the risks of a "painless" dependence on subsidies, which can reduce incentives for modernisation and adaptation to market conditions (Hardaker *et al*., 2015; Amaglobeli *et al*., 2024). At the same time, access to CAP subsidies could create competitive advantages for Ukrainian producers in the European market, especially in the context of growing demands for product sustainability and traceability. A compromise approach could be to gradually adapt to CAP standards, taking into account the specifics of the Ukrainian agricultural sector, and to gradually increase environmental requirements in parallel with the development of supporting infrastructure. The experience of Central and Eastern European countries that joined the EU in 2004-2007 shows that successful integration into the CAP is possible with an adequate transition period and technical support from European institutions (Runge *et al*., 2022). Poland, which has the largest agricultural sector among the new EU members, was able to modernise its agriculture by combining CAP financial support with investments in education, infrastructure and technology.

An alternative strategy could be to create a hybrid model that combines elements of European standards with global competitiveness of Ukrainian products. Such a model would involve a differentiated approach to different types of production: maximum integration with European standards for products intended for the EU internal market and more flexible requirements for export-oriented production for global markets. This would allow Ukraine to maintain its position in the global grain and oilseed markets while developing segments of high-quality products for European consumers. The long-term prospects for Ukraine's integration into European agricultural policy will depend on the country's ability to develop its own model of sustainable development that takes into account both European standards and national characteristics. Key success factors will include investment in education and advisory services for farmers, development of infrastructure for the introduction of environmentally friendly technologies, and creation of an effective system for monitoring compliance with standards. Ukraine has a promising opportunity to develop innovative approaches to combining productivity and sustainability in the agricultural sector, using its developed scientific potential and large land resources to demonstrate the capabilities of modern agriculture in the face of climate challenges.

Practical results of modernisation and recommendations for improvement

An analysis of the practical results of implementing budgetary mechanisms to stimulate the ecological modernisation of Ukraine's agricultural sector shows the formation of a transformation model that combines elements of European experience with adaptation to the specific conditions of large-scale agricultural production in a state of martial law. The documented successes of environmental technologies demonstrate the potential for systemic change, but also reveal structural constraints and the need for a comprehensive approach to

coordinating national and international efforts. The documented results of the implementation of environmental technologies in Ukrainian enterprises demonstrate measurable indicators of the effectiveness and economic feasibility of modernisation. According to the Research Institute of Precision Farming, Ukrainian agricultural enterprises that have implemented precision farming technologies have achieved a 30% reduction in the use of mineral fertilisers and plant protection products while maintaining productivity levels (Hrynevych *et al*., 2022). Statistics from the Ministry of Agrarian Policy of Ukraine show that fertilisers accounted for between 17% and 28% of costs per hectare in 2023, creating potential for savings through optimisation of their use (ReliefWeb, 2024). In the organic production sector, 33 companies from 13 regions of Ukraine received grant support amounting to 160 thousand Swiss francs under the fourth phase of the Organic Sector Grant Programme, which allowed them to expand the range of organic products and establish new supply chains (Organicinfo, 2024). Research by the Research Institute of Organic Agriculture (FiBL) indicates that Ukrainian organic enterprises continue to increase their export potential even under wartime conditions, demonstrating the resilience of the sector and the effectiveness of state support for organic production (FiBL, 2024).

Precision farming, as a priority area of environmental modernisation, shows the most promising results in terms of combining economic efficiency with environmental benefits. The introduction of GPS navigation, IoT (Internet of Things) sensors and artificial intelligence systems allows for a 15-25% reduction in fertiliser use while maintaining or even increasing yields (Khanal *et al*., 2017). European experience in the application of precision farming, particularly within the Horizon Europe programmes, shows that the integration of digital technologies with agroecological approaches can reduce greenhouse gas emissions by 20-30% compared to traditional methods (Bucci *et al*., 2018). In the Ukrainian context, the potential of precision farming to optimise resource use over large areas is critical, as the average size of an agricultural enterprise is 23,700 hectares, which is 1,763 times larger than the EU average (European Parliament, 2024). Research conducted as part of the European MACHINAIDE project shows that the automation of agricultural processes through robotic systems can increase the efficiency of pesticide use by up to 90% thanks to precise application only in the necessary areas (Gonzalez-de-Santos *et al*., 2017). For Ukraine, where the average size of agricultural enterprises significantly exceeds European indicators, such technologies can provide a pronounced effect of scale. At the same time, the introduction of precision farming requires significant initial investments and highly qualified personnel, which highlights the role of state support through co-financing mechanisms and educational programmes.

Bioenergy represents the second strategic direction of environmental modernisation with high potential for creating closed production cycles and reducing dependence on imported energy sources. European experience in developing bioenergy under the Renewable Energy Directive demonstrates the possibility of achieving a 32% share of renewable energy sources by 2030, with the agricultural sector as a key supplier of biomass (Scarlat *et al*., 2015). Ukraine has significant potential for the production of biofuels from agricultural waste, in particular cereal straw, which is estimated at 40-50 million tonnes per year (Ukrainian Bioenergy Association, n.d.; Vaskina *et al*., 2025). Research by the Biomass Futures project shows that the utilisation of agricultural waste for bioenergy production can provide farmers with additional income of EUR 50-100 per hectare while reducing CO_2 emissions by 2-4 tonnes per hectare (Dees *et al*., 2017). In the Ukrainian context, it is most expedient to develop biogas plants based on large agricultural enterprises, which will not only generate energy but also produce high-quality organic fertilisers as a by-product of anaerobic processing (Chepeliev *et al*., 2021).

Organic farming demonstrates the most documented positive results in terms of improving soil quality and restoring natural fertility. Long-term studies conducted by the European Long-term Ecosystem Research Network show that switching to organic farming for 5-7 years leads to a 10-25% increase in soil organic matter, a 30-50% increase in biological activity, and a

15-20% improvement in water retention capacity (Maeder *et al.*, 2002). The Ukrainian experience of Mykola Mysnyk's farm in the Chernihiv region fully correlates with European data, demonstrating an increase in the content of essential nutrients and humus over a five-year period of organic farming (Suspilne Chernihiv, 2021). The commercial success of organic production in Europe sets important benchmarks for Ukrainian producers – according to the Research Institute of Organic Agriculture (FiBL), the organic market in the EU is growing by 7-8% annually, reaching a volume of EUR 45 billion in 2021 (Willer *et al.*, 2023). The premium for organic products averages 20-40% compared to conventional products, which makes the transition to organic technologies economically attractive even with lower yields during the transition period (European Commission, 2023). Successful Ukrainian organic brands such as "Ekorod" and "Garna Organica" demonstrate the potential for integration into European supply chains and the achievement of high profitability. At the same time, exports of Ukrainian organic products to the European Union grow annually by 15-20%, indicating increasing competitiveness of Ukrainian producers in premium market segments (BrandStory, n.d.). However, the share of organic farmland in Ukraine remains only 1.1% of the total agricultural land area, which is significantly lower than the European Union average of 9.1% (European Commission, 2023).

A synthesised assessment of the current state of budgetary mechanisms for stimulating environmental modernisation reveals a complex system characterised by both high potential and structural constraints. The multi-vector nature of the system is reflected in the variety of support instruments – from direct grants to tax incentives and preferential lending – which allows to cover a wide range of needs of different categories of producers, but this diversity is accompanied by fragmented approaches, the lack of a unified strategy for integrating environmental criteria, and the complexity of coordination between different institutions. Dependence on international standards and funding, although it provides access to advanced technologies and resources, creates risks for the autonomy of national policy, which is particularly noticeable in the case of the introduction of environmental and social assessment within the framework of the "Affordable Loans 5-7-9%" programme under the influence of World Bank requirements, which illustrates how external factors can radically change the logic of internal support programmes. On the one hand, this accelerates the introduction of advanced standards and improves the quality of environmental regulation, but on the other hand, it creates risks of inconsistency between international requirements and the specific needs of the Ukrainian agricultural sector. The adaptability of policy to feedback demonstrates positive dynamics in improving support mechanisms based on practical experience. in particular, the revision of grant programme conditions, including the reduction of job creation requirements in greenhouse projects, demonstrates the ability of state institutions to respond to signals from the business community and adjust policies to increase their effectiveness, which is an important competitive advantage for rapid adaptation to changing conditions and optimisation of support programmes.

European experience in developing and implementing policies to support environmental modernisation provides important lessons for improving Ukrainian mechanisms. Studies on the effectiveness of agri-environmental measures (AEM) within the CAP show that the most successful programmes are those that combine economic incentives with technical support and educational components (Pe'er *et al.*, 2022). In particular, Swiss experience shows that involving farmers in programme development and providing advisory support increases participation by 40-60% compared to programmes based solely on financial incentives (AHDB, n.d.). Key recommendations for improving budgetary mechanisms to stimulate environmental modernisation are based on a synthesis of Ukrainian experience and European best practices, where the synchronisation of national and international programmes requires the creation of a single coordination platform that would ensure the alignment of objectives, criteria and procedures of different funding sources.

The experience of the Netherlands in creating the National Strategic Framework for CAP

demonstrates the possibilities of effective integration of European requirements with national priorities through the development of comprehensive multi-year plans (European Commission, 2022). The development of environmental monitoring indicators is critical for assessing the real effectiveness of budget expenditures and adjusting policies based on objective data, as European experience with the Farm Sustainability Data Network shows that systematic collection of data on environmental performance at the farm level allows not only to assess the effectiveness of programmes, but also to identify best practices for their scaling up (Zasada *et al*., 2019). It is important for Ukraine to develop digital monitoring systems that will allow environmental indicators to be integrated with existing reporting systems through the DAR. Simplifying access to support programmes should be based on the principles of a "one-stop shop" and the digitalisation of procedures, as European experience shows that reducing the administrative burden can significantly increase the participation of small farmers in support programmes. At the same time, it is important to maintain the necessary level of control and reporting to ensure the targeted use of funds and the achievement of environmental results.

Using the DAR as a single point of entry for all support programmes creates unique opportunities for Ukraine to coordinate national and international initiatives, where expanding the platform's functionality to include planning, monitoring and reporting tools could transform it into a comprehensive system for managing the environmental modernisation of the agricultural sector. Experience with the digitalisation of agricultural subsidy management systems shows that the introduction of digital solutions can reduce administrative costs by 40% while improving the quality of control and transparency of fund distribution (Ehlers *et al*., 2021). The practical results of implementing budgetary mechanisms to stimulate environmental modernisation in Ukraine demonstrate measurable indicators of the effectiveness of the system for supporting sustainable development in the agricultural sector. Under the eRobota programme, UAH 723 million has been invested in horticulture and greenhouse farming over a year and a half, providing 70% of state co-financing for projects (Cabinet of Ministers of Ukraine, 2024). The company Carbominer, having received a grant from the Climate Innovation Vouchers initiative, developed a technology for capturing CO_2 to enhance greenhouse crop growth, accelerating the development of tomatoes and cucumbers using environmentally safe methods (EBRD, 2024). The FAO and EU support programme provided USD 2.8 million to 237 Ukrainian agricultural producers in four regions, enabling investment in green technologies and critical infrastructure (European External Action Service, 2024). In the precision farming sector, Ukrainian enterprises have achieved a 30% reduction in the use of mineral fertilisers and plant protection products while maintaining productivity (Hrynevych *et al*., 2022). In organic production, 33 companies received 160,000 Swiss francs in grant support to expand their product range and establish new supply chains (Organicinfo, 2024). However, scaling up these results requires coordination of national and international efforts, development of a system for monitoring environmental results, and simplification of access to support programmes by reducing co-financing requirements and administrative barriers.

DISCUSSION

The results of the study indicate the formation of a multi-level system of budgetary incentives for the ecological modernisation of Ukraine's agricultural sector, characterised by funding of UAH 24.4 billion for 2025 and coverage of over 308,000 beneficiaries. Traditional subsidy mechanisms (70% of the total volume) were found to dominate over targeted environmental programmes, with international support demonstrating stricter environmental criteria and a smaller coverage of participants. A transformation of preferential lending programmes was identified through the introduction of mandatory environmental and social assessments, which changed the logic of financial support from general economic to environmentally oriented.

An analysis of financial instruments supporting the agricultural sector in the context of climate change showed similar trends to the conclusions of B. Olajide *et al.* (2025), who substantiated the critical importance of integrating

climate risks into agribusiness financial mechanisms. The researchers proved that traditional approaches to financing agriculture have proved incapable of ensuring the sustainability of food systems in the context of climate change, which fully corresponded to the Ukrainian reality of the dominance of subsidy programmes without environmental criteria. B. Olajide *et al.* focused on the need to develop innovative financial products that take into account long-term environmental risks and benefits, confirming the validity of Ukraine's transition to environmental and social assessment within the framework of its preferential lending programme. The authors' conclusion that mixed financing from public and private sources could increase the availability of capital for sustainable agricultural technologies by 40-60% was decisive, which was consistent with Ukraine's experience of coordinating national and international programmes through the State Agrarian Register. At the same time, the authors did not consider the specifics of large-scale agricultural production characteristic of Ukraine, where the average size of an enterprise was 2,000 hectares compared to 17 hectares in the EU, which required the adaptation of financial mechanisms to the conditions of the latifundia model of farming.

The issue of combining different financial instruments to stimulate sustainable transitions in agriculture was further confirmed in the work of T. Havemann *et al.* (2022), which explored the limitations and opportunities of blended finance. Ukrainian data on the synergistic effect of the simultaneous use of 30% of recipients of international grants from state support programmes confirmed the researchers' thesis that combining grants, preferential loans and technical assistance could increase the effectiveness of investments in sustainable technologies by 25-35%. The authors emphasised the importance of creating "financial ecosystems" that integrate different types of capital to reduce risks and increase the attractiveness of investments in sustainable development, which correlated with Ukraine's experience of creating a unified digital platform through the DAR. However, T. Havemann *et al.* focused mainly on blended finance mechanisms for smallholder farms in developing countries, while Ukrainian realities demonstrated the need to adapt these approaches to the conditions of industrial agricultural production with a high level of technological equipment. The researchers identified the critical role of blending in overcoming the "valley of death" for innovative agricultural technologies, which partly explained the success of Ukrainian grant programmes with co-financing requirements of 30-50%, which created incentives for attracting private capital.

The barriers to sustainable agribusiness were reflected in a systematic review by R. Brenya *et al.* (2023), who identified financial constraints as one of the key obstacles to the transition to sustainable practices. The results of a Ukrainian study on the complexity of access to support programmes, where only 15-20% of applications submitted met the formal requirements, confirmed the researchers' conclusions that administrative complexity and documentation requirements were critical barriers for small producers. R. Brenya *et al.* substantiated a conceptual framework in which financial barriers interacted with technological, institutional and information constraints, creating systemic obstacles to modernisation. The authors emphasised the role of insufficient access to long-term financing and high transaction costs, which fully correlated with Ukrainian findings about the inaccessibility of co-financing requirements for most farms cultivating up to 50 hectares. At the same time, the researchers did not take into account the specifics of martial law and its impact on financial accessibility, which proved to be critically important for the Ukrainian context, where infrastructure destruction and population displacement created additional challenges for the implementation of support programmes.

The transformation of transition management systems towards sustainable agriculture, identified in the study by I. Melchior & J. Newig (2021), resonated with Ukrainian conclusions about the evolution from reactive support to proactive shaping of the investment climate. The researchers argued for the need to integrate different levels of governance and create adaptive institutional mechanisms, which was reflected in the Ukrainian experience of coordinating national and international programmes through a single digital platform. I. Melchior & J. Newig

identified the importance of multiple stakeholders' participation in policy-making, which was partially implemented in Ukrainian practice of adapting programmes based on feedback from the business community, in particular, revising the requirements for job creation in greenhouse projects. The authors substantiated the concept of "governed transitions", where public policy played a catalytic role in stimulating systemic change, which correlated with Ukraine's experience of using budgetary mechanisms as tools for the forced greening of agribusiness. However, the researchers focused mainly on the theoretical aspects of transition management, without considering the practical challenges of coordinating different sources of funding and ensuring environmental efficiency in a context of limited resources.

The bioeconomic aspects of agricultural transformation analysed by T. Wang *et al.* (2022) in the context of ASEAN (Association of Southeast Asian Nations) countries demonstrated alternative approaches to stimulating sustainable development compared to the Ukrainian model. The Ukrainian results on the development of bioenergy with a potential utilisation of 40-50 million tonnes of straw per year were consistent with the authors' conclusions about the critical role of biomass in shaping the circular economy. They proved that the bioeconomic approach could provide additional sources of income for farmers through the creation of integrated production systems, which correlated with Ukrainian data on the potential for additional income of EUR 50-100 per hectare from the utilisation of agricultural waste. At the same time, T. Wang *et al.* focused primarily on the policy framework and strategic planning, without considering specific financial incentive mechanisms, which was a fundamental difference from the Ukrainian focus on budgetary instruments. The researchers identified the importance of cross-sectoral coordination and the creation of innovative ecosystems, which was partially implemented in the Ukrainian initiative "Green Modernisation of the Agro-Industrial Complex 2025" with a budget of UAH 120 billion, but without a detailed analysis of the mechanisms for ensuring synergy between the various components of the programme.

The challenges of sustainable development within the European Green Deal, researched by C. Boix-Fayos & J. de Vente (2023), directly concerned Ukraine's prospects for European integration and adaptation to EU standards. Ukrainian conclusions regarding the strategic dilemma between access to European markets and maintaining the competitiveness of agricultural exports were confirmed by the work of scientists who substantiated the complexity of balancing ambitious environmental goals and the economic viability of agriculture. C. Boix-Fayos & J. de Vente found that achieving the goals of the "Farm to Fork" strategy required a radical change in production practices and significant investment, which correlated with Ukrainian estimates of potential losses from excessive regulatory burdens. The authors argued for the need for a differentiated approach to different agro-ecological zones and types of farming, which resonated with Ukrainian proposals to create a hybrid model with different requirements for domestic and export production. However, the authors focused mainly on the environmental aspects of the transformation, paying insufficient attention to financial mechanisms and their effectiveness in stimulating the necessary changes.

The role of digitalisation in achieving sustainable development goals, analysed by J. MacPherson *et al.* (2022), correlated with Ukrainian conclusions regarding the potential of precision farming to combine economic efficiency with environmental benefits. The results of the Ukrainian study on the possibility of reducing fertiliser use by 15-25% while maintaining crop yields confirmed the thesis that the integration of IoT sensors, GPS navigation and artificial intelligence could radically increase the resource efficiency of agricultural production. The authors identified a synergistic effect from combining digital technologies with agroecological approaches, which could reduce greenhouse gas emissions by 20-30%, consistent with Ukrainian estimates of the environmental potential of precision farming. At the same time, J. MacPherson *et al.* did not consider specific financial mechanisms to stimulate the adoption of digital technologies, while the Ukrainian study demonstrated the critical role

of state support through equipment cost compensation programmes and grant funding to ensure the accessibility of innovative solutions to a wide range of producers.

The importance of legumes in the transition toward sustainable agri-food systems, substantiated by H. Ferreira *et al.* (2021), further confirms Ukrainian conclusions regarding the importance of production diversification for improving environmental resilience. Ukrainian findings on the ecological potential of the "Orchard Grant" programme aimed at stimulating diversification of agricultural production find theoretical support in the work of H. Ferreira *et al.*, who demonstrated the role of legumes in preserving biodiversity and restoring soil fertility. The authors found that integrating legumes into crop rotations could reduce the need for synthetic fertilisers by 40-60% and increase carbon sequestration in the soil, which correlated with Ukrainian data on soil quality improvement in organic farms. H. Ferreira *et al.* argued for the need for policy support to encourage legume cultivation through financial incentives and educational programmes, which resonated with the Ukrainian experience of grant support for production diversification. However, the researchers focused mainly on agronomic aspects, without considering specific budgetary mechanisms and their effectiveness in stimulating the necessary changes in the structure of cultivated areas.

Thus, the study of budgetary mechanisms for stimulating the ecological modernisation of Ukraine's agricultural sector revealed the formation of a unique model that combined elements of international experience with adaptation to specific national conditions. A comparative analysis with the works of leading researchers confirmed the validity of Ukrainian approaches to integrating environmental criteria into financial programmes, while also revealing the need for further improvement in coordination between different levels of support and strengthening the targeting of budget expenditures to achieve specific environmental results.

CONCLUSIONS

The study shows that Ukraine is developing a comprehensive system of budgetary incentives for the ecological modernisation of the agricultural sector, characterised by significant structural transformations and adaptation to European standards in conditions of martial law. An analysis of existing budgetary instruments has revealed a multi-level support architecture with total funding of over UAH 24 billion in 2025, covering more than 300,000 beneficiaries through various mechanisms ranging from direct grants to tax incentives. At the same time, a fundamental imbalance has been identified between the volume of traditional subsidy programmes, which account for the bulk of funding, and targeted environmental initiatives with clear environmental criteria. A key trend in the development of the system has been the integration of environmental standards into financial programmes under the influence of international partners, which has been most evident in the introduction of mandatory environmental and social assessments as part of the preferential lending programme. This demonstrates an evolution from reactive support to proactive shaping of the investment climate, where access to financial resources becomes a tool for enforcing the greening of agribusiness. International support, despite its smaller absolute volumes compared to national programmes, is characterised by stricter environmental criteria and higher funding intensity per beneficiary, creating a synergistic effect with government initiatives.

The systematisation of European experience has revealed Ukraine's strategic dilemma between the need to adapt to the standards of the EU's Common Agricultural Policy and maintaining the competitiveness of agricultural exports on global markets. An analysis of the CAP architecture demonstrates a fundamental transformation of European agricultural policy from a mechanism for ensuring food security to an instrument for implementing climate ambitions, which creates additional challenges for Ukraine's integration into the European agricultural space. The specifics of the Ukrainian agricultural sector, with an average enterprise size of over 2,000 hectares, differ radically from the European model of family farms, requiring the development of hybrid approaches to environmental modernisation that take into account the large scale of Ukrainian agricultural production.

Potentially giving up CAP subsidies in exchange for relaxing the European Green Deal requirements could be a compromise that would let the industry keep its export potential while gradually adapting to environmental standards. The practical results of the implementation of precision farming, bioenergy and organic production technologies demonstrate the potential of combining economic efficiency with environmental benefits, showing the possibility of reducing resource use while maintaining productivity. However, scaling up these technologies requires coordinated state support through the creation of comprehensive financing and technical support programmes.

The main limitations to the effectiveness of the existing system are the fragmentation of environmental criteria in traditional support programmes, the difficulty of access to grant funding for small producers due to high co-financing requirements, and the lack of a comprehensive system for monitoring the environmental results of budget expenditures. To improve the effectiveness of budgetary mechanisms, it is necessary to develop a unified coordination platform that will ensure the synchronisation of national and international programmes, the introduction of digital technology-based environmental monitoring indicators, and the simplification of administrative procedures while maintaining control functions. The limitations of the study are related to the dynamic nature of transformation processes in a state of martial law and the lack of long-term data to assess the environmental effects of the programmes implemented. Prospects for further research include analysing the impact of digitalisation on the effectiveness of budgetary mechanisms, studying models for financing the transition to a circular economy in the agricultural sector, and developing a methodology for assessing ecosystem services as a basis for new budgetary incentive tools.

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Бюджетні механізми стимулювання екологічної модернізації аграрного бізнесу в Україні

Анотація. Метою даного дослідження було здійснення комплексного аналізу системи бюджетних інструментів стимулювання екологічної трансформації українського агросектору та розроблення науково обґрунтованих рекомендацій щодо оптимізації механізмів державного фінансування сталого розвитку аграрного виробництва. Методологічну основу склали принципи системності, об'єктивності та історизму, застосовувалися структурно-функціональний аналіз, порівняльний аналіз, контент-аналіз та аналіз вторинних даних для дослідження нормативно-правової бази, офіційних звітів та статистичних матеріалів за період 2024 – початку 2025 років. Встановлено формування багаторівневої системи бюджетного стимулювання з обсягом фінансування понад 24 млрд грн у 2025 році, що охоплює понад 300 тисяч бенефіціарів через механізми від прямих грантів до податкових стимулів, при цьому виявлено диспропорцію між традиційними субсидійними програмами, які становлять 70 % від загального обсягу, та цільовими екологічними ініціативами. Ключовою тенденцією стала інтеграція екологічних стандартів у фінансові програми під впливом міжнародних партнерів, що проявилося у впровадженні обов'язкової екологічної та соціальної оцінки в рамках програми пільгового кредитування, демонструючи еволюцію від реактивної підтримки до проактивного формування інвестиційного клімату. Систематизація європейського досвіду виявила стратегічну дилему України між адаптацією до стандартів Спільної аграрної політики Європейського Союзу та збереженням конкурентоспроможності агроекспорту, при цьому практичні результати впровадження технологій точного землеробства, біоенергетики та органічного виробництва засвідчили потенціал скорочення використання ресурсів на 15-25 % при збереженні продуктивності. Основними обмеженнями ефективності визначено фрагментарність екологічних критеріїв у традиційних програмах підтримки, складність доступу до грантового фінансування для малих виробників через високі вимоги до співфінансування та відсутність комплексної системи моніторингу екологічних результатів бюджетних витрат. Дослідження сформувало науково-методичну основу для удосконалення державної політики стимулювання екологічної модернізації агросектору через створення координаційних платформ, впровадження цифрових систем екологічного моніторингу та розроблення диференційованих підходів до фінансування різних категорій виробників

Ключові слова: державна підтримка; фінансові інструменти; грантові програми; субсидії; податкові пільги

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Ecological and economic approaches to assessing damage caused to agricultural land by military actions

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Abstract. This article aimed to evaluate the ecological and economic consequences of military actions on agricultural land in Ukraine, identifying key indicators to assess the environmental impact of warfare and facilitate subsequent agribusiness restoration in the post-war period. The research was based on a comprehensive analysis of the environmental, economic, and social consequences of military actions for Ukraine's agricultural sector. This analysis used field surveys, satellite data, laboratory soil analyses, and official statistics. The research established that more than 200,000 hectares of agricultural land were damaged as a result of hostilities, around 20% of which was the most fertile land taken out of agricultural use. Exceedances of permissible levels of heavy metals in soil were recorded in the Kharkiv, Donetsk, Mykolaiv, Luhansk and Zaporizhzhia regions: lead by three times, cadmium by 2.5 times, arsenic by twice, nickel by more than twice and zinc by 1.6 times. Conversely, no exceedance of the maximum permissible concentrations of mobile forms of heavy metals, including lead and cadmium, was detected within the agricultural lands studied in the Vyshhorod district of the Kyiv region. Significant exceedances of background levels of heavy metals in soil pose long-term risks to the quality and safety of food products, lead to economic losses, and endanger public health. This emphasises the importance of monitoring soil contamination in areas affected by hostilities and at agricultural enterprises. The research revealed that direct economic losses included the loss of over 4 million hectares of crops and the destruction of over 100 grain storage facilities with a total capacity of 2 million tonnes. There was also a decrease in yields on over 500,000 hectares due to the loss of irrigation systems. Indirect losses were reflected in a 15-20% reduction in production, a 35-40% increase in food prices, a 40% decline in investment volumes, and the suspension of operations for more than 30% of small and medium-sized enterprises. The socio-economic consequences included the migration of over 6.5 million people and a deterioration in food security. However, the territory in question also possesses significant potential for recovery

Keywords: soil degradation; agricultural sector; costs; food security; state support

INTRODUCTION

The relevance of the research topic was determined by significant transformations in Ukraine's agricultural sector resulting from military action. Damage to the soil cover, destruction of infrastructure, loss of harvests and technical resources created multidimensional consequences requiring systematic scientific assessment. Combining ecological and economic approaches in the assessment of damage was deemed necessary because land degradation and loss of productivity were reflected not only in a reduction in agricultural production potential, but also in a decline in investment attractiveness and an increase in socio-economic risks. Scientific research into the impact of military action on the economy and the environment provides a comprehensive understanding of the negative consequences of armed conflict for various sectors, including agriculture. L. Khomych & N. Khrushch (2024) have proposed an analytical assessment of the impact of the war on Ukraine's economic activity. This contributes to understanding of the extent of the structural changes to the national economy caused by the conflict. The impact on the agricultural sector is particularly significant, as war leads to reduced production, lost land and increased investment risks. A. Verstyak (2023) described methods for assessing environmental damage, helping to analyse the impact of war on agricultural land. Soil contamination with heavy metals and ecosystem degradation lead to substantial economic losses. Meanwhile, O. Sushchenko & V. Tymkovan (2024) examined the impact of martial law on the development of agro-industrial formations, confirming the importance of studying the socio-economic consequences of war for the agricultural sector, as well as the need to develop effective recovery models. The environmental consequences of war are also addressed in L.A. Sakhno's (2023) research, which highlights the impact of military operations on accounting policies and land resource auditing. This is directly relevant to the need to combine ecological and economic approaches to restoring agricultural land after war.

A. Kucher (2022), meanwhile, proposed changes to the methods used to determine the extent of damage resulting from mechanical, physical, chemical, physico-chemical and biological forms of soil degradation, based on a cost-based methodological approach. T.M. Gerlyand *et al.* (2024) presented examples of integrating educational practices into the reconstruction of the agricultural sector, emphasising the importance of environmental education for the sustainable development of rural areas. When assessing the environmental consequences of hostilities on soils, particularly agricultural land, results from studies analysing changes in the physicochemical and toxicological characteristics of soils are particularly relevant. O.V. Dmytrenko *et al.*'s (2023) study focuses on the ecotoxicological assessment of sod-podzolic soil under the influence of military actions. The authors identified changes in the soil's agrochemical indicators, demonstrating the need to develop methods for assessing and restoring soils after hostilities. Another important aspect is monitoring the environmental consequences, particularly the impact of fires resulting from hostilities. A.E. Honcharova (2024) examines the environmental consequences of military actions in Ukraine, including the impact of fires on ecosystems. The author emphasises the necessity of a comprehensive approach to monitoring and assessing environmental consequences, including studying the impact of fires on soils and agricultural land. These studies emphasise the importance of taking an integrated approach to assessing and restoring agricultural land after conflict, particularly by applying a cost-based method to determine the extent of the damage based on the cost of soil restoration. R. Wenning & T.D. Tomasi (2023), for example, applied natural resource damage assessment approaches to identify the scale of environmental damage by evaluating ecosystem services. Satellite-based assessment of agricultural crop losses in near-real time is also widely used. K. Deininger (2023) conducted such an assessment, making it possible to record the spatial reduction of agricultural areas and demonstrating the effectiveness of remote sensing for rapidly monitoring damage. M. Nehrey & R. Finger (2024) examined the impact of the initial phase of the full-scale war in Ukraine on soil degradation and the decline in land productivity. Their work analysed regional differences in degradation rates and the development of differentiated recovery strategies.

A synthesis of scientific sources showed that modern approaches to studying the ecological and economic consequences of military action involve analysing soil conditions, biodiversity and ecosystem losses, and the economic impact of losses resulting from hostilities. These approaches also include the application of satellite technologies and the development of institutional mechanisms for restoring degraded territories, including agricultural land. Meanwhile, some studies have focused on specific aspects of the impact of military action on the environment and agricultural production. However, insufficient attention has been paid to studying ecological-economic approaches or developing an integrated model for assessing damage to the agricultural sector caused by military actions. This article aimed to investigate the scale of damage to agricultural land resulting from military actions, as well as changes to its ecological and economic characteristics. The article also aimed to determine priority areas for restoring productivity and safety within Ukraine's agricultural sector. To achieve this, the following tasks were set: to determine the scale of soil degradation and the level of contamination of agricultural land resulting from active hostilities, comparing regions; to assess direct and indirect economic losses in the agricultural sector resulting from hostilities, including losses of crops, infrastructure, and investment attractiveness; to analyse he socio-economic consequences of the war and prospects for the management of agricultural enterprises in the post-war period were outlined.

MATERIALS AND METHODS

Conducted between 2022 and 2025, the research aimed to provide a comprehensive examination of the ecological and economic consequences of military actions for Ukraine's agricultural sector. The analysis was based on agricultural lands in the central, eastern and southern regions, which were the most significantly impacted by hostilities. Territories were selected based on official data from the Ministry of Agrarian Policy

presented... (2024), the State Statistics Service of Ukraine (2024) and a Copernicus-enabled assessment (2023). Satellite images presented in Farming Amidst a War (2023) enabled the scale of damage to arable land and infrastructure degradation in the Kyiv region to be identified. Inclusion in the sample was dependent on the availability of confirmed data regarding damage to soil cover, infrastructure destruction, or productivity decline resulting from military actions. Territories where information was incomplete or not confirmed by independent sources were excluded from the research. To assess the environmental consequences, studies of pollutant concentrations in soil were conducted in agricultural land located in the de-occupied territories. Analytical methods were employed to gather data on the contamination of agricultural land in the liberated areas of the Donetsk, Luhansk, Kharkiv, Zaporizhzhia, and Mykolaiv regions. Field studies were carried out within agricultural lands in the Kyiv region that had been liberated and experienced the impact of hostilities in 2022 (Fig. 1).

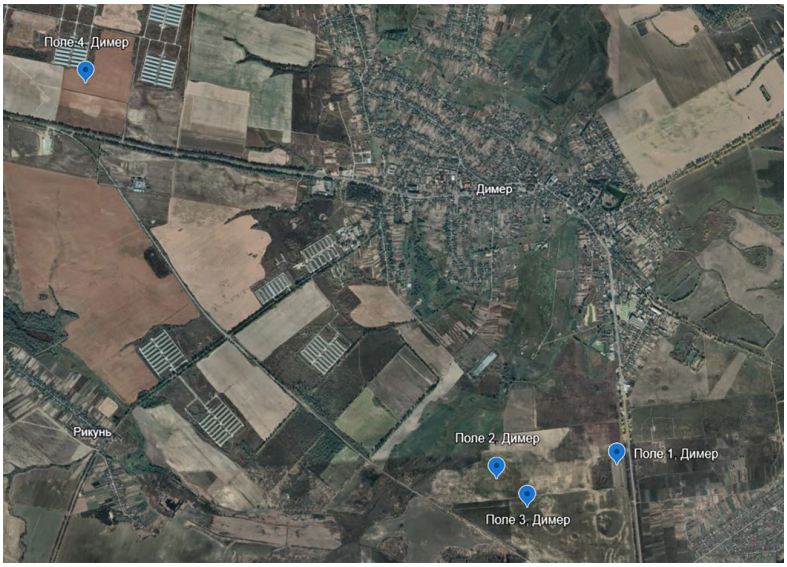

Figure 1. Location of the studied sites within the Vyshhorod district of the Kyiv region on agricultural land affected by hostilities in 2022

Source: Google Maps (n.d.)

The satellite image shows the location of the agricultural plots that were studied within the territory of the Dymer settlement (Vyshhorod district). The individual fields selected for assessing soil conditions and the consequences of military impact are indicated. Sampling to determine agrophysical and agrochemical soil indicators, as well as pollutant content, was carried out in accordance with ISO 10381-1:2004 (2006), ISO 10381-2:2004 (2006) and ISO 10381-4:2005 (2007). Composite soil samples were taken from the 0-30 cm layer using a manual sampler. To ensure comparability, control soil samples were also taken from areas unaffected by military action. Heavy metal concentration studies (cadmium (Cd), cobalt (Co), nickel (Ni), lead (Pb) and chromium (Cr)) were conducted using a combination of chromatographic and mass spectrometry techniques with Agilent 1260, 1290 and 7890B liquid and gas chromatographs (Agilent 6125, 6460 and 5977 and 7000 detectors). The biodiversity of the Kyiv, Kharkiv and Zaporizhzhia regions was assessed using indicators of soil microbiological activity and the abundance of saprophytic organisms obtained from control plots. To this end, the Shannon (H') and Simpson (D) indices, as well as the abundance of saprophytic organisms in the

studied plots, were employed in accordance with widely accepted methodologies.

The economic component of the research was based on official statistics from the World Bank (2023), the OECD (2023), and the FAO of Ukraine. Food Security (2024). Direct losses were assessed by considering the area of lost crops, the volume of damaged or destroyed warehouses and grain storage facilities, the number of lost agricultural machines, and the area of land left without irrigation. Indirect losses were calculated based on reduced enterprise productivity, declining exports and falling investment activity. To evaluate the financial risks to agribusinesses, lending dynamics and changes in interest rates were analysed using data from the National Bank of Ukraine (2025). The socio-economic component of the study was based on statistical materials from the Country Report: Ukraine (2022) and Food Security and Livelihoods (2023). The analysis examined increases in food prices, household budget composition, the scale of internal and external migration, and the reduction in labour potential within the agricultural sector. Statistical analysis was carried out using SPSS Statistics 26 software.

RESULTS AND DISCUSSION

Environmental consequences of military actions for agricultural land

In the context of Ukraine's current environmental policy, the key areas of environmental protection and ecological safety defined in Law No. 188/98-BP (1998) provide for the implementation of sustainable development principles, the rational use of natural resources and consideration of environmental risks, which intensify under conditions of armed conflict. In view of the significant losses incurred by the agricultural sector, particularly in terms of soil degradation and territorial contamination resulting from hostilities, these priorities assume particular relevance in the context of post-war agricultural recovery and ensuring the country's environmental stability. In this context, it is important to assess the current state of agricultural land in areas affected by military action. During the active phase of hostilities, significant soil degradation was recorded, characterised by mechanical soil disturbance, changes in physicochemical properties, and pollutant accumulation. The mechanical pressure exerted by heavy military equipment caused the upper soil layers to become compacted, which negatively affected their agrophysical properties (porosity, water permeability, aeration, etc.), agrochemical indicators, and pollutant content. This has led to a reduction in agricultural land productivity, accelerated degradation processes and, in some cases, made it impossible to produce high-quality, safe agricultural products. The destruction of hydraulic structures, particularly the Kakhovka Hydroelectric Power Plant, resulted in heavy metals such as arsenic, nickel, and zinc migrating from bottom sediments into the Dnipro River and Black Sea ecosystems (Solokha *et al*., 2024). The use of contaminated water to irrigate adjacent agricultural land resulted in soil contamination, creating long-term environmental risks. The biodiversity of agroecosystems declined, as evidenced by a reduction in the number of saprophytic microorganisms and invertebrates that play a fundamental role in forming soil structure.

According to estimates by Ukraine's State Statistics Service (2024), more than 200,000 hectares of agricultural land were contaminated and damaged during the active phase of hostilities. Around 20% of the most valuable agricultural land was taken out of use as it was impossible to carry out agrochemical investigations, even after de-occupation. The chemical contamination of soils with heavy metals such as lead and cadmium, which significantly exceeded standard values, has intensified degradation processes and reduced the productivity of agricultural enterprises. According to the Ministry of Agrarian Policy presented... (2024), grain harvest losses in 2023 amounted to over 4 million tonnes, equivalent to a 25% reduction in gross output, with farmers incurring losses in excess of USD 1.5 billion. According to data from the State Statistics Service of Ukraine (2024), over 20% of agricultural land has been taken out of use due to soil degradation, limiting the potential to restore agricultural production and export capacity. This leads to lower farm incomes and an annual reduction in GDP of 0.8-1.0%. To establish the actual impact of hostilities on agricultural enterprise territories and determine

ecological and economic approaches to assessing the impact of military actions, a series of analytical, field, and laboratory studies were carried out. A study of heavy metal content in the arable soil layer was conducted on the basis of statistical data in territories where active hostilities took place, particularly involving the use of munitions and the movement of heavy equipment, in the Kharkiv, Donetsk and Luhansk regions. Exceedances of the maximum permissible concentrations (MPCs) of the heavy metals lead, cadmium, chromium and arsenic were identified in the soils of the Kharkiv, Luhansk and Zaporizhzhia regions (Table 1).

Table 1. Specific indicators of the environmental consequences of military actions for agricultural land

Indicator	Value	Unit of measurement	Standard / Reference value
Area of damaged land	200,000	ha	–
Share of the most fertile land taken out of use	20	%	–
Soil lead (Pb) concentration	95	mg/kg	≤ 32 mg/kg (standard)
Soil cadmium (Cd) concentration	2.5	mg/kg	≤ 1.0 mg/kg (standard)
Soil arsenic (As) concentration	20	mg/kg	≤ 10 mg/kg (standard)
Soil zinc (Zn) concentration	350	mg/kg	≤ 220 mg/kg (standard)
Soil nickel (Ni) concentration	85	mg/kg	≤ 40 mg/kg (standard)

Source: compiled by the authors on the basis of data from The Ministry of Agrarian Policy presented... (2024)

A substantial exceedance of standard values was recorded: lead by three times, cadmium by 2.5 times, arsenic by twice, nickel by more than twice, and zinc by 1.6 times. The obtained data indicate a probable reduction in the area of agricultural land suitable for producing safe, high-quality products, as well as the need to restrict the use of such land and to develop protocols for applying new reclamation methods and approaches to cultivating crops on contaminated soils. The rising risks to public safety, loss of fertile land and need for long-term land reclamation measures create long-term economic risks. Field studies carried out in the Kyiv region showed elevated levels of cadmium, cobalt, nickel, lead, and chromium compared to background values, though without exceeding maximum permissible concentrations (MPCs) (Table 2).

Table 2. Content of mobile forms of heavy metals in fields liberated from military actions on agricultural land in the Vyshhorod district of Kyiv region

Indicator	Value	Unit of measurement	MPC for mobile forms
Soil lead (Pb) concentration	0.85 ± 0.1	mg/kg	≤ 6.0 mg/kg (standard)
Soil cadmium (Cd) concentration	0.018 ± 0.001	mg/kg	≤ 0.7 mg/kg (standard)
Soil cobalt (Co) concentration	0.31 ± 0.1	mg/kg	≤ 5.0 mg/kg (standard)
Soil chromium (Cr) concentration	0.060 ± 0.001	mg/kg	≤ 6.0 mg/kg (standard)
Soil nickel (Ni) concentration	0.81 ± 0.01	mg/kg	≤ 4.0 mg/kg (standard)

Source: compiled by the authors on the basis of data from Resolution of the Cabinet of Ministers of Ukraine No. 1325 (2021)

As shown in Table 2, the levels of mobile lead, cadmium, cobalt, chromium and nickel in the soils of the agricultural land under study are higher than background values. However, all indicators remain significantly below the maximum permissible concentration standards. Therefore, even in the absence of exceedances of the standard values for pollutants, military actions lead to complex disruptions in the functioning of agroecosystems, including the environmental consequences of agro-landscape transformation. This is consistent with

the conclusions of A. Santini *et al.* (2023), who emphasised the importance of analysing biological invasions. They noted that disrupting the ecological integrity of agro-landscapes through explosions and destroying the fertile layer significantly complicates the process of natural recovery and compounds threats to biodiversity. The results of the study correlate with the conclusions of M.J. Lawrence *et al.* (2015), who found that military action significantly reduces biodiversity and worsens the ecological condition of land, resulting in long-term consequences for agriculture. The results also confirmed the conclusion regarding the negative impact of mechanical soil compaction caused by heavy machinery and chemical contamination, which reduces the land's ability to recover naturally. This is consistent with the findings of A.B. Rexhepi *et al.* (2023), who confirmed a significant economic decline in Ukraine's agricultural sector during the war, due to reduced sown areas and falling productivity in agricultural enterprises. The Ukrainian government has launched a programme to recover the agricultural sector. Under this programme, investments totalling more than USD 5 billion are planned for the repair of damaged infrastructure, particularly irrigation systems, and for land reclamation. The programme also involves the government providing concessional loans to farms to help them restore production, at a maximum rate of 5-7% (National Bank of Ukraine, 2025).

A study by M. Khan (2022) highlighted the environmental consequences of war and conflict, particularly with regard to soils and natural resources. P. Broomandi *et al.* (2020) indicated that soil contamination by heavy metals reduces fertility and affects ecological systems, particularly in war zones. As M. Khan's study noted, these changes pose long-term risks to ecosystems and agricultural productivity, both of which are crucial for the post-war restoration of land in Ukraine. D. Rawtani *et al.* (2022) focused their work on the environmental damage caused by the war in Ukraine, particularly the contamination of soils and water resources by heavy metals and toxic substances. They also emphasised that the resulting decline in soil fertility from hostilities and explosive munitions poses serious threats to food security. The present study confirms this, recording elevated concentrations of heavy metals such as lead, cadmium and arsenic in agricultural soils, thereby limiting their suitability for agricultural activity. L. Chai *et al.* (2024) analysed the impact of war on the global expansion of agricultural land and biodiversity. The findings point to possible changes in global agricultural landscapes, which could affect Ukraine through changes in agri-food networks and the adaptation of agriculture to new conditions. This is supported by the present findings, which note that environmental losses, particularly through land degradation, may make it more difficult to restore production and alter global food flows. B. Chen *et al.* (2024) assessed the impact of military actions on agricultural production in eastern Ukraine, identifying a significant reduction in cultivated areas and a decline in productivity. This is an important component of the present analysis, in which it was calculated that more than 30% of agricultural land remained unused due to hostilities, resulting in substantial economic losses. At the same time, their conclusions confirm the need for international assistance and state support to restore the agricultural sector in the post-war period. The assessment of agroecosystem biodiversity involved determining the microbiological activity of soils and the abundance of saprophytic organisms in both intact and damaged areas (Table 3).

Table 3. Assessment of soil biodiversity in control and damaged plots

Plot	Shannon index (H')	Simpson index (D)	Number of saprophytic organisms (CFU/g)
Kharkiv region (control)	3.5	0.92	2.3×10^6
Kharkiv region (damaged)	2.1	0.87	1.1×10^5
Zaporizhzhia region (control)	3.4	0.90	2.0×10^6
Zaporizhzhia region (damaged)	2.0	0.85	1.0×10^5

Table 3, Continued

Plot	Shannon index (H')	Simpson index (D)	Number of saprophytic organisms (CFU/g)
Kyiv region (control)	3.7	0.96	2.8×10^6
Kyiv region (damaged)	3.4	0.93	2.2×10^6

Note: for the assessment of soil biodiversity, samples were taken from control and damaged plots in Kharkiv and Zaporizhzhia regions; Luhansk, Donetsk and Mykolaiv regions were not included in the study because of restricted access to these regions during active hostilities or because of insufficient reliable data for comparison
Source: compiled by the authors

The evaluation results showed that the Shannon index reached H' = 3.5 in control plots that had not experienced significant mechanical or chemical damage, indicating high organism diversity. By contrast, the index was significantly lower (H' = 2.1) in plots damaged by hostilities in the Kharkiv and Zaporizhzhia regions. Meanwhile, within the studied territories of the Vyshhorod district in the Kyiv region, a slight reduction in the number of saprophytic microorganisms was observed, suggesting recovery processes and lower intensity of hostilities. Damage to the soil cover created preconditions for long-term weakening of the natural recovery potential of agricultural land. Without the application of special remediation measures, it was found that degraded soil components may remain unsuitable for agricultural use for many years. The results confirm substantial environmental damage to Ukrainian agricultural land caused by the mechanical compaction of soils by heavy machinery and chemical contamination by heavy metals. Significant damage to agricultural land and degradation of the natural environment lead to substantial economic losses affecting Ukraine's agricultural sector. According to World Bank data from 2023, the decline in yields caused by soil contamination and loss of fertility resulted in a 15-20% reduction in agricultural production volumes. The cost of restoring agricultural land degraded by military action is estimated at over USD 4 billion.

Economic losses in the agricultural sector resulting from the destruction of infrastructure and the loss of productivity

The economic consequences of military action on Ukraine's agricultural sector have manifested in a variety of ways, broadly categorised as direct and indirect losses. Direct losses include the physical destruction of crops resulting from fires, explosions, and the movement of military equipment; damage to material and technical resources and infrastructure; and the theft of agricultural machinery. Indirect losses, meanwhile, encompass a decline in enterprise productivity, loss of investment attractiveness, and growing bankruptcy risks. Hostilities resulted in part of the sown area becoming inaccessible for cultivation, substantially reducing the gross harvest of grain and oilseed crops, which had traditionally formed the basis of Ukrainian exports. According to the Food and Agriculture Organization of the United Nations (FAO): Food Security (2024), around 30% of sown areas in the eastern and southern regions of Ukraine were unused in 2022, amounting to over 4 million hectares. Calculations show that crop losses in Ukraine caused by hostilities exceeded USD 4 billion. Ukraine suffered considerable economic losses as a result of armed aggression, particularly in the agricultural sector, which was affected by infrastructure destruction and declining productivity. D. Andrienko *et al.* (2024) noted that the indirect financial losses to the economy caused by the war exceeded USD 1.164 trillion, USD 83.1 billion of which was related to the agricultural sector and included the destruction of agricultural machinery, as well as damage to land and infrastructure. This has led to a significant decrease in agricultural productivity and investment attractiveness. Therefore, effective strategies are required to restore infrastructure and modernise agricultural production in order to rebuild the agricultural sector and ensure food security. The economic consequences have also been confirmed by the findings of the study by R.P. Tucker & J.R. McNeill (2025), which

described the economic losses caused by war. Damage to grain storage facilities, destruction of agricultural machinery, and demolition of irrigation systems made the recovery of agricultural production more difficult.

A significant aspect of these direct losses was the destruction of agricultural enterprises, machinery and infrastructure for storing and transporting harvested crops. In particular, more than 100 grain storage facilities and elevators were damaged or destroyed in the Kharkiv, Mykolaiv and Zaporizhzhia regions, with a combined storage capacity of over 2 million tonnes of grain. This resulted in double losses: a decline in yields and the loss of the ability to store and export products that had already been harvested (FAO Ukraine: Food Security..., 2024). According to agricultural associations, thousands of tractors, combine harvesters, and other specialised machinery were damaged, destroyed, or stolen in territories where hostilities took place, as well as in occupied areas. The total value of such losses is estimated to be in the hundreds of millions of US dollars. An additional factor was the loss of irrigation infrastructure. The destruction of the Kakhovka Hydroelectric Power Plant in 2023 caused water levels in the North Crimean Canal and the Kakhovka Canal to fall sharply, making it impossible to irrigate more than 500,000 hectares of agricultural land in southern Ukraine. This resulted in long-term yield losses, as the average productivity of these areas declined two to threefold without irrigation (Farming Amidst a War..., 2023; Klimentov, 2025). As the agricultural sector is a key part of Ukraine's economy, accounting for around 13% of total gross domestic product (GDP) prior to the war, active hostilities have led to a sharp fall in GDP. In particular, agricultural production declined by 20-25% in 2022-2023 due to military actions, resulting in a 3-4% reduction in the sector's share of GDP. These losses include lower yields, causing a reduction in the production of grain, oilseeds, and other important agricultural crops.

There was also a decline in the country's overall economic growth, which in 2022 amounted to only 3.2% of the pre-war level (World Bank, 2023). Indirect losses included a fall in the productivity of agricultural enterprises. From 2022 to 2023, agricultural production declined by an average of 15-20% compared to pre-war levels. This was caused not only by a reduction in sown areas, but also by shortages of resources: fuel prices increased fivefold in 2022, there were disruptions in the supply of mineral fertilisers and plant protection products, and it was difficult to attract labour due to mobilisation and migration processes. Declining production volumes and high risks caused a sharp fall in the investment attractiveness of agribusiness. In 2022, private investment in Ukrainian agriculture fell by around 40%. This hindered the implementation of modernisation programmes, the purchase of new machinery, and the adoption of innovative technologies. Financial instability also led to a significant increase in the risk of enterprise bankruptcy (World Bank, 2023). According to OECD (2023) estimates, more than 30% of small and medium-sized farms ceased operations due to a lack of access to sales markets, damaged logistics routes, and reduced credit opportunities Large agricultural holdings were also placed in a high-risk zone since blocking seaports and increasing export costs resulted in losses for companies with diversified assets. The war also had a significant impact on the financial stability of agricultural enterprises. As most farms rely on imported mineral fertiliser and fuel, the 2.5-fold increase in the price of these resources in 2022 reduced their profit margins. Farmers began to spend considerably more on logistics and ensuring production safety in their cost structure of production, which increased total enterprise costs by 30-40%. These factors caused a significant decline in the profitability of agricultural enterprises. Total economic losses in the agricultural sector caused by the war exceed USD 10 billion, with the largest share accounted for by losses resulting from declining yields, damaged infrastructure, and destroyed agricultural machinery. Losses caused by soil degradation, reduced production capacity, and a decline in investment attractiveness account for a significant proportion of these losses. By way of comparison, the agricultural sector generated over USD 20 billion in export revenues in 2021, accounting for around 15% of the country's total exports (State Statistics Service of Ukraine, 2023). Thus, the economic losses to the agricultural sector were complex in nature. Direct losses in the

form of destroyed crops, damaged infrastructure and lost machinery were combined with indirect losses, including declining productivity, reduced investment and growing bankruptcy risks. Taken together, these factors pose long-term threats to the recovery of agricultural production and require systematic state support, international assistance, and the implementation of anti-crisis management strategies.

Socio-economic impact of the war on agriculture in Ukraine

The study by T. Ben Hassen & H. El Bilali (2022) emphasised that the war in Ukraine had serious consequences for global food security, creating threats to sustainable and resilient food systems worldwide. I. Liadze *et al.* (2023) highlighted the economic costs of war, manifested through reduced production capacity and resource losses. According to I. Liadze *et al.*, the principal economic losses were the destruction of agricultural infrastructure, the reduction in sown areas, and lower yields as a result of hostilities, which led to significant financial losses. Similar conclusions were presented in the work of J. Bluszcz & M. Valente (2022), which focused on the economic costs of hybrid warfare. H. El Bilali & T. Ben Hassen (2024) found that the war affected global food systems by disrupting crop production cycles and the distribution of food resources. H. Hussein & M. Knol (2023) emphasised the impact of the war on global food trade networks, further complicating the supply of agricultural products to international markets. Studies by S. Musisi & E. Kinyanda (2020) and J. Nyssen *et al.* (2023) have emphasised the long-term consequences of war, including post-traumatic stress disorder (PTSD) among civilian populations in African communities. The lack of seasonal workers in combat zones complicated land cultivation and harvesting processes significantly. The socio-economic consequences of the war for the agricultural sector manifested in three key ways: deterioration of food security; increased household spending on food; mass migration of the rural population; reduction in labour potential; and increased business risks alongside restricted access to financial resources. Military action had a significant impact on the domestic food market. The blocking of exports through seaports, the mining of territories, and the reduction in cultivated areas led to shortages of certain goods and a significant increase in food prices. Following the blocking of the main seaports on 24 February 2022, Ukraine lost the ability to export more than 90% of its agricultural goods by sea. By the end of 2022, grain exports had fallen by 57% and oilseed exports by 42%, compared to 2021 (Copernicus-enabled Assessment, 2023). This blockade caused serious shortages of wheat, maize and sunflower oil on international markets, significantly increasing global prices for these products. Wheat prices, for example, rose by 58% in 2022, while maize and sunflower oil prices increased by 30-40% (World Bank, 2023). Ukraine's domestic market also underwent significant changes due to the blocking of export routes and declining production. According to the State Statistics Service of Ukraine (2024), consumer food prices rose by an average of 35-40% in 2022, including bread (37%), vegetables (52%) and poultry meat (28%). This resulted in household expenditure on food increasing by around 20% of family budgets, particularly in rural areas where incomes were below the national average. Ukraine's food security declined substantially, falling 13 places in the Global Food Security Index between 2021 and 2022 (Country Report: Ukraine, 2022).

One consequence of the conflict was large-scale population migration. According to the 2023 Food Security and Livelihoods report, more than 6.5 million Ukrainians had left the country by the end of 2022, while the number of internally displaced persons exceeded 5 million. A significant proportion of these individuals had lived in rural areas, directly reducing the labour resources available to the agricultural sector. Labour shortages were reflected in a deficit of seasonal workers for harvesting, resulting in direct losses of agricultural produce. Furthermore, the outflow of young and working-age individuals diminished the prospects of restoring agricultural production once the active phase of hostilities had ended. Business conditions for agricultural enterprises became substantially more difficult, particularly as banking institutions reduced lending to the agricultural sector due to the high risk of non-repayment. According to estimates by the National Bank of

Ukraine, lending to agribusiness fell by 45% in 2022 compared with the pre-war period. The situation was further complicated by rising interest rates, with the average short-term loan rate for farmers increasing from 14% in 2021 to 24% in 2022. Access to international investment was also restricted. According to the World Bank, foreign investment in Ukrainian agriculture fell by almost 40% in 2022. Additionally, the cost of insuring agricultural risks increased, and insurance companies often refused to conclude contracts due to the uncertain situation. This led to financial instability among farming enterprises and increased the risk of bankruptcy, particularly for small and medium-sized businesses, of which more than 30% were forced to suspend operations (World Bank, 2023). To analyse the risks that agricultural enterprises will face in the post-war period comprehensively, the categorisation of risks presented in Table 4 can be used.

Table 4. Risk analysis for agribusiness

Risk category	Description	Examples of potential threats
Economic risks	Risks associated with economic instability and reduced productivity	Reduced investment attractiveness, rising raw material prices, exchange rate fluctuations
Environmental risks	Risks associated with soil degradation and environmental contamination	Land damage due to heavy metal contamination, changes in ecosystems, decline in soil fertility
Social risks	Risks associated with population migration and changes in labour potential	Loss of workforce, high level of rural out-migration, reduction in the number of workers in the agricultural sector
Logistical risks	Risks associated with damaged infrastructure and disruptions in supply chains	Destruction of logistics routes, blocking of ports, restricted access to irrigation systems

Source: compiled by the authors on the basis of World Bank (2023), FAO Ukraine: Food Security... (2024), The Ministry of Agrarian Policy presented... (2024)

As shown in Table 4, the risks are complex in nature and may affect the financial stability of enterprises, production productivity, labour availability and infrastructure effectiveness. This classification provides a foundation for targeted risk management and the development of strategies to minimise potential negative impacts on agribusiness. Thus, the socio-economic impact of the war on agriculture was characterised by systemic losses. Food security deteriorated, reflected in rising prices and household expenditure. The migration of the rural population reduced the labour potential of agricultural production, while financial constraints and high business risks prevented enterprises from functioning and developing stably. These factors combined to increase the vulnerability of the agricultural sector, requiring comprehensive state support measures, international assistance and long-term recovery programmes. The study's results confirm the significant impact of the war on Ukraine's agricultural sector, evident in environmental and economic losses as well as social consequences for food security and global agri-food networks.

Recovery opportunities and prospects for managing agribusiness in the post-war period

Once the active phase of military action has ended, the agricultural sector's primary task will be to restore land, natural resources and production potential. A key priority will be the reclamation of land that has been mechanically damaged, degraded or chemically contaminated. In de-occupied territories, surveys of soils were conducted, explosive hazards were removed and agrochemical analyses were carried out. According to a Copernicus assessment from 2023, more than 200,000 hectares of arable land were surveyed for their suitability for reuse between 2023 and 2024. Of this land, around 40% required deep reclamation before economic activity could resume. To restore soil fertility, bioremediation technologies, the local application of organic fertilisers and green manure crops were used, as well as chemical neutralisation methods where heavy metal concentrations exceeded permissible standards. For Ukraine to recover sustainably after the end of hostilities, it is crucial to rebuild infrastructure, reconstruct

old agricultural enterprises and modernise their technical base. The cost of restoring irrigation infrastructure in southern Ukraine alone is estimated at over USD 1.5 billion, while the total cost of restoring agricultural infrastructure exceeds USD 8 billion. Modernising the technical base includes renewing the agricultural machinery fleet, introducing energy-efficient solutions, and increasing the mechanisation of field operations (FAO Ukraine: Food Security..., 2024). The resilience of agricultural enterprises can be strengthened by diversifying production areas. This includes developing new crops that require fewer resources, such as water-efficient and drought-resistant varieties. Integrating livestock farming and horticulture is also important in order to reduce dependence on a single line of activity and improve the economic stability of agricultural enterprises. A key aspect of financial stability is introducing insurance mechanisms for farmers. Insurance against risks such as natural disasters, war, and other unforeseen circumstances would mitigate financial losses and enable agricultural enterprises to recover from crises. Both public and private insurance products must be introduced to increase the sector's resilience. Using innovative digital technologies for agribusiness management would significantly reduce costs and improve production efficiency. Precision farming systems and digital platforms for monitoring soil and crop conditions would allow enterprises to optimise operations, reduce costs and integrate into global supply chains. Public-private partnership models involving cooperation between the state and the private sector could be an effective means of implementing large-scale infrastructure recovery projects and ensuring access to finance. This could include financing the restoration of irrigation systems, creating new logistics networks, and developing agricultural infrastructure. These measures would help to improve production efficiency and reduce costs. This study developed recommendations for increasing the resilience of agricultural enterprises, particularly through diversifying production areas, introducing insurance mechanisms, and using digital technologies. These recommendations were developed based on an analysis of the current situation in Ukraine's agricultural sector, as well as international research and best practices for adapting agricultural enterprises to crisis conditions.

Innovative technologies and digital solutions have become key to improving the effectiveness of post-war recovery. In practice, precision farming systems and satellite and unmanned monitoring of soil conditions and crops are being implemented. These technologies were also recommended in studies by A. Bhardwaj & H. Parveen (2024), which suggest that the efficiency of agricultural production could be significantly improved through innovative solutions. The findings of A.B. Avagyan (2021) are consistent with the conclusions of the present study regarding the environmental impact of military activities on agricultural land. Particular attention was given to land recovery mechanisms through bioenergy processes and bioremediation technologies, as discussed in both studies. Geographic information systems should also play an important role in mapping the level of land degradation and planning recovery measures. Using digital platforms would enable agricultural producers to optimise management processes, reduce production costs, and integrate into global supply chains. According to the World Bank's (2023) estimates, introducing digital solutions into restored agricultural enterprises would increase productivity by an average of 15-18% in the first years following integration. State support, international assistance and investment also played an important role in shaping resilient management strategies. Ukrainian government programmes provided for concessional loans and grants for farmers to restore production. Under the "Affordable Loans 5-7-9%" initiative, the National Bank of Ukraine (2025) provided agricultural enterprises with financing at subsidised rates, which partly compensated for limited access to banking resources. FAO Ukraine: Food Security... (2024) allocated more than USD 1 billion in 2022-2024 to support the agricultural sector in the form of technical assistance, equipment and financial grants. In addition, the European Union launched the Ukraine Facility programme, which provided long-term financing for the modernisation of agriculture and its integration into the European agricultural space

(Strategic Orientations of the Ukraine..., 2024). Thus, opportunities for restoring agribusiness were formed at the intersection of three interrelated directions: land reclamation and infrastructure restoration, the introduction of innovative technologies and digital solutions, and the development of mechanisms for state support and international investment. The combination of these factors created the preconditions not only for rebuilding agricultural production, but also for transforming it into a more resilient and competitive model of development. The synthesis of the results made it possible to systematise the main consequences of military actions for Ukraine's agricultural sector into four interrelated blocks: environmental losses, economic losses, socio-economic consequences, and recovery opportunities. Such a structure makes it possible to assess not only the scale of the degradation of agricultural resources, but also the potential for their recovery in the post-war period (Table 5).

Table 5. Comprehensive consequences of the war for Ukraine's agricultural sector

Results block	Main indicators	Consequences for agribusiness
Environmental losses	200,000 ha of damaged land; 20% of the most fertile land taken out of use; lead ↑ threefold, cadmium ↑ 2.5-fold	Reduction in the area of agricultural land, decline in soil fertility, soil contamination, risks to public health, deterioration in environmental quality, disruption of ecological balance, decline in biodiversity
Economic losses	-4 million ha of crops; > 2 million tonnes of losses in grain storage; 500,000 ha without irrigation; -15-20% productivity	Crop losses, decline in the value of produce due to lower quality, losses of agricultural machinery, reduced investment, increasing bankruptcy rates
Socio-economic consequences	Prices +35-40%; 6.5 million refugees; lending -45%; SMEs -30%	Deterioration of food security, labour shortages, financial instability
Recovery opportunities	200,000 ha surveyed; need for USD 8 billion in recovery; productivity ↑ by 15-18% owing to digital technologies	Reclamation, modernisation, innovation, state and international support

Source: compiled by the authors on the basis of Copernicus-enabled assessment... (2023), Food Security and Livelihoods (2023), FAO Ukraine: Food Security... (2024)

Analysis of the summary data revealed that the consequences of the war were multi-level in nature, ranging from physical land degradation and infrastructure losses to socio-economic challenges that undermined agribusiness resilience. At the same time, the table shows that there is substantial potential for recovery based on reclamation, the introduction of innovative technologies, and attracting investment. Combining these factors laid the groundwork for a new management model for the agricultural sector, which aimed to not only reconstruct the sector, but also enhance its competitiveness in the post-war period. According to the analysis, hostilities caused significant soil degradation, heavy metal contamination and destruction of agricultural infrastructure, creating long-term risks to food security and economic stability. Using modern technologies to monitor and assess land conditions is key to determining the scale of losses and planning recovery measures. The results obtained confirm the conclusions of S. Ulihanets *et al.* (2025), who demonstrated the negative impact of fire and military action on natural ecosystems, including soil and water contamination. The assessment of saprophytic microorganism abundance and the Shannon index correspond to the concept proposed by W. Leal Filho *et al.* (2024) regarding soil ecosystem degradation processes and their connection with agricultural activity and regional land resource stability. Mapping destruction based on satellite data, as proposed by O. Dietrich *et al.* (2024), enabled the spatial distribution of damaged land and the extent of heavy metal standard exceedances to be refined, which is

important for determining economic losses and recovery priorities. The partial preservation of soil quality in the Kyiv region suggests the impact of local agronomic practices and the time interval between the onset of hostilities and sample collection. This is consistent with the concept of gradual changes in land structure, as evidenced by satellite image time series, as noted by S. Holail *et al.* (2024). A comparison with the analysis by Y. He *et al.* (2025) demonstrated the effectiveness of multi-level monitoring and the integration of satellite data in assessing long-term environmental consequences of hostilities. This confirms the suitability of applying similar methods to Ukrainian territories. A comprehensive assessment of the economic and socio-economic consequences enables more informed decisions to be made regarding the restoration of agricultural infrastructure and the planning of land reclamation measures.

CONCLUSIONS

The study enabled a comprehensive assessment of the environmental, economic and socio-economic consequences of military action on agricultural land and Ukraine's agricultural sector. It identified damage to over 200,000 hectares of land, around 20% of which was the most fertile land taken out of use. Significant exceedances of permissible heavy metal concentrations in the soils of the Kharkiv, Luhansk and Zaporizhzhia regions were identified. Substantial exceedances of standard values were recorded: lead by three times, cadmium by 2.5 times, arsenic by twice, nickel by more than twice and zinc by 1.6 times. This creates long-term risks to public health and makes it impossible to obtain safe, high-quality crop products. Within the agricultural land of the Kyiv region, elevated levels of cadmium, cobalt, nickel, lead and chromium were recorded compared to background values. However, no exceedance of standard indicators was identified. This can be explained by the selective impact on soils, the partial disturbance of their integrity, the application of agronomic measures involving the filling of craters with clean soil and the considerable time interval since the damage occurred. In Kharkiv and Zaporizhzhia regions, the assessment results showed that in control plots that had not experienced significant mechanical or chemical damage, the Shannon index reached H' = 3.5, indicating high organism diversity. By contrast, in plots damaged as a result of hostilities, the index was significantly lower (H' = 2.1). In the Kyiv region, a decline in the content of saprophytic microorganisms was observed, with H' = 3.7 in control plots and 3.4 in damaged plots. This indicates recovery processes and lower intensity of hostilities in these areas.

Significant economic losses result from a decline in the natural recovery potential of land, soil contamination, increased concentrations of heavy metals in soils, and the inability to produce safe, high-quality agricultural products. Economic losses caused by military action included the loss of more than 4 million hectares of crops, the destruction of machinery and storage facilities, and damage to irrigation systems. Yields declined two- to threefold. Indirect losses are reflected in a 15-20% reduction in production, rising resource costs, and the suspension of activities by over 30% of small and medium-sized farms. Socio-economic consequences included a 35-40% increase in food prices, higher household expenditure, the migration of more than 6.5 million people and restricted access to credit. However, a significant recovery potential has been identified: the estimated cost of recovery is more than USD 8 billion, and modernising the technical base and introducing digital technologies could increase productivity by 15-18%. Further research should focus on developing methods for assessing damage to agricultural enterprises caused by military action, models of the long-term resilience of the agricultural sector and the effectiveness of reclamation measures and the implementation of innovative technologies in the post-war period.

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Еколого-економічні підходи до визначення збитків, завданих сільськогосподарським угіддям воєнними діями

Анотація. Метою статті було оцінити еколого-економічні наслідки воєнних дій для сільськогосподарських угідь України та визначити основні еколого-економічні показники для оцінки впливу воєнних дій на довкілля з подальшою можливістю відновлення аграрного бізнесу в післявоєнний період. Дослідження базувалося на комплексному аналізі екологічних, економічних та соціальних наслідків воєнних дій для аграрного сектору України із використанням польових обстежень, супутникових даних, лабораторних аналізів ґрунту та офіційної статистики. Встановлено, що внаслідок бойових дій понад

200 тис. гектарів сільськогосподарських земель зазнали ушкоджень, з них близько 20 % найродючіших угідь виведено з обігу, при цьому у Харківській, Донецькій, Миколаївській, Луганській та Запорізькій областях зафіксовано перевищення нормативів важких металів у ґрунті: свинець – у 3 рази, кадмій – у 2,5 раза, арсен – у 2 рази, нікель – більш як у 2 рази та цинк – в 1,6 раза. У свою чергу, на досліджуваних сільськогосподарських угіддях у межах Вишгородського району Київської області не було зафіксовано перевищення гранично допустимої концентрації рухомих форм важких металів, зокрема свинцю, кадмію та ін. Зафіксоване значне перевищення фонових рівнів важких металів у ґрунтах створює довгострокові ризики для якості та безпечності продовольчої продукції, економічних збитків і здоров'я населення, що підкреслює важливість моніторингу забруднення ґрунтів у зонах впливу бойових дій на сільськогосподарських підприємствах. Проведене дослідження показало, що прямі економічні втрати включали втрату понад 4 млн гектарів посівів, руйнування понад 100 зерносховищ загальною потужністю 2 млн тон, а також зниження врожайності на понад 500 тис. гектарів через відсутність зрошення. Непрямі збитки проявилися у скороченні виробництва на 15-20 %, зростанні цін на продукти харчування на 35-40 %, падінні обсягу інвестицій на 40 % та припиненні діяльності понад 30 % малих і середніх підприємств. Виявлено, що соціально-економічні наслідки охоплювали міграцію понад 6,5 млн осіб та погіршення продовольчої безпеки, проте досліджувана територія володіє також значним потенціалом відновлення

Ключові слова: деградація ґрунтів; аграрний сектор; витрати; продовольча безпека; державна підтримка

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Competitiveness of the national economy of Ukraine

Abstract. The article analysed the competitiveness of the Ukrainian economy, according to the World Economic Forum (WEF) Global Competitive Index and Institute of Management Development (IMD) World Competitiveness Ranking. The competitiveness of Ukraine's national economy is a key factor in its integration into the global economic community and in ensuring sustainable development. The purpose of the research was to comprehensive analyse the competitiveness of Ukraine's economy according to the WEF Global Competitiveness Index and the IMD World Competitiveness Ranking, as well as identifying internal and external factors and substantiating

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practical recommendations for increasing the competitiveness of the national economy of Ukraine. The methodological basis of the study of the competitiveness of the national economy of Ukraine allowed for a comprehensive analysis and assessment based on international indicators. This might help identify key aspects that should be paid attention to in order to increase Ukraine's competitiveness on the global stage. The study identified the main challenges facing Ukraine, in particular corruption, slow introduction of innovations. The article focused on the importance of state policy in the fight against corruption, stimulating the development of innovations and improving the quality of education, which are essential conditions for strengthening competitiveness. Special attention was paid to the impact of globalisation processes and international cooperation on Ukraine's competitive advantages. The study concluded that only a comprehensive approach that combines economic, social, technological and environmental aspects will allow Ukraine to increase its competitiveness in the international market, improve the well-being of the population and ensure sustainable economic development. The practical significance of the study was to develop scientifically based recommendations for government agencies, businesses, and other stakeholders to increase the competitiveness of the national economy

Keywords: globalisation; innovation; human capital; sustainable development; risks

INTRODUCTION

In the global world, countries are constantly competing for resources, investments and markets, so the competitiveness of the national economy is becoming a key factor in its sustainable development, improving the standard of living of the population and strengthening the country's position in world markets. The relevance of the study is due to the need for the survival and development of the state in the face of global challenges. For Ukraine, which faces numerous internal and external challenges, understanding and analysing the competitiveness of the economy is an extremely important task. Competitiveness is formed by a set of factors: the quality of institutions, business conditions, infrastructure, human capital, the level of innovation, macroeconomic stability, labour market efficiency, etc. Therefore, the study allows to substantiate the benefits of development and develop recommendations that increase the effectiveness of management decisions. Without a scientific analysis of competitiveness factors, state policy risks being chaotic, and resources for recovery may be spent inefficiently.

According of the research M. Gerashchenko (2023) analysis of rating assessments in dynamics allows to step by step assess the effectiveness of state policy measures and the impact of foreign policy changes on the country's ability and willingness to compete internationally. In R. Kohut's (2023) opinion, the competitiveness of a national economy is defined as the ability of a country to produce goods and services that meet the requirements of the international market, while ensuring the growth of the well-being of its citizens. A high level of competitiveness attracts both domestic and foreign investments, which contributes to economic growth. A competitive economy provides a stable source of income for the population, improves social living conditions, and forms a balance between economic, social and environmental aspects of development. A country with a competitive economy is better prepared for global challenges such as climate change, economic crises, etc. Contemporary approaches to competitiveness go beyond classical market competition and emphasise the role of the state in shaping inclusive and innovation-oriented development. In particular, K. Aiginger & D. Rodrik (2020) develop the concept of "inclusive competitiveness" and the revival of industrial policy as a tool for ensuring long-term economic growth.

Having substantiated the conceptual foundations of the problem of sustainable development of the national economy of Ukraine A. Datsenko (2023) concluded that increasing the competitiveness of the national economy is an important task for ensuring sustainable economic growth, improving the well-being of citizens and integrating Ukraine into the global economy. Effective public policy, innovation

and investment in human capital are key factors for success in this process. In a retrospective review of Ukraine's competitiveness A. Gavrikova (2024) remarked, that each country needs to develop a unique strategic map, based on the totality of existing potentials (natural resource, production, labour, and scientific and technical), which will allow for a systematic approach to obtaining the desired level of competitiveness. The authors S. Solodovnikov & V. Lebid (2024) indicated, that one of the key factors affecting a country's competitiveness is the effectiveness of its higher education system. The level of training of qualified personnel, their knowledge, skills and innovativeness directly affect the country's ability to compete in the international market, ensuring sustainable economic growth and development.

Yu. Naumenko (2024) concluded that competitiveness in the post-conflict period will depend on the ability to adapt to new conditions, invest in modernisation, innovation, human capital, and actively integrate into international markets. In the context of globalisation, the Ukrainian economy faces competition from other countries, which will require the introduction of new technologies, innovations and an increase in the overall level of efficiency. Internal political and economic conflicts, as well as crisis phenomena in the country, can negatively affect competitiveness. V. Solodkyi (2024) indicated that the technological sector of the economy is one of the most promising in the context of post-war recovery, since it does not involve significant investments (with the exception of the direction of high-tech production) and requires a significant number of personnel of various qualifications. The study aimed to identify factors that affect this competitiveness and suggest ways to overcome them. Ukraine needs to implement a number of reforms to increase competitive advantages, including reforms in the education, healthcare, justice and administrative management systems. To improve competitiveness, it is necessary to attract domestic and foreign investments. Understanding the factors that attract investors can help in the formation of an effective investment policy.

The purpose of the research was to analyse the competitiveness of Ukraine's economy (according to the WEF Global Competitive Index and IMD World Competitiveness Ranking) and identification key factors affecting competitiveness, as well as development recommendations for its improvement. The main objectives of this study were: to study the impact of internal and external factors on the competitiveness of the economy; to identify international experience in increasing the competitiveness of national economies and the possibility of its adaptation for Ukraine; to develop practical recommendations for increasing the competitiveness of the Ukrainian economy based on the results obtained.

MATERIALS AND METHODS

This study covered the period from 2010 to 2024. This period was chosen because until 2014, Ukraine's economy was characterised by high dependence on external raw material markets and political instability, while the period after 2014 was defined by structural transformation against the backdrop of post-revolutionary consequences, military aggression, reorientation to the EU market, the coronavirus crisis, the effects of quarantine restrictions, and a full-scale invasion. The methodology used to assess national competitiveness has inevitably evolved over time, as it has taken into account the factors that significantly influence the formation and growth of competitiveness. The article provided a general analytical overview of the level of international competitiveness of the following countries: Singapore, the United States, Hong Kong, the Netherlands, Switzerland, Japan, Germany, Sweden, the United Kingdom, Denmark, Finland, Taiwan, South Korea, Canada, France, Ukraine, Yemen, Chad, Ireland, the United Arab Emirates, Norway, Qatar, Australia, China, Argentina, and Venezuela, taking into account their positions in leading global rankings assessing competitive development.

The methodological basis of the study was the general theoretical methods of scientific knowledge of economic processes and phenomena, fundamental provisions and principles that are highlighted in the works of Ukrainian and foreign scientists on the problems of national competitiveness. To achieve the goal, general scientific methods were used: bibliographic (for

studying the essence and content of national competitiveness); analysis and synthesis (for detailed study, systematisation and generalisation of criteria and indicators for assessing competitiveness), induction and deduction (for determining trends in the state of the country's competitiveness); economic and statistical (for the purpose of collecting and processing statistical data when highlighting the state of national competitiveness); expert method (for assessing the effectiveness of decisions made in managing the competitiveness of agricultural enterprises); systematisation and generalisation method (for developing a concept for forming the stages of the mechanism for innovative management of agricultural enterprises); abstract-logical (when formulating conclusions and proposals). The methodology for analysing the competitiveness of the Ukrainian economy was based on a combination of quantitative (statistical) and qualitative methods, using data from official data sources, international ratings WEF (n.d.), IMD (n.d.), and analytics from CASE Ukraine (2018). The analysis of the competitiveness of the Ukrainian economy is based on a comparison of the WEF and IMD comprehensive indices, which combine quantitative (statistical) and qualitative (expert) data. The methods included a comparative, structural, and index method for assessing the dynamics and ranking of Ukraine among other countries.

The genesis of the theory of assessing the competitiveness of countries in the world was developed from the use of matrix approaches to complex index approaches, combining a huge number of components and indicators determined by various methods and assessments. A review of methodological approaches to assessing the competitiveness of a country's economy showed that one of the main ones is the construction of ratings (Lunyova, 2022). The competitiveness of an economy cannot be reduced only to a country's gross domestic product (GDP) and productivity. Constructive or destructive political, social and cultural aspects are also an undeniable reality of the functioning of enterprises. Governments and institutions play a crucial role in creating an environment characterised by effective infrastructure, institutions and policies that can encourage the sustainable development of enterprises and the prosperity of the economy as a whole. Ukraine is listed in two global competitiveness rankings: in terms of economic competitiveness – in the Global Competitiveness Index (IGC), calculated according to the methodology of the World Economic Forum, and in the World Competitiveness Index according to the International IMD in Switzerland.

The choice of these two indices for analysing Ukraine's competitiveness was a standard in economic research due to their complementarity and high level of trust. The comprehensive coverage of the Global Competitiveness Index (GCI) focuses on productivity and macroeconomic factors, which allows to assess Ukraine's ability to ensure stable growth in the long term. The IMD emphasised the effectiveness of the business environment and short-term results. It assessed how the state and firms interact to create wealth, relying on hard statistical data and surveys of executives, using both indices avoids subjectivity. The IGC gave a broader picture of structural reforms, and the GCI – a dynamic cross-section of managerial and economic efficiency. These indicators are universal, using them, it is possible to compare Ukraine with neighbouring countries correctly and other developing countries, based on a single globally recognised scale. It is these indices that international investors (IMF, World Bank) focus on when assessing the country's risks and potential.

The World Economic Forum methodology is based on an approach to competitiveness as a set of political, institutional, and economic factors that ensure the level of productivity in a country and, as a result, the ability of the country and its institutions to ensure stable rates of economic growth. The current GCI was formed from a combination of publicly available statistical data (about 15,000 reports from 142 countries) and the results of a global survey of company leaders (14,039 leaders were surveyed, 13,359 responses were received, of which 36% were from partner organisations (over 150 organisations) in the countries analysed in the report. In Ukraine, such an organisation is CASE Ukraine (2018). The overall coordination and publication of the Report is carried out by the "Centre for Global Competitiveness and Produc-

tivity within the World Economic Forum" under the leadership of K. Schwab, a German economist, founder and president of the World Economic Forum in Davos.

RESULTS AND DISCUSSION

The IMD (n.d.) World Competitiveness Ranking was created 36 years ago to provide a practical analysis of data on economies, regions and sub-regions according to how they optimise their individual competencies to achieve long-term value creation for their citizens. It provided comparative analysis and identifies trends using both statistics and real-world survey data. The 2024 edition of the World Competitiveness Ranking, released in June, provides extensive coverage of 67 global economies and is a global guide to the competitiveness of economies. Three new economies were added in 2024: Ghana, Nigeria and Puerto Rico. The WEF Global Competitiveness Report has been published since 1979 and was originally a joint project of the World Economic Forum in Davos and the International Institute for Management Development in Lausanne, two organisations headquartered in Switzerland. The link and coordinator of the project was the famous Swiss economist S. Garelli, a professor at IMD and the University of Lausanne, who simultaneously held the position of Managing Director of the World Economic Forum. In 1987, S. Garelli left his post and immediately created the Center for Competitiveness Studies (World Competitiveness Center) at IMD, which two years later published the World Competitiveness Yearbook (Schwab *et al*., 2002).

After S. Garelli left, the WEF involved several famous economists in developing the rating. For example, the famous specialist in the field of competitiveness M. Porter, a professor at Harvard University, the creator of the theory of competitive advantages of countries, developed a microeconomic index, The Business Competitiveness Index, first used in the Global Competitiveness Report (Schwab *et al*., 2002). J. Sachs from Columbia University and J. McArthur from the Earth Institute developed the macroeconomic index The Growth Competitiveness Index (GCI), which was first used in the Global Competitiveness Report (Schwab *et al*., 2002). In 2004-2005, a new index was introduced – the GCI, developed under the leadership of Professor X. Sala-i-Martin of Columbia University and a synthesis of previous indices. Ukraine was first included in the GCI rating in 2004 (World Economic Forum, n.d.). This index, developed by the World Economic Forum, assesses the competitiveness of countries based on various economic indicators and factors. Since then, Ukraine has regularly participated in this rating, which allows to analyse changes in the country's competitiveness over time.

The competitiveness of the national economy is the ability of a country to produce goods and services that can compete on the world market, while ensuring efficiency, innovation and sustainable growth. This concept reflects the level of success of economic agents (companies and industries) in attracting consumers and investments, as well as in ensuring sustainable development. The main components of the competitiveness of the national economy are high labour and capital productivity, the ability to implement new technologies, products and business models, the development of scientific research and technological startups, the quality of goods and services, the ability to offer products and services at reasonable prices without losing quality, recognition and support of national brands in the international market, the formation of a positive image of the country in the context of business and investment, a favourable environment for doing business, the absence of corruption, equal access to resources and opportunities, stable political conditions that promote development, active participation in international trade relations and agreements, the inclusion of the country in global supply chains, developed transport, communication, energy and social infrastructure capable of supporting business processes. The WEF has been studying the competitiveness of nations for nearly three decades. Since 1979, the annual Global Competitiveness Reports have examined the factors that enable national economies to achieve sustainable economic growth and long-term prosperity (WEF, n.d.). Over the years, the WEF reports have served as benchmarking tools for business leaders and policymakers to identify obstacles to competitiveness and develop strategies to overcome them. It is in this

context that in 2004 the WEF introduced the GCI, a comprehensive index for measuring national competitiveness, taking into account the microeconomic and macroeconomic foundations of national competitiveness (WEF, n.d.).

The WEF defines competitiveness as the set of political institutions and factors that determine and influence a country's level of productivity. The level of productivity, in turn, determines the sustainable level of prosperity that an economy can achieve. In other words, a more competitive economy is generally able to provide higher levels of income for its citizens. The level of productivity also determines the rates of return obtained from investment in the economy. Since rates of return are the main determinants of the rate of economic growth, a more competitive economy is one that is likely to grow faster in the medium and long term. The WEF (n.d.) publishes annual reports assessing the competitiveness of countries around the world. The Global Competitiveness Report is a globally recognised and influential benchmark that identifies weaknesses, gaps in national economies, and areas of potential success. The report is based on the GCI. Globalisation and the Fourth Industrial Revolution have created new opportunities and polarised economies and societies. In this context, in 2018, the WEF launched the new GCI 4.0, which is a much-needed new economic compass, building on 40 years of benchmarking of long-term competitiveness drivers. As 2020 the WEF has suspended the publication of annual rankings of the GCI, considering the period from 2010 to 2019. The GCI consists of 111 variables that characterise in detail the competitiveness of countries around the world at different levels of economic development. The set of variables consists of two-thirds of the results of a global survey of company executives (to cover a wide range of factors affecting the business climate in the countries studied), and one-third of publicly available sources (statistical data and research results carried out on a regular basis by international organisations). All variables that determine national competitiveness are combined into 12 control indicators (pillars), divided into four groups: a favourable environment, human capital, market efficiency, and innovative factors. M. Olczyk *et al.* (2022) conducted a detailed comparative study of GCI and GCI 4.0 and determined that the use of a smaller set of indicators (mostly accurate data) and new specific weights are justified. The enabling environment includes the following indicators: institutions, infrastructure, the use of information and computer technologies, macroeconomic stability; human capital, which includes healthcare, higher education and vocational training; the efficiency of market functioning, which includes the efficiency of the product market, the efficiency of the labour market, the development of the financial market, the size of the market; innovative factors, which include business dynamism, innovative potential. Competitiveness must be studied in dynamics, therefore, the rank of Ukraine in the world according to the GCI for the years 2010-2018 in Table 1.

Table 1. The rank and score of Ukraine in the Global Competitiveness Index for 2010-2018

Global Competitiveness Index	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018
Rank of Ukraine/countries	89/139	82/142	73/144	84/148	76/144	79/140	85/138	81/137
Score (1-7)	3.90	4.00	4.14	4.05	4.14	4.0	4.00	4.11
Basic requirements subindex (key for factor-driven economies)	3.9	4.2	4.4	4.3	4.4	4.1	4.0	4.2
Pillar 1. Institutions	3.0	3.0	3.1	3.0	3.0	3.1	3.0	3.2
Pillar 2. Infrastructure	3.8	3.9	4.1	4.1	4.2	4.1	3.9	3.9
Pillar 3. Macroeconomic environment	3.2	4.2	4.4	4.2	4.1	3.1	3.2	3.5
Pillar 4. Health and primary education	5.7	5.6	5.8	5.8	6.1	6.1	6.0	6.0
Efficiency enhancers subindex (key for efficiency-driven economies)	4.0	4.0	4.1	4.0	4.1	4.1	4.0	4.1
Pillar 5. Higher education and training	4.6	4.6	4.7	4.7	4.9	5.0	5.1	5.1
Pillar 6. Goods market efficiency	3.5	3.6	3.8	3.8	4.0	4.0	4.0	4.0
Pillar 7. Labour market efficiency	4.5	4.4	4.4	4.2	4.1	4.3	4.2	4.0

Table 1, Continued

Global Competitiveness Index	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018
Pillar 8. Financial market development	3.3	3.4	3.5	3.5	3.5	3.2	3.0	3.1
Pillar 9. Technological readiness	3.4	3.5	3.6	3.3	3.5	3.4	3.6	3.8
Pillar 10. Market size	4.5	4.5	4.6	4.6	4.6	4.5	4.4	4.5
Innovation and sophistication factors subindex (key for innovation-driven economies)	3.3	3.3	3.4	3.4	3.4	3.6	3.5	3.5
Pillar 11. Business sophistication	3.5	3.5	3.7	3.7	3.7	3.7	3.6	3.7
Pillar 12. Innovation	3.1	3.1	3.2	3.0	3.2	3.4	3.4	3.4

Note: the index ranges from 0 to 7, with higher values being better
Source: compiled by the authors based on WEF (n.d.)

The main differences in the construction of the GCI (2017-2018) and GCI 4.0 were based on three characteristics: indicators, weighting, hard versus soft data. The GCI is an average of 114 indicators grouped into 12 groups. The weighting ranges from 5% to 15% depending on the sub-index to which the group belongs and the stage of development of the country. Hard data makes up a smaller part compared to soft data (37 indicators based on hard data; 77 based on survey data). The GCI 4.0 is a composite indicator, the calculation of which is based on successive aggregations of scores from the indicator level (the most disaggregated level) to the overall score (the highest level). At each level of aggregation, each indicator is calculated by taking the average of the scores of its components. The overall GCI score of 4.0 is the average of 103 indicators across 12 components. At the same time, all "pillars" have the same weight of 8.33%, regardless of the country's stage of development, and hard data outweighs soft data (56 indicators based on hard data; 47 based on surveys). Ukraine maintains relatively high positions due to healthcare and primary education (6,0 according to the results of 2016-2018), higher education and vocational training (5.1), and the size of the domestic market (4.5). Since the methodology for determining the GCI was changed in 2017, which makes it impossible to compare the analysed indicators, will display the determinants of the rating for 2019 (methodology 4.0). The GCI 4.0 framework is organised into 12 main drivers of productivity, or "pillars". It places a premium on factors that will grow in significance as the Fourth Industrial Revolution gathers pace: human capital, agility, resilience, and innovation. The GCI 4.0 introduces a new progress score ranging from 0 to 100. The frontier (100) corresponds to the goal post for each indicator and typically represents a policy target. Each country should aim to maximise its score on each indicator, and the score indicates its current progress against the frontier as well as its remaining distance. This approach emphasises that competitiveness is not a not a zero-sum game between countries – it is achievable for all countries. Competitiveness is an important starting point because it contributes to higher living standards and generates the resources needed for wider societal goals. There are, inevitably, tensions – social, economic, and environmental – between the various dimensions of economic progress. The competitiveness of the national economy of Ukraine is a key factor in its integration into the global economic community and ensuring sustainable development. In order to determine the cause-and-effect relationships between the declines and rises of the national economy of Ukraine in the ranking of the GCI, it is necessary to examine the values of the main indicators that are its components in Table 2.

Table 2. Assessment of Ukraine's competitiveness in the World Economic Forum ranking 2018-2019

Index	2018	Index value	2019	Index value
General ranking	83	57	85	57
Enabling environment				
Pillar 1. Institutions	110	46.3	104	47.9

Table 2, Continued

Index	2018	Index value	2019	Index value
Pillar 2. Infrastructure	57	70.1	57	70.3
Pillar 3. ICT adoption	77	51.0	78	51.9
Pillar 4. Macroeconomic stability	131	55.9	133	57.9
Human capital				
Pillar 5. Health	94	92.0	101	65.6
Pillar 6. Skills	46	68.9	44	69.9
Markets				
Pillar 7. Product market	73	55.3	57	56.5
Pillar 8. Labour market	66	59.5	59	61.4
Pillar 9. Financial system	117	48.7	136	42.3
Pillar 10. Market size	47	62.7	47	63.0
Innovative ecosystem				
Pillar 11. Business dynamism	86	55.3	85	57.2
Pillar 12. Innovation capability	58	39.0	60	40.1

Note: scale ranges from 0 to 100
Source: compiled by the authors based on WEF (n.d.)

According to the analysis of the socio-economic system according to the GCI in 2019, Ukraine remained at the level of 2018 (57 points), but there are positive trends in individual indicators. According to the "Institutions" indicator, the Ukrainian economy during 2018-2019 demonstrates a growth trend (+1.6 points and 104th place), which indicates the country's sustainable institutional development. There is also a trend towards improvement in the indicators of infrastructure development (+0.2 points and 57th place); introduction of information and communication technologies (+0.9 points and 78th place); macroeconomic stability (+2 points and 133rd place) and the "knowledge and skills" indicator (+1 point and 44th place). The state of commodity markets in the reporting period had a positive trend (+1.2 points and 57th place). This is explained by the increase in internal competition and competition in the services market (+4.9 points and 64th place), the dispositive impact of taxes and subsidies on competition (+3.4 points and 104th place), an increase in market share (+3.6 points and 89th place), non-tariff barriers (+4.1 points and 91st place). The labour market (+1.9 points and 59th place) and the domestic market (+0.3 points and 47th place) also have a growth trend. There is also a slight improvement in the business dynamism indicator (+1.9 points and 85th place). Some indicators have a negative trend, in particular, the health indicator (-6.4 points) dropped seven positions in the ranking, to 101st place as a result of a decrease in life expectancy; the financial system indicator (-6.4 points and 136th place) due to the deterioration of private sector lending indicators (-47.5 points and 76th place). Negative trends in the labour market that developed in the prewar period significantly intensified during the war, creating new risks for the country's economy (Herasymenko *et al.*, 2024). In 2019, Ukraine ranked 85th in the ranking among 141 countries in the world, which worsened the country's position in the ranking by two positions due to macroeconomic stability (-2.0), the quality of institutions (-1.6) and business dynamism (-1.9), falling to the indicator of three years ago.

Scientist M. Chepelyuk (2020) focuses on the GCI as a tool for measuring countries' adaptability and notes that countries with high GCI scores (in particular, those with developed innovation ecosystems and digital infrastructure) demonstrate significantly higher resilience to economic crises. The author argues that the key factor

of resilience is the institutional framework and macroeconomic stability. These findings are supported; however, in the context of geopolitical challenges, particular emphasis is placed on economic modernisation, digital resilience, and industrial competitiveness. Over all the years that Ukraine participated in the ranking, it did not rise above 68th place out of 125 countries in 2005. The underdeveloped factors include low institutional development, due to the lack of principles of transparency in the state and the loss of citizens' trust in the authorities, however, the dynamics show that the situation is slowly improving; outdated technologies; macroeconomic instability; imperfect medicine and an outdated healthcare system, in 2019 Ukraine ranked 101st according to this indicator, in 2020 this fact was confirmed by the high level of morbidity and mortality during the COVID-19 pandemic; instability in the financial market; lack of incentives for engaging in innovative activities. As a positive aspect that form the basis of Ukraine's competitive advantages on the global stage worth noting is a sufficient level of higher education and professional training; increased efficiency of the product market and the labour market; a significant market size compared to other countries; high innovation potential.

The competitiveness of the national economy of Ukraine is a multifaceted concept that encompasses various aspects, including macroeconomic stability, technological development, institutional quality, and the ability to adapt to external changes. In the context of Ukraine, this issue is particularly relevant due to ongoing structural changes, geopolitical challenges, and the need to integrate into the global economy. In the study by N. Kuprina (2023) on global competitiveness and economic transformation, a relevant addition is the consideration of the impact of martial law on business entities, the implementation of digitalisation tools, sustainable development (environmental, social, and governance (ESG)), adaptation to European standards, human capital development in conditions of migration, and business relocation tools. The competitiveness of the national economy of Ukraine is impossible without the development of human capital, the restoration and improvement of infrastructure, and the encouragement of enterprises to social responsibility, which can improve their reputation and contribute to the development of local communities. Supporting sustainable business models that take into account environmental aspects, the introduction of environmentally friendly technologies and policies to reduce the burden on the environment contribute to attracting greater investment and the growth of new markets, which can become a competitive advantage for the national economy.

In 2019, Singapore's economy was the best in terms of indicators (overall index 84.8) and took first place in GCI 4.0 in the rating of 141 countries. The United States of America, Hong Kong, the Netherlands, Switzerland, Japan, Germany, Sweden, the United Kingdom, and Denmark took the highest positions in the GCI 4.0 rating for 2019. At the same time, in 2019, Yemen ranked 140th and Chad 141st in the GCI (WEF, n.d.). The WEF (n.d.) is not publishing a Global Competitiveness Report for several reasons. In 2021, the WEF decided to change its approach to assessing the competitiveness of countries. Instead of the traditional GCI, a new format was introduced that focuses on reporting on global and regional trends in the economy. The WEF focuses on new criteria and trends that have emerged as a result of the COVID-19 pandemic and its impact on the global economy, directly on the competitiveness of countries. Typically, this is associated with the transition to more sustainable development, digitalisation and social inclusion. The world is facing new challenges, such as geopolitical risks, climate change, inequality, and the social and economic consequences of the pandemic. These factors require new approaches to understanding competitiveness, which cannot always be adequately reflected in the traditional form of the index. The new approach to analysis includes more factors and indicators than just economic data, as the WEF seeks to assess how different countries are adapting to new conditions. 2024 was a year of escalation of armed conflicts, increased extreme weather events caused by climate change, political polarisation, and the spread of technologies that facilitate disinformation. According to the experts' evaluations of the basic indicators, therefore, follow how the positions of the countries in this rating changed in Table 3.

Table 3. Ranking of countries in the world according to the Global Competitiveness Index in 2017-2019

Ranking by years			Country	Index by years		
2017 (135 countries)	2018 (140 countries)	2019 (141 countries)		2017	2018	2019
2	2	1	Singapore	83.0	83.5	84.8
1	1	2	United States	84.8	85.6	83.7
7	7	3	Hong Kong	82.0	82.3	83.1
5	6	4	Netherlands	82.2	82.4	82.4
4	4	5	Switzerland	82.4	82.6	82.3
8	5	6	Japan	81.6	82.5	82.3
3	3	7	Germany	82.6	82.8	81.8
8	9	8	Sweden	81.6	81.7	81.2
6	8	9	United Kingdom	82.1	82.0	81.2
11	10	10	Denmark	79.9	80.6	81.2
12	11	11	Finland	79.8	80.3	80.2
13	13	12	Taiwan	79.2	79.3	80.2
17	15	13	South Korea	78.0	78.8	79.6
10	12	14	Canada	80.0	79.9	79.6
18	17	15	France	77.4	78.0	78.8
89	83	85	Ukraine	53.9	57.0	57.0
134	139	140	Yemen	35.5	36.4	35.5
134	140	141	Chad	35.5	35.5	35.1

Note: scale ranges from 0 to 100
Source: compiled by the authors based on WEF (n.d.)

In the research of scientists N. Volosnikova *et al.* (2022), it was established that the WEF classified Ukraine as a country in transition from a factor-oriented economy to an economy focused on efficiency. To countries at this stage of development, the WEF (n.d.) suggests that, in order to strengthen national competitiveness, they ensure the effective functioning of public and private institutions and stabilise the macroeconomic environment, and then improve the efficiency of production processes and professional training of personnel. It should be noted that for Ukraine's transition from a factor-oriented to an economy focused on efficiency (according to the methodology of the WEF (n.d.), it is also key to shift the focus from the use of cheap resources to the intensification of production and the quality of institutions.

The IMD (n.d.) World Competitiveness Ranking is conducted according to the methodology of the IMD. The authors of the study understand the competitiveness of a country as the ability of a national economy to create and maintain an environment in which competitive business arises. The Institute has been conducting an annual analytical study of competitiveness since 1989 in collaboration with partner organisations around the world. Until 1996, the Institute prepared reports on the competitiveness of economies jointly with the analytical group of the WEF, and since 1996 these two organisations have produced two separate studies. The WEF (n.d.) publishes its own annual report and an accompanying global competitiveness ranking, which is based on the GCI. The WEF (n.d.) emphasises that long-term economic growth must be based on a combination of innovation, inclusion, and sustainability, and identifies the quality of institutions, human capital development, digital transformation, and environmental responsibility as key factors for future competitiveness.

The annual IMD World Competitiveness Yearbook is one of the most comprehensive periodic studies on the competitiveness of countries and regions, which is used in a number of countries to form public policy and determine further government actions to increase the competitiveness of the national economy, as well as strategic business decisions in large companies IMD (n.d.). Each country in the ranking is evaluated based on an analysis of more than 300 criteria (the number of which is periodically

increasing) according to four main indicators of key aspects of the country's economic life: the state of the economy (domestic economy, international trade, international investment, employment, prices); government effectiveness (public finances, tax policy, institutional structure, business legislation, social structure); business effectiveness (productivity and efficiency, labour market, financing, management practices, attitudes and values); infrastructure (basic infrastructure, technological infrastructure, scientific infrastructure, health and environment, education). The indicators have equal weight. The ranking uses a wide range of indicators and statistical data, including data from international organisations, including the United Nations, the Organisation for Economic Cooperation and Development, the World Trade Organization, the World Bank, the International Monetary Fund and other institutions, as well as 57 partner organisations around the world. The business climate in the countries covered by this study is assessed based on the opinions of analysts, surveys of heads of large companies and specialists in the field of management. The final ranking is based on the inverse ratio: two-thirds – statistical data and one-third – expert assessments. Ukraine's place in the IMD World Competitiveness Ranking for 2016-2021 is presented in Table 4.

Table 4. Ukraine's position in the IMD World Competitiveness Ranking for 2016-2021

Years	Overall assessment	Economic indicators	Government efficiency	Business efficiency	Infrastructure
2016	59	60	57	60	50
2017	60	55	59	59	53
2018	59	58	59	55	53
2019	54	56	54	50	52
2020	55	54	58	49	54
2021	54	54	53	50	51

Source: compiled by the authors based on IMD (n.d.)

According to IMD (n.d.), until 2018, a downward trend was observed, only in 2019. Ukraine managed to rise 5 places in the ranking, which was due to the rapid growth of government and business efficiency, the state of the economy and infrastructure also improved, but not so significantly. In 2020, due to the weakening of the positions of government efficiency and the state of infrastructure, one position was lost. In 2021, Ukraine again took 54th place, while the state of the economy remained unchanged, government efficiency and the state of infrastructure contributed to growth, and business efficiency, on the contrary, moved one place lower. Starting from 2022, Ukraine is not included in the World Competitiveness Ranking due to the limited reliability of the collected data. It is worth noting that in 1991, state had good starting economic opportunities, for example, the level of GDP per capita was higher than in some European countries, USD 6,790 per person versus 6,176 in Poland 5,272 in Romania (Vasylchak *et al.*, 2024). The study by S. Vasylchak *et al.* (2024) indicates a significant gap between Ukraine and the EU in terms of sustainable development indicators, which has been exacerbated by military actions. The analysis confirms Ukraine's lagging behind in the environmental and economic spheres, requiring a focus on "green" recovery, which complements the author's study with an emphasis on external risks. Analytical review carried out by P. Kutsyk *et al.* (2024) rightly focuses on digitalisation and the internal market. This concept can be complemented by emphasising sustainable development (green economy), cybersecurity of infrastructure, human capital development (STEM) and integration into European digital value chains, which will make the reform more sustainable. Modern studies adapt these approaches, focusing on digitalisation, ESG factors, and the impact of military aggression on economic stability. The ranking of world economies by level of global competitiveness (IMD World Competitiveness) is presented in Table 5. Ukraine rose by 5 positions and was ranked 54th in the 2021 World Competitiveness

Index, compiled annually by the International Institute for Management Development in Switzerland (IMD, n.d.). Country ranks between Slovakia and Peru. Among post-Soviet countries, the highest places in the ranking are occupied by Lithuania (29), Kazakhstan (34) and Estonia (35). In total, 63 countries are ranked. Singapore took first place in 2019, displacing the United States from the top of the ranking (this country is in third place). Hong Kong is in second place.

Table 5. Ranking of world economies by global competitiveness (IMD World Competitiveness)

Rank by year					Country	Index by year				
2020	2021	2022	2023	2024		2020	2021	2022	2023	2024
1	5	3	4	1	Singapore	100.0	94.7	98.11	97.44	100.0
3	1	2	3	2	Switzerland	98.37	100.0	98.92	99.13	97.55
2	3	1	1	3	Denmark	99.5	96.67	100.0	100.0	97.07
12	13	11	2	4	Ireland	90.73	87.02	89.55	99.71	91.86
5	7	5	7	5	Hong Kong	97.06	93.54	94.89	92.05	91.49
6	2	4	8	6	Sweden	95.87	96.71	97.71	91.86	90.30
9	9	12	10	7	United Arab Emirates	93.5	89.56	88.67	90.52	89.75
11	8	7	6	8	Taiwan	91.27	92.6	93.13	93.11	88.50
4	4	6	5	9	Netherlands	98.35	96.35	94.29	95.58	86.94
7	6	9	14	10	Norway	94.6	94.49	92.96	88.33	86.22
14	17	18	12	11	Qatar	87.86	82.72	83.85	89.72	85.33
10	10	10	9	12	United States	92.36	89.13	89.88	91.14	83.48
18	22	19	19	13	Australia	85.03	77.17	82.56	83.02	81.86
20	16	17	21	14	China	82.04	83.01	83.94	82.1	81.04
13	11	8	11	15	Finland	88.63	88.47	93.04	89.33	80.26
55	54	–	–	–	Ukraine	51.87	50.1	–	–	–
62	63	62	63	66	Argentina	38.06	32.85	34.23	34.03	35.89
63	64	63	64	67	Venezuela	25.37	22.0	21.95	26.18	28.85

Source: compiled by the authors based on IMD (n.d.)

In 2021, the global competitiveness ranking was led by European countries: Switzerland in first place, Sweden in second, Denmark in third, and the Netherlands in fourth. In turn, Singapore, which was first in 2019 and 2020, was in fifth place. The determining factors of competitiveness were the presence of innovations, digitalisation, supportive policies, and social cohesion. The Top ranking of countries with the most competitive economies in 2022, out of 63 countries studied, consists of the following countries: 1 – Denmark, 2 – Switzerland, 3 – Singapore, 4 – Sweden, 5 – Hong Kong, 6 – Netherlands, 7 – Taiwan, 8 – Finland, 9 – Norway, 10 – USA. Ukraine's indicators were not considered – the data for 2021 remained. Singapore is the most competitive economy in 2024. Switzerland came second, Denmark came third, and Nigeria, Ghana, and Puerto Rico debuted in 2024. The countries with the lowest level of economic competitiveness over the studied period were Argentina and Venezuela (IMD, n.d.).

The state of the economy is negatively affected by inefficient management of public finances and high inflation, and a positive effect is achieved through the protection of intellectual property rights, a developed judicial system and other measures. Along with institutional factors, education and advanced training of the workforce, constant access to new knowledge and technologies are of crucial importance. Factors that determine the competitiveness of the economy affect the economic systems of countries around the world in different ways depending on the starting conditions and the current level of development. Increasing the competitiveness of the national economy of Ukraine is possible only by understanding and optimising the impact of both internal and external factors. Coordinated action in these two categories will allow Ukraine not only to increase its competitiveness in the global market, but also to ensure sustainable development, social well-being and adaptation and adaptation to modern challenges. When

studying the competitiveness of the national economy of Ukraine, scientists O. Kireitseva *et al.* (2024) emphasise what is needed focusing on European markets offers promising opportunities for growth and cooperation. To unlock the full potential of partnerships, internal challenges such as excessive tax burdens and burdensome customs regulations need to be addressed.

Understanding the relationship between internal and external factors will contribute to the formation of effective strategies that will allow Ukraine to maximise its competitive advantages. In the traditional model of economic development formed in Ukraine, drivers of economic growth are understood primarily as industries and sectors of the economy whose development ensures GDP growth, as well as internal and external factors that influence the increase in the volume of production of products or services (demand, competition, changes in global markets, investments, etc.) (Matseliukh & Korzh, 2021). The prospects for the recovery of the Ukrainian economy largely depend on the ability of enterprises to use their competitive advantages and adapt to new conditions. Enterprises that effectively respond to external challenges will be able to implement innovative approaches and cooperate internationally, have the potential for successful development and strengthening their positions in the market. Yu. Naumenko(2024) focuses on the ability of Ukrainian business to adapt to the extreme challenges of wartime and post-war reconstruction. The author proves that traditional factors (resource base, cheap labour) are losing their primary importance, instead, financial stability, operational flexibility, and innovative activity are becoming key. The need to create a favourable investment climate and active state support to attract capital to the modernisation of the national economy is substantiated. In addition, traditional factors – the resource base and labour costs – are being transformed today. In order for them to become a real competitive advantage in the modern world, they need to be considered through the prism of modernisation and integration into global value chains. These factors are becoming an undeniable advantage not in themselves, but as a foundation for building technological production. It is extremely important to improve the investment climate, namely through the introduction of tax incentives, simplification of business registration procedures, increased transparency in public procurement, guaranteeing property rights, combating corruption, and creating an effective justice system to ensure investor protection.

The study by V. Strilets *et al.* (2024) is devoted to the analysis of factors of innovative development that determine international competitiveness. The authors conducted a comparative analysis of Ukraine and the EU countries using modern methods of economic and mathematical modelling. It was found that in the European Union countries, eco-innovations, innovation management and intellectual property development have the most significant positive impact on competitiveness. In Ukraine, a weak connection was found between the protection of intellectual property, innovations in industry and the overall competitiveness of the country. Digital innovations are identified as the most powerful and positive factor stimulating the competitiveness of the national economy of Ukraine. The study confirmed that innovations in the business sector are critical for both objects of analysis, however, in Ukraine there is a significant gap between the innovation potential and its actual implementation. It is worth adding that the migration of human capital and the relocation of innovative enterprises (both within the country and abroad) have changed the structure of Ukraine's innovation potential. Researchers V. Shkola *et al.* (2021) investigated the direct relationship between the development of intellectual capital (IC) and competitiveness. The main result is confirmation that a higher level of intellectual capital provides more stable positions in global competitiveness rankings, where the EU is the leader, and Ukraine has a significant lagging, but potential trend. Modernisation of the Ukrainian economy requires not only increased funding for education, but also the creation of conditions for the realisation of intellectual potential in business. The study by V. Shkola *et al.* (2021) is basic for understanding the priorities of Ukraine, where the advanced development of human capital is a prerequisite for the competitiveness of the national economy.

N. Kuprina (2023) explores the relationship between global competitiveness and the transformation of the national economy of Ukraine, highlighting theoretical foundations and practical results. The author analyses the impact of external and internal factors on the positions of business entities, suggesting ways to adapt the economy to global challenges. Increasing the competitiveness of the national economy of Ukraine depends on a number of internal and external factors. These factors interact with each other and determine the overall efficiency of the economy in the context of globalisation. To increase the competitiveness of the national economy of Ukraine, it is necessary to take into account both internal and external factors. Internal and external factors of increasing the competitiveness of the national economy of Ukraine are presented in Table 6.

Table 6. Internal and external factors of increasing the competitiveness of the national economy of Ukraine

Internal factors	External factors
Economic policy. Stability of macroeconomic policy, control over inflation and the exchange rate of the national currency create favourable conditions for business development.	Globalisation. Openness to foreign trade and investment, which allows a country to integrate into the world economy and gain access to new markets.
Infrastructure. Developed transport, communication and social infrastructure reduces costs for enterprises and facilitates access to markets.	International agreements and cooperation. Participation in international treaties, free trade agreements, and economic unions, which helps reduce barriers to business and increase competitiveness.
Education and vocational training. Availability of a qualified workforce, prepared to adapt to rapidly changing labour market requirements and new technologies.	Foreign investment. Attracting foreign investment can provide not only financial resources, but also technology, skills, and management experience.
Innovation and technology. Introduction of new technologies and support for innovation in entrepreneurship, which leads to increased labour productivity and product quality.	International markets. The situation in international markets and global trends that affect the demand for Ukrainian goods and services.
State support system. Effective state policy to support industry, small and medium-sized businesses, including financial, consulting and organisational aspects.	Competition on the world stage. The experience of competitors from other countries, which stimulates Ukrainian enterprises to improve product quality, reduce costs, and innovate.
Legal framework. Creation of a transparent and fair legal system that ensures protection of property rights and simplifies regulatory procedures.	The state of the global economy. The impact of macroeconomic factors, such as economic crises, changes in commodity prices, and currency fluctuations, which can positively or negatively affect Ukraine's relations in foreign markets.
Social responsibility of business. Enterprises that adhere to the principles of social responsibility are able to improve their image, which affects consumer demand and investment attractiveness.	Social and economic challenges in the world. The impact of global challenges such as climate change, epidemics and demographic changes, which will require adaptation to increase competitiveness.

Source: compiled by the authors

Increasing the competitiveness of the national economy is an important task for ensuring sustainable economic growth, improving the well-being of citizens and integrating Ukraine into the global economy. Effective public policy, innovation and investment in human capital are key factors for success in this process. Effective implementation of these strategies will allow Ukraine not only to increase its competitiveness in the global market, but also to create conditions

for sustainable economic growth, improving the quality of life of citizens and achieving social justice. The development of partnership between the state and business should take place in the format of establishing effective communication channels between the government and the business sector, which will allow taking into account the needs and proposals of entrepreneurs when forming economic policy. It is also worth involving representatives of business and the expert community in the process of developing regulatory acts and legislative initiatives. Support for small and medium-sized enterprises through microfinancing, soft loans and state grants is an important component of increasing the competitiveness of the national economy. An important component of a competitive national economy is improving the international image of Ukraine, promoting the formation and promotion of Ukrainian brands in international markets to increase the recognition and competitiveness of products. Recommendations for increasing the competitiveness of the national economy of Ukraine are presented in Table 7.

Table 7. Recommendations for increasing the competitiveness of the national economy of Ukraine

Recommendations	Description
Structural reforms	Modernisation of the economy: It is necessary to introduce innovative technologies in traditional sectors, such as industry and agriculture, and to support the development of new sectors, in particular IT and the green economy.
	Diversification of the economy: Reducing dependence on individual industries and developing new markets to reduce the economy's vulnerability to external shocks.
Improving the investment climate	Stimulating investment: Introducing tax incentives, simplifying business registration procedures and increasing transparency in public procurement.
	Protection of investor rights: Guaranteeing property rights, combating corruption and creating an effective justice system to ensure investor protection.
Supporting innovation and research	Development of scientific technologies: Supporting scientific research and innovation initiatives through funding, research grants and cooperation between universities and businesses.
	Innovation hubs: Creating innovation clusters and technology parks to facilitate the exchange of knowledge and ideas.
Developing human capital	Education and vocational training: Reforming the education system with an emphasis on modern skills, critical thinking and entrepreneurial abilities to prepare competitive specialists.
	Upskilling: Providing a continuous training programme for workers to adapt to rapidly changing labour market conditions.
Improving infrastructure	Transport infrastructure: Investing in the modernisation of transport networks, which will ensure the efficiency of logistics and reduce the cost of transporting goods.
	Digital infrastructure: Developing fast Internet and digital technologies to ensure access to information and convenient business.
Supporting exports	State export support programmes: Providing enterprises with information about foreign markets, assistance in participating in international exhibitions and fairs.
	Deepening trade relations: Active participation in international economic organisations, concluding free trade agreements to expand access to new markets.
Environmental policy	Sustainable development: Introducing environmentally friendly technologies and policies to reduce the burden on the environment, which can also become a competitive advantage.
	Green economy development: Supporting sustainable business models that take into account environmental aspects, which can contribute to attracting investment and the growth of new markets.
Developing social policy	Ensuring social justice: Creating conditions for reducing social inequalities, which will contribute to social peace and sustainable economic development.
	Corporate social responsibility: Encouraging enterprises to be socially responsible, which can improve their reputation and contribute to the development of local communities.

Source: compiled by the authors

Ensuring flexibility in state economic policy for rapid adaptation to changes in the global economic environment, in particular in response to challenges associated with the pandemic or economic crises, as well as the introduction of a competitiveness monitoring system that will allow for timely identification of the strengths and weaknesses of the economy, as well as adapting policy in accordance with new conditions. Practical steps that can be taken to adapt to change and increase competitiveness are identified, including: integrating internal and external strategies through harmonisation of economic policy and strategic planning; systematic monitoring and analysis; cooperation with international partners to share experiences; investment in human capital through skills development and workforce mobility; creating a favourable business environment and implementing environmental practices.

CONCLUSIONS

The competitiveness of the national economy is a key element for ensuring the country's well-being, sustainable development and integration into the global economic system. Successfully increasing competitiveness will require a comprehensive approach, synergy of efforts of the state, business and society to implement strategies aimed at economic growth and innovation. The results of the study will contribute to the formation of new approaches to strategic planning in the economic policy of Ukraine, as well as provide scientifically sound recommendations for state structures, business and other stakeholders in increasing the competitiveness of the national economy. Research into the problem of the competitiveness of the national economy of Ukraine is of great importance for its sustainable development, social well-being of citizens and strengthening its positions in the international arena. Increasing the competitiveness of the national economy of Ukraine is a complex and multifaceted task that will require a comprehensive approach and cooperation of all participants in the economic process. The implementation of these recommendations can become the basis for the formation of a new economic model that can ensure the stability, development and prosperity of the country. So, according to the WEF study for the period of 2010-2019, Ukraine had the highest rating in terms of indicators in 2012-2013 (73rd place out of 144 economies in the world). From 2014 to 2016, there is an obvious downward trend, Ukraine lost 9 positions in two years. In 2017, there was a rise of 4 steps, however, by 2019 the country returned to the 2016 level, taking 85th place in the rating among 141 countries. A study of the state of Ukraine's ranking in the Global Competitiveness Index according to the corresponding index showed that the country's positions are not stable and have a negative trend towards a rapid decline.

Research prospects will focus on adapting the GCI and World Competitiveness Ranking methodologies to the context of war and post-war reconstruction, namely, developing new indicators that take into account security risks, infrastructure destruction, and internal migration. Key areas include digital transformation, fighting corruption, human capital development, and assessing the resilience of infrastructure to attract investment. The main focus of future research should be on identifying priority competitive advantages for post-war reconstruction and improving positions in global rankings.

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Конкурентоспроможність національної економіки України

Анотація. В статті проведено аналіз конкурентоспроможності економіки України, за даними Глобального індексу конкурентоспроможності (Всесвітнього економічного форуму) та Рейтингу світової конкурентоспроможності (Інституту розвитку менеджменту). Конкурентоспроможність національної економіки України є ключовим фактором інтеграції в глобальну економічну спільноту та забезпечення сталого розвитку. Метою дослідження був комплексний аналіз конкурентоспроможності економіки України за даними Глобального індексу конкурентоспроможності та Рейтингу світової конкурентоспроможності, а також визначення внутрішніх, зовнішніх факторів та обґрунтування практичних рекомендацій

щодо підвищення конкурентоспроможності національної економіки України. Методологічна основа дослідження конкурентоспроможності національної економіки України дозволила провести комплексний аналіз та оцінку на основі міжнародних показників. Це допоможе визначити ключові аспекти, на які слід звернути увагу з метою підвищення конкурентоспроможності України на світовій арені. У дослідженні визначено основні виклики, що стоять перед Україною. У статті основна увага приділялася важливості державної політики в боротьбі з корупцією, стимулюванні розвитку інновацій та підвищенні якості освіти, що є необхідними умовами посилення конкурентоспроможності. Особлива увага приділялася впливу процесів глобалізації та міжнародного співробітництва на конкурентні переваги України. Зроблено висновок, що лише комплексний підхід, який поєднує економічні, соціальні, технологічні та екологічні аспекти, дозволить Україні підвищити свою конкурентоспроможність на міжнародному ринку, покращити добробут населення та забезпечити сталий розвиток. Практичне значення дослідження полягає в розробці науково обґрунтованих рекомендацій для державних органів, бізнесу та інших зацікавлених сторін щодо підвищення конкурентоспроможності національної економіки

Ключові слова: глобалізація; інновації; людський капітал; сталий розвиток; ризик

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The role of digital performance indicators in shaping the promotion strategy of construction services in agribusiness

Abstract. In the context of economic digitalisation, the marketing activities of construction companies oriented towards agribusiness depend on data and analytical tools that enable informed decision-making based on quantitative indicators. The aim of the article was to establish quantitative relationships between the main SEO indicators of websites and the volume of organic traffic, as well as to assess their influence on the development of an effective promotion strategy for construction services aimed at agribusiness enterprises. To achieve this aim, a sample of 17 Ukrainian construction companies specialising in the construction of facilities for the agricultural sector was formed. The data were obtained from the Ahrefs service as of October 2025. The study employed correlation analysis according to the Chaddock scale, single-factor linear regression models, multifactor non-linear regression models with interaction elements, and simulation sensitivity analysis. The results revealed strong positive correlations between organic traffic and key SEO metrics: the number of keywords ranked in positions 1-3 ($r = 0.87$) and positions 4-10 ($r = 0.89$), the total number of referring domains ($r = 0.91$), the number of "dofollow" referring domains ($r = 0.91$), the number of unique referring IP addresses ($r = 0.88$), and the number of unique Class C subnets ($r = 0.88$). Six statistically significant single-factor linear regression models were developed with coefficients of determination R^2 ranging from 0.7427 to 0.8126. Multifactor non-linear models with interaction elements demonstrated higher explanatory power (R^2 up to 0.999). The simulation sensitivity analysis confirmed that the greatest increase in organic traffic is achieved through an increase in the number of keywords in the top 3 positions (+282 visits/month) and through improving the URL rating of web pages (+150-162 visits/month). The practical significance of the study lies in the fact that the obtained results enable construction companies to develop KPI-oriented promotion strategies, optimise the allocation of marketing resources, and improve the effectiveness of interaction with clients in the agricultural sector

Keywords: digital marketing; web analytics; mathematical models; organic traffic; SEO metrics; agricultural enterprises; B2B strategies

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INTRODUCTION

In the context of the digitalisation of the economy, the marketing activities of enterprises are increasingly based on the use of data and analytical tools that enable managerial decisions to be substantiated through quantitative indicators. This is particularly relevant for the market of construction services oriented towards agricultural enterprises, which is characterised by high capital intensity of projects, long decision-making cycles, and a limited number of potential clients. Under such conditions, digital communication channels perform not only an informational function but also become an important element in building trust in the contractor and strengthening its competitive advantages. Scientific research confirms the growing role of digital performance indicators in shaping agribusiness marketing strategies. In their work on SMM strategies for the agricultural sector, S. Koberniuk *et al.* (2025) concluded that content quality, a balance of practical and emotional material, and constant monitoring of ROI are key factors in increasing audience engagement and loyalty in the agricultural sector. Researchers N.B. Zelisko & V.V. Maliuha (2025) analysed the application of marketing tools in the construction industry and found that the integrated use of SMM, SEO and email marketing significantly increases the effectiveness of promoting B2B services in particular. Author I. Yatskevych (2024) described a five-stage model for developing an SMM strategy and emphasised the need to integrate KPIs (reach, engagement, conversion) at each stage to achieve measurable results. Author I. Gushcha (2023) investigated digital technologies in agromarketing and demonstrated that the implementation of the Internet of Things, virtual and augmented reality, as well as data analytics, enables the creation of personalised promotion strategies that directly influence customer loyalty.

D. Nyangoma *et al.* (2024), in their models of strategic digital marketing for agribusiness, demonstrated that a data-driven approach with a focus on ROI and conversion rates is key to enhancing the competitiveness of agricultural companies. Researcher W. Shen (2024), using agricultural machinery manufacturers as an example, demonstrated that the application of artificial neural networks and fuzzy cognitive mapping for traffic analysis enables the optimisation of digital advertising costs and the enhancement of marketing channel effectiveness. In her study of digital marketing for agricultural mechanisation in Africa, A.S. Ajibola (2025) emphasised that KPIs (engagement, conversion to purchases, ROI) are essential for assessing the impact of social media and mobile platforms on the sustainability of small agribusinesses. Authors E.A. Inyommom *et al.* (2025), based on a regression analysis of Nigerian agricultural firms, found that social media marketing, relationship marketing and content marketing collectively explain over 51% of the variation in company performance, with SMM having the strongest influence.

M. Braglia *et al.* (2022) proposed a structured Industry 4.0 approach to KPIs (penetration, recognition, productivity) and demonstrated that systematic monitoring of digital technologies via a metrics matrix is the key to effective digital transformation of production. The authors U.S. Nwabekee *et al.* (2021) demonstrated that integrating digital marketing with financial metrics (ROI, CAC, CLV, ROAS) enables companies in competitive sectors to significantly increase profitability, particularly when organisational barriers between marketing and finance are overcome. In their study of brand awareness and digital marketing in the agricultural sector, M. Sheeraz *et al.* (2023) found that media analytics, web analytics and UTM parameters enable the precise measurement of the impact on brand awareness and organic traffic. According to research into digital marketing strategies in the agri-food sector by N. Kanellos *et al.* (2024), it was found that increased digital marketing effectiveness helps to reduce advertising costs and boost profitability through more efficient use of resources and the optimisation of advertising campaigns.

The specific characteristics of the B2B market for construction services aimed at agricultural enterprises, where organic traffic serves as the primary source of high-quality leads and key SEO indicators (the number of keywords in top positions, backlink profile, URL rating) directly determine promotion effectiveness, remain insufficiently studied. Under conditions

of the growing importance of digital marketing, a considerable proportion of agricultural-oriented construction companies utilise websites and other digital tools in a fragmented manner, without a clearly defined system of performance indicators or strategic orientation. In marketing management practice, the evaluation of isolated metrics, such as the number of visits or keyword rankings, predominates without consideration of their combined influence on promotion outcomes. Thus, the absence of empirical studies combining organic traffic analysis with correlation and regression methods specifically for this segment highlighted the need to determine the role of digital performance indicators in shaping the promotion strategy of construction services for agricultural enterprises.

The object of the study was the marketing activities of construction companies providing design and construction services for agricultural enterprises in Ukraine. The subject of the study was the digital performance indicators of the websites of these companies, namely: organic traffic and key SEO metrics, and their impact on the results of promoting construction services in the digital environment. The aim of the article was to determine the role of digital performance indicators in shaping the strategy for promoting construction services for agricultural enterprises based on a correlation and regression analysis of web analytics data from Ukrainian construction companies. To achieve this aim, the article set out to address the following objectives: to analyse the key digital performance indicators of websites belonging to construction companies in the agricultural sector; to assess the strength of the relationship between digital indicators and outcome variables; and to justify the use of digital indicators as a tool for strategic marketing planning.

MATERIALS AND METHODS

The methodological framework of the study was developed with consideration of the specific characteristics of the construction services market for agricultural enterprises, which is characterised by high-value transactions, long decision-making cycles, and the dominance of B2B communications. Under such conditions, digital promotion channels perform not only an informational function but also a strategic one, fostering trust in the contractor and supporting the customer acquisition process. To achieve the stated aim, the study employed a combination of general scientific and specialised methods. In particular, methods of analysis and synthesis were used to generalise theoretical approaches to evaluating the effectiveness of the digital promotion of services, while the comparative method was applied to compare the levels of digital activity among the analysed companies. The principal tool of quantitative analysis was correlation analysis, which enabled the assessment of the strength and direction of relationships between digital website indicators and the resulting variables. To evaluate linear relationships between variables, a matrix of pairwise Pearson correlation coefficients (r) was calculated, and the interpretation of the strength of relationships was conducted according to the Chaddock scale. Correlation coefficients were determined using the following formula (Illowsky & Dean, 2018):

$$r = \pm\sqrt{R^2}, \tag{1}$$

where, R^2 – the coefficient of determination, which indicates how well the factors explain the outcome, where a value of 0 means that the model explains nothing, while a value of 1 means that the model fully explains the variability of the data (Illowsky & Dean, 2018). Correlation coefficients may vary within the range from -1 to +1 (LibreTexts Ukrayinska, 2025), where values of $|r| > 0.7$ according to the Chaddock scale indicate a strong (close) relationship, $0.3 \leq |r| < 0.7$ indicate a moderate relationship, $0.1 \leq |r| < 0.3$ indicate a weak relationship, and $|r| < 0.1$ indicate a very weak or absent relationship (Tyutchenko, 2022).

To identify causal relationships between the indicators, econometric modelling methods were employed. At the first stage, single-factor linear regression models with separate independent variables were constructed, which made it possible to identify the key influencing factors affecting the resulting indicator and to select statistically significant variables with high coefficients of determination. At the second stage of the study, multifactor non-linear

regression models with interaction elements in the form of second-order polynomials without quadratic terms were developed. This approach was chosen in order to account for the synergistic influence of digital indicators on promotion outcomes. Particular attention was devoted to avoiding multicollinearity between independent variables, which was achieved through preliminary analysis of the correlation matrix and the construction of models only with relatively independent factors (Farrar & Glauber, 1967). The adequacy of the constructed models was assessed on the basis of the coefficient of determination R^2, the Fisher criterion, and the level of statistical significance of the regression coefficients (p-value). In addition, average and maximum approximation errors were analysed in order to assess forecasting accuracy.

Sensitivity simulation analysis of multiple regression models was also applied, enabling the assessment of how changes in independent variables (X_n) affect the dependent variable Y_1 (organic traffic). This approach has practical value for marketing applications, as it helps predict the effect of investments in SEO factors for companies operating within the agricultural construction sector. It constituted a logical continuation of the previous regression analysis and was based on the principles of econometrics and scenario modelling. The applied methodological approach made it possible not only to establish statistical relationships between digital website performance indicators and the results of construction service promotion, but also to create a foundation for the practical application of the obtained results within the process of strategic marketing planning for construction companies oriented towards the agricultural sector.

The information base of the study consisted of data from the leading web analytics service Ahrefs (n.d.) and SEO analysis tools (Bek, 2023), reflecting the organic presence of websites in search engines, keyword structure, traffic volume and value, as well as indicators of the external backlink profile. The initial population comprised 32 Ukrainian companies specialising in the construction of facilities for the agricultural sector, selected from search query results across the five most effective search engines: Bing, DuckDuckGo, Yahoo, Ecosia, and Google, which are characterised by relevant, accurate, and unique search outputs (Chertinov, 2025). During the sample formation process, step-by-step data cleaning was conducted: resources not directly belonging to companies (aggregators and advertising platforms), websites displaying signs of fraud or technical threats, and web resources hosted on web studio domains not indexed by analytical services were excluded. In addition, paid advertising indicators were deliberately excluded from the analysis, since only a small proportion of companies used paid traffic acquisition channels, making it impossible to produce representative conclusions. Certain indicators relating to outgoing and backlinks were also excluded because of their low representation within the overall population of analysed websites. Following the completion of the staged data cleaning process, a final sample of 17 companies and a 17 × 17 data matrix containing 17 digital performance indicators were formed.

RESULTS

The construction of facilities for agricultural enterprises (silos, farms, warehouses, etc.) represents a narrow B2B segment with limited search demand. Clients (agricultural producers) search for such services infrequently (seasonally or during investment projects), mainly using local or highly specific queries ("elevator construction", "grain storage construction", "metal structures for farms", etc.). Organic traffic in this sector is consistently lower than in B2C or mass-market B2B segments. Global benchmarks for the construction sector (Kaufman, 2025; Rudan, n.d.) indicated average traffic of approximately 1,000-4,000 sessions per month, primarily characterising large-scale or consumer-oriented companies. According to Ahrefs (n.d.), SEMrush (n.d.), and BrightEdge (n.d.), the volume of organic traffic for professional services in 2024 was generally distributed as follows: small companies generated 1,200-3,500 sessions per month, medium-sized companies 4,000-12,000 sessions per month, and large companies more than 20,000 sessions per month (International Outsourcing Group, n.d.). Reports demonstrated that, globally, the construction sector in the United States and Europe recorded lower average traffic

than mass-market industries (e-commerce approximately 20K-200K), but higher traffic than narrow B2B segments in Ukraine (International Outsourcing Group, n.d.). According to B2B statistics for 2025, organic traffic from the first search position generated a 27% CTR on mobile devices (First Page Sage Team, n.d.); the average CTR for keywords ranked in positions 1-3 ranged between 27-32%, whereas for positions 4-10 it declined to 10-15%. This justified the need for a detailed distribution of organic keywords by ranking positions within the data matrix and for subsequent regression analysis in order to accurately determine their influence on organic traffic within the B2B segment (Shum, 2026).

To identify Ukrainian construction companies specialising in the construction of facilities for the agricultural sector, search queries were conducted in five search engines: Bing, DuckDuckGo, Yahoo, Ecosia, and Google (Chertinov, 2025). Each search engine produced search results, from which no fewer than 20 relevant entries were selected. Subsequently, the list of companies was consolidated into a single table with duplicates removed. As a result, a list of 32 companies was obtained (Table 1).

Table 1. Companies specialising in the construction of facilities for agricultural enterprises in the Top 5 organic search results of search engines

No.	Company name	No.	Company name	No.	Company name
1	Lubnymash	12	Platonmax	23	Innovative Technologies Ukraine
2	Pulsar Construction	13	Budmontazh Kolos	24	KMZ
3	Demetra	14	UCG	25	Sokol
4	Eridon Bud	15	Elkos LTD	26	Agrovector
5	Adept Group	16	Invest Bud	27	Grain Capital
6	Finpro Group	17	ServiceStroy	28	Ravaro
7	Neuero Ukraine	18	Neobud-Montazh	29	Delta Engineering
8	Elevator Machinery Plant	19	BOEZ Ukraine	30	Arsenal
9	MUR	20	Ecorembud	31	APK Global
10	Vityaz	21	Bogart Bud	32	TransBud Project
11	Grain Complexes and Systems	22	Rilia Ukraine		

Source: compiled by the author

Company No. 26 in Table 1 was excluded from the analysis because the link directed not to the company's website, but to the AgroVector platform containing advertisements for the construction of agricultural facilities. Position No. 29 was excluded from the analysis due to an antivirus warning identifying the site as a scam. Positions No. 31 and No. 32 were removed because the websites were developed on studio domains that are not indexed by Ahrefs (n.d.). Companies No. 8, No. 15, No. 21, and No. 23 were excluded from the analysis due to an insufficient number of indexed indicators, as well as having a zero domain rating and no Ahrefs rank assigned (Ahrefs, n.d.). In addition, companies No. 5, No. 14, No. 18, No. 19, No. 20, No. 28, and No. 30 were excluded because of the absence of data on organic traffic. From the dataset obtained through the Ahrefs analytics service (Bek, 2023), indicators related to paid advertising were excluded, since only 3 out of the 32 companies (9.4%) used such services: BOEZ Ukraine (No. 19), KMZ (No. 24), and Grain Capital (No. 27). Indicators relating to the uniqueness of outgoing domains, outgoing links, and backlinks were also excluded from the analysis due to their limited coverage, representing only 25% of the total number of analysed construction companies (8 out of 32). As a result of the step-by-step data cleaning process, a final sample of 17 companies and a 17 × 17 data matrix were formed, including 17 digital performance indicators (Table 2).

Table 2. Analysis of the main performance indicators of the websites of Ukrainian companies in the construction sector for agricultural enterprises (beginning)

No.	Target	Rating		Organic							
				Keywords					51+	Traffic	Value
		URL	Domain	Total	Top 3	4-10	11-20	21-50			
		X_1	X_2	X_4	X_5	X_6	X_7	X_8	X_9	Y_1	Y_2
1	lubnymash.com/	8	8	31	3	18	1	4	5	207	21.27
2	pulsar-construction.ukr/uk	0	15	17	4	4	0	6	3	67	3.25
3	demetra.ua/	5	16	72	7	35	4	17	9	179	13.72
4	www.eridonbud.com/	5	2.6	12	1	4	0	4	3	56	0.05
5	finpro.group/uk	0	10	19	2	2	2	8	5	18	0.09
6	neuero-ukraina.com.ua/	7	1.1	23	3	6	4	7	3	59	5.62
7	mur.vn.ua/	4.5	3	14	1	4	0	5	4	33	0
8	mzv.com.ua/	13	20	70	4	25	10	16	15	75	9.45
9	gcs.com.ua/	5	2.8	9	0	3	1	4	1	16	4.65
10	platonmax.com.ua/	0	0	15	1	7	2	3	2	10	2.14
11	bmkolos.com/	6	3.6	21	2	12	2	4	1	22	3.74
12	invest-bud.com.ua/	0	0	25	2	6	1	9	7	7	1
13	servicestroy.com.ua/	8	18	63	5	26	6	13	13	109	13.76
14	rielaukr.com.ua/	7	0	25	3	9	5	5	3	41	7.13
15	kmzindustries.ua/	4.9	32	138	20	63	16	24	15	327	45.94
16	zeosokol.com.ua/uk	0	0.8	13	2	3	1	6	1	26	4.09
17	zeo.ua/	6	30	61	5	22	11	17	6	79	9.57

Source: compiled by the author using data from Ahrefs (n.d.)

In the study, the indicator of Organic Traffic was used as the dependent variable Y_1, representing the estimated monthly number of website visits generated through organic search (Ahrefs, n.d.). Additionally, Y_2 was calculated as the monetary value of organic traffic (Organic Value), reflecting the equivalent cost of such traffic if acquired through paid advertising (USD/month) (Ahrefs, n.d.). The independent variables X_1-X_{17} consisted of key SEO metrics characterising the backlink profile and organic ranking of websites (Bek, 2023): X_1 – the strength rating of a specific URL page (URL Rating) on a scale from 0 to 100; X_2 – the strength rating of the entire domain (Domain Rating) on a scale from 0 to 100; X_3 – the overall domain ranking (Ahrefs Rank) among all websites in the Ahrefs database, where a lower value indicates a stronger domain; X_4 – the total number of organic keywords (Organic Keywords Total) for which the website ranks within the top 100 results; X_5 – the number of keywords ranked in positions 1-3; X_6 – the number of keywords ranked in positions 4-10; X_7 – the number of keywords ranked in positions 11-20; X_8 – the number of keywords ranked in positions 21-50; X_9 – the number of keywords ranked in positions 51-100; X_{10} – the total number of referring domains (Referring Domains Total); X_{11} – the number of referring domains with "dofollow" links, which transfer "link equity" and authority from the donor site to the recipient; X_{12} – the number of referring domains with "nofollow" links, which do not transfer authority or link equity; X_{13} – the total number of unique IP addresses from which backlinks originate (Referring IPs); X_{14} – the number of unique Class C subnets (Referring Subnets); X_{15} – the total number of backlinks (Backlinks Total); X_{16} – the number of "dofollow" backlinks, which transfer search authority and ranking value from the donor website to the target website, directly influencing rankings; and X_{17} – the number of "nofollow" backlinks, which do not transfer search authority but may generate direct traffic (Table 2 and Table 3). All data were obtained from the Ahrefs service (n.d.) as of October 2025.

Table 3. Analysis of the main performance indicators of the websites of Ukrainian companies in the construction sector for agricultural enterprises (conclusion)

No.	Target	Ahrefs Rank	Referring					Backlinks		
			Domains			IPs				
			All	Followed	Not followed	IPs	Sub nets	All	Followed	Not followed
		X_3	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}
1	lubnymash.com/	19739586	148	105	44	121	107	2,289	2,122	167
2	pulsar-construction.ukr/uk	10759264	13	12	1	13	13	54	50	4
3	demetra.ua/	9902041	111	81	31	103	91	369	281	88
4	www.eridonbud.com	40920917	57	46	11	41	40	85	48	37
5	finpro.group/uk	17127335	3	3	0	3	3	3	3	0
6	neuero-ukraina.com.ua/	56175383	19	2	17	18	18	41	3	38
7	mur.vn.ua/	38046653	47	17	31	45	43	169	56	113
8	mzv.com.ua/	7478921	71	45	28	77	70	1,400	1,175	225
9	gcs.com.ua/	39166039	67	47	20	63	59	149	113	36
10	platonmax.com.ua/	0	0	0	0	0	0	0	0	0
11	bmkolos.com/	34444817	46	29	18	40	38	1,883	38	1,845
12	invest-bud.com.ua/	0	16	0	16	15	15	20	0	20
13	servicestroy.com.ua/	8624514	145	109	37	152	130	990	582	408
14	rielaukr.com.ua/	0	1	0	1	1	1	1	0	1
15	kmzindustries.ua/	2873777	363	310	59	332	278	1,178	967	211
16	zeosokol.com.ua/uk	61285701	6	6	0	2	2	13	13	0
17	zeo.ua/	3505420	136	90	53	138	127	2,205	1,039	1,166

Source: compiled by the author using data from Ahrefs (n.d.)

For the agricultural construction B2B sector in Ukraine, the actual figures for organic traffic proved to be 12 times lower than global indicators, with a typical range for small and medium-sized enterprises of 7-327 organic visits per month, highlighting the need for stimulation and clear expansion of traffic generation efforts. Using Formula 1, the author calculated Pearson correlation coefficients (r) between the website performance indicators of construction companies and constructed a matrix of pairwise coefficients (Table 4 and Table 5), in which changes in cell background colour were used to highlight indicators demonstrating strong relationships between variables.

Table 4. Correlation between the website performance indicators of construction companies (beginning)

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
X_1	1,0									
X_2	0.31	1.0								
X_3	-0.05	-0.48	1.0							
X_4	0.38	0.85	-0.48	1.0						
X_5	0.15	0.75	-0.37	0.92	1.0					
X_6	0.38	0.79	-0.45	0.98	0.92	1.0				
X_7	0.46	0.82	-0.45	0.90	0.80	0.84	1.0			
X_8	0.30	0.88	-0.45	0.94	0.83	0.88	0.88	1.0		
X_9	0.48	0.74	-0.53	0.86	0.69	0.80	0.75	0.85	1.0	
X_{10}	0.34	0.76	-0.29	0.88	0.87	0.91	0.74	0.75	0.68	1.0

Table 4, Continued

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
X_{11}	0.28	0.75	-0.29	0.88	0.90	0.91	0.74	0.74	0.66	0.99
X_{12}	0.53	0.72	-0.24	0.75	0.62	0.76	0.66	0.69	0.63	0.86
X_{13}	0.37	0.80	-0.32	0.90	0.87	0.92	0.78	0.78	0.71	1.00
X_{14}	0.38	0.80	-0.31	0.89	0.86	0.92	0.78	0.78	0.71	0.99
X_{15}	0.57	0.56	-0.22	0.44	0.29	0.48	0.47	0.36	0.34	0.55
X_{16}	0.57	0.56	-0.29	0.51	0.37	0.54	0.46	0.40	0.51	0.62
X_{17}	0.27	0.26	-0.02	0.13	0.04	0.16	0.23	0.12	-0.04	0.17
Y_1	0.32	0.67	-0.29	0.83	0.87	0.89	0.62	0.68	0.63	0.91
Y_2	0.31	0.64	-0.29	0.82	0.88	0.85	0.74	0.63	0.61	0.92

Source: calculated by the author

Table 5. Correlation between the website performance indicators of construction companies (conclusion)

	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	Y_1	Y_2
X_{11}	1.0								
X_{12}	0.80	1.0							
X_{13}	0.99	0.88	1.0						
X_{14}	0.98	0.89	1.0	1.0					
X_{15}	0.49	0.72	0.55	0.57	1.0				
X_{16}	0.57	0.73	0.61	0.62	0.81	1.0			
X_{17}	0.13	0.33	0.19	0.20	0.70	0.15	1.0		
Y_1	0.91	0.74	0.88	0.88	0.46	0.65	0.03	1.0	
Y_2	0.93	0.70	0.90	0.89	0.49	0.63	0.06	0.88	1.0

Source: calculated by the author

All correlation coefficients with Y_1 were positive, indicating a direct relationship, except for X_3, where the negative sign was expected, since a lower rank corresponds to a stronger website. The values were rounded to two decimal places for ease of interpretation. The highest correlation coefficients with Y_1 were observed for X_4 (0.83), X_5 (0.87), X_6 (0.89), X_{10} (0.91), X_{11} (0.91), X_{12} (0.74), X_{13} (0.88), and X_{14} (0.88), which justified the subsequent selection of variables (X_5, X_6, X_{10}, X_{11}, X_{13}, X_{14}) for single-factor regressions with $r > 0.7$ and $R^2 > 0.7$.

Six simple linear regression equations were identified, representing single-factor models with separate independent variables X_5, X_6, X_{10}, X_{11}, X_{13}, and X_{14} and the dependent variable Y_1. These models demonstrated a linear relationship and were statistically significant with a high level of probability at coefficients of determination $R^2 > 0.7$: $R^2 = 0.7427$ for Formula 2, $R^2 = 0.7915$ for Formula 3, $R^2 = 0.8126$ for Formula 4, $R^2 = 0.8096$ for Formula 5, $R^2 = 0.7712$ for Formula 6, and $R^2 = 0.7581$ for Formula 7.

$$Y_1 = 15.658 + 16.376 \times X_5. \quad (2)$$
$$Y_1 = 8.4065 + 4.7714 \times X_6. \quad (3)$$
$$Y_1 = 16.158 + 0.8507 \times X_{10}. \quad (4)$$
$$Y_1 = 26.201 + 1.0046 \times X_{11}. \quad (5)$$
$$Y_1 = 17.719 + 0.8913 \times X_{13}. \quad (6)$$
$$Y_1 = 14.627 + 1.0502 \times X_{14}. \quad (7)$$

The positive sign of the coefficients associated with the independent variables confirmed a direct relationship (Beyer, 2023), whereby an increase in the independent variable X_n correspondingly resulted in an increase in the dependent variable Y_1, as illustrated in the graphs (Fig. 1). The magnitude of the coefficient associated with the independent variable indicated the strength of the factor's influence on the outcome.

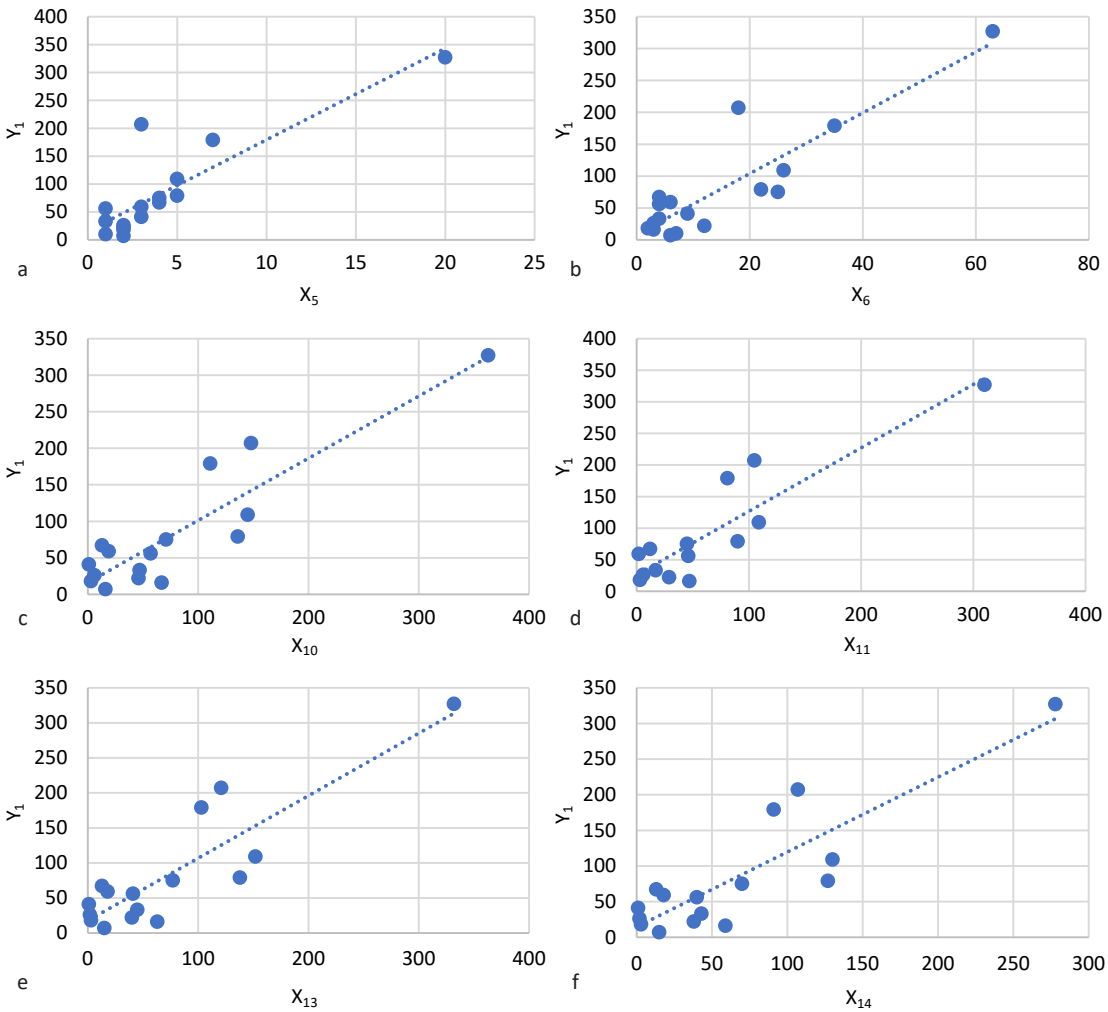

Figure 1. Scatter plots with regression lines for single-factor models of the dependence of organic traffic (Y_1) on key SEO indicators (X_5, X_6, X_{10}, X_{11}, X_{13}, X_{14})

Source: compiled by the author

Figure 1 presents scatter plots with linear regression lines for six single-factor models that proved to be statistically significant with coefficients of determination $R^2 > 0.7$. The points on the plots correspond to empirical observations, the straight line represents the constructed linear regression model, and the equations together with the R^2 values are provided directly in Formulas 2-7. Each diagram illustrates the relationship between organic traffic (Y_1, visits/month) and the corresponding independent variable for the 17 analysed companies, where:

a) the diagram with the steepest regression slope (coefficient 16.376) demonstrates the strongest influence: an increase of one keyword in the top-3 positions increases organic traffic by an average of 16.376 visits. The points are densely concentrated around the line, and the model explains 74.27% of the variability between X_5 and Y_1;

b) the second strongest factor of influence (coefficient 4.7714), where an increase of one keyword in positions 4-10 results in an average traffic increase of 4.771 visits. The model explains 79.15% of the variability between X_6 and Y_1;

c) the diagram illustrating the influence of the total number of referring domains with a coefficient of 0.8507. This model demonstrated the highest explanatory power, accounting for 81.26% of the variability between X_{10} and Y_1, although with a relatively limited influence on organic traffic;

d) the diagram illustrating the influence of "dofollow" referring domains on organic traffic, with a modest coefficient of 1.0046 and an explanatory power of 80.96%. The regression line has a moderate slope but a high density of data points;

e) the diagram illustrating the influence of the diversity of referring IP addresses, with a modest coefficient of 0.8913 and explanatory power of 77.12%;

f) the diagram illustrating the influence of the diversity of Class C subnets, with a modest coefficient of 1.0502 and explanatory power of 75.81%.

All graphs demonstrate a clear positive linear trend without pronounced non-linear deviations or outliers, confirming the adequacy of applying simple linear models for these factors.

The six identified models demonstrated good explanatory power, where between 74.27% and 81.26% of the variation in the dependent variable Y_1 was explained by variability in factors X_5, X_6, X_{10}, X_{11}, X_{13}, and X_{14}. The remaining variation in Y_1, ranging from 25.73% to 18.74%, was attributed to other factors not included in the models and to random influences. These equations described a strong direct linear relationship between the variables, representing a strong result for simple regression models, and may therefore be used to forecast Y_1 with relatively high accuracy. The influence of the independent variables on the dependent variable Y_2 was not investigated due to the strong direct linear relationship with the dependent variable Y_1, where the correlation coefficient $r = 0.88 > 0.7$. Since part of the variation remained unexplained, the study additionally considered extending the model with supplementary factors through the application of multifactor regression analysis.

A prerequisite for constructing the multifactor regression model was the avoidance of multicollinearity, whereby the independent variables had to remain relatively independent from one another in order to prevent instability of regression coefficients, reduce standard errors, increase the reliability of forecasts, and improve the assessment of the influence of individual factors (Farrar & Glauber, 1967). Combinations of independent variables with weak inter-factor relationships between X_n variables were identified, and equations of multiple non-linear regressions with interaction elements were developed in the form of second-order polynomial models without quadratic terms, depending on combinations of independent variables.

Equation No. 7 for the combination of independent variables X_1-X_3-X_5-X_9-X_{15}:

$$\begin{gathered} Y_1 = -713.336 - 677.512 \times X_1 + 7.01 \times 10^{-5} \times X_3 + \\ + 682.908 \times X_5 + 128.841 \times X_9 - 3.679 \times X_{15} + \\ + 6.85 \times 10^{-6} \times X_1 \times X_3 + 219.359 \times X_1 \times \\ \times X_5 - 26.914 \times X_1 \times X_9 + 0.018 \times X_1 \times X_{15} - \\ - 3.9 \times 10^{-5} \times X_3 \times X_5 - 5 \times 10^{-7} \times X_3 \times X_9 + \\ + 9.02 \times 10^{-8} \times X_3 \times X_{15} - 108.622 \times X_5 \times \\ \times X_9 + 0.439 \times X_9 \times X_{15}. \end{gathered} \tag{8}$$

The equation contains both linear terms (X_1, X_3, X_5, X_9, X_{15}), and bilinear products of individual factors ($X_1 \times X_3$, $X_1 \times X_5$, $X_1 \times X_9$, $X_1 \times X_{15}$, $X_3 \times X_5$, $X_3 \times X_9$, $X_3 \times X_{15}$, $X_5 \times X_9$, $X_9 \times X_{15}$), incorporating 5 independent variables and 9 interaction terms, giving a total of 14 regressors and a constant term. The model explains 99.5% of the variation in the dependent variable Y_1 (coefficient of determination $R^2 = 0.995$). The Fisher criterion $F = 0.054 \approx 0.05$ lies on the threshold of significance, under which the model is formally insignificant; however, due to the exceptionally high coefficient of determination, it possesses substantial practical value. The average approximation error amounted to 2.2%, while the maximum error was 11.2%, indicating high forecasting accuracy across the entire sample.

The significance level of the observed result (p-value) in the statistical hypothesis testing proved to be less than 0.05 for each independent variable and interaction term, except for the term $X_1 \times X_{15}$, for which p-value = 0.099 > 0.05, and $X_3 \times X_9$, for which p-value = 0.153 > 0.1. The p-value indicates the probability of obtaining an extreme value of the statistic under the

assumption that the null hypothesis is true. Thus, when $p < 0.05$, there is strong evidence against the null hypothesis in favour of the alternative hypothesis, meaning that the factor influences the dependent variable Y_1; when $p > 0.1$, the data are consistent with the null hypothesis; and when $0.05 < p < 0.1$, a borderline case with weak evidence against the null hypothesis is observed, under which the null hypothesis is formally not rejected.

Since the effect size of factor $X_3 \times X_9$ proved to be extremely small and influenced the dependent variable only within the seventh decimal place, and considering its consistency with the null hypothesis, it was decided to disregard this factor. Given the small effect size, factor $X_1 \times X_{15}$, which demonstrated weak inconsistency with the null hypothesis, was also disregarded. As a result, an equation with 12 regressors and a constant term was obtained in the following form:

$$Y_1 = -713.336 - 677.512 \times X_1 + 7.01 \times 10^{-5} \times X_3 + 682.908 \times X_5 + 128.841 \times X_9 - 3.679 \times X_{15} + 6.85 \times 10^{-6} \times X_1 \times X_3 + 219.359 \times X_1 \times X_5 - 26.914 \times X_1 \times X_9 - 3.9 \times 10^{-5} \times X_3 \times X_5 + 9.02 \times 10^{-8} \times X_3 \times X_{15} - 108.622 \times X_5 \times X_9 + 0.439 \times X_9 \times X_{15} \quad . (9)$$

Equation No. 8 for a combination of independent variables X_1-X_4-X_{15}:

$$Y_1 = -75.484 + 17.74 \times X_1 + 8.802 \times X_4 - 0.287 \times X_{15} - 1.211 \times X_1 \times X_4 + 0.045 \times X_1 \times X_{15}. \quad (10)$$

The equation contains both linear terms (X_1, X_4, X_{15}), and bilinear products of individual factors ($X_1 \times X_4$, $X_1 \times X_{15}$), including 3 independent variables and 2 interaction terms, giving a total of 5 regressors and a constant term. The model explains 97.0% of the variation in the dependent variable Y_1 (coefficient of determination $R^2 = 0.97$), which confirmed the excellent fit of the model to the data and its high quality. The Fisher criterion $F = 5.43 \times 10^{-6} < 0.05$ demonstrated that the model is statistically significant at any conventional level and confirmed that the regressors collectively explain Y_1 substantially better than the simple mean value. The average approximation error was determined at 16.1% and is considered acceptable; however, the maximum error reached 38.5%, which is associated with outliers and with the fact that, at these points, the values of the factors extend beyond the typical data range. The significance level of the observed result (p-value) in the statistical hypothesis testing proved to be less than 0.05 for each independent variable and interaction term, indicating a low probability of obtaining extreme statistic values under a true null hypothesis and providing strong evidence in favour of the alternative hypothesis, whereby each factor and interaction contributes substantially.

Equation No. 9 for the combination of independent variables X_1-X_3-X_7-X_{12}-X_{17}:

$$Y_1 = = 64.101 + 1.1 \times X^{17} + 1.86 \times 10^{-7} \times X_1 \times X_3 + 0.975 \times X_1 \times X_{12} - 0.181 \times X_{_1} \times X_{17} - 1.96 \times 10^{-7} \times X_3 \times X_{12} + 0.05 \times X_{_7} \times X_{12} - 0.024 \times X_7 \times X_{17}. \quad (11)$$

The dependence of Y_1 on the factors is described exclusively through one linear term (X_{17}) and six bilinear interaction terms ($X_1 \times X_3$, $X_1 \times X_{12}$, $X_1 \times X_{17}$, $X_3 \times X_{12}$, $X_7 \times X_{12}$, $X_7 \times X_{17}$). The model assumes that the influence of most factors manifests only in combination with others and explains 99.9% of the variation in the dependent variable Y_1 (coefficient of determination $R^2 = 0.999$), which demonstrated the excellent fit of the model to the data and its high quality. The Fisher criterion $F = 7.18 \times 10^{-4} < 0.05$ showed that the model is statistically significant at any conventional level and confirmed that the regressors collectively explain Y_1 substantially better than the simple mean value. The average approximation error was determined at 1.0%, while the maximum error was 3.2%, indicating high forecasting accuracy across the entire sample and demonstrating an almost perfect fit of the model to the data within the sample range. The significance level of the observed result (p-value) in the statistical hypothesis testing proved to be less than 0.05 for the independent variable (X_{17}) and the six interaction terms, indicating strong evidence in favour of the alternative hypothesis, where the factor and each interaction are statistically significant and make a substantial contribution.

High values of the coefficient of determination in the multifactor models confirmed the appropriateness of a comprehensive approach to shaping a digital promotion strategy based on the interaction of several key indicators rather than the isolated management of individual metrics. To assess the marginal effect of each independent variable on Y_1 through "what-if" simulation analysis, the interactions of factors in the non-linear models were taken into account, making it possible to obtain average values of traffic growth resulting from a unit change in Xn. The research was conducted on a sample of 17 companies using actual data from Tables 2 and 3 within the original Equations No. 7, 8, and 9. Actual values of the independent variables (Xn) for each of the 17 websites were separately substituted into each second-order polynomial equation, enabling the determination of baseline (initial) theoretical values of Y_1 for each equation. Subsequently, each independent variable Xn was increased by one unit ($\Delta Xn = +1$), while all other variables remained unchanged. For each such iteration, a new predicted value of Y_1 was recalculated, and this procedure was repeated for all Xn variables in Equations No. 7, 8, and 9 and for each of the 17 websites. For every variable Xn, website, and equation, the absolute increase ΔY_1 was calculated using the following Formula 12:

$$\Delta Y_1 = (\text{predicted } Y_1 =) - (\text{baseline } Y_1). \quad (12)$$

The absolute increase ΔY_1 represents a quantitative measure of influence, indicating traffic growth when the value is positive and traffic decline when the value is negative. Calculations according to Formula 12 were performed separately in order to account for variation between websites. For each Xn variable, the average value of the increase ΔY_1 for the sample of 17 websites was aggregated, producing a generalised effect (Table 6), where each value is accompanied by the symbols "+" for direct influence and "–" for inverse influence.

Table 6. Average increase in organic traffic resulting from a one-unit increase in one of the independent variables of the model

Equation	Average increase in Organic Traffic (ΔY_1), visits/month resulting from a one-unit increase in the independent variable								
	X_1+1	X_3+1	X_4+1	X_5+1	X_7+1	X_9+1	$X_{12}+1$	$X_{15}+1$	$X_{17}+1$
Equation 7 (F. 8)	+161.8	$+6.1\times10^{-6}$		+282		-142.6		+0.7	
Equation 7 (F. 9)	+150.2	$+8.9\times10^{-6}$		+282		-132.2		+0.7	
Equation 8 (F. 10)	+1.6		+3.1					-0.1	
Equation 9 (F. 11)	-21.6	-3.4×10^{-6}			-5		+0.7		+0.2

Source: calculated by the author

Table 6 contains cells with missing data. This is due to the absence of the corresponding independent variables Xn in Equations 7, 8 and 9 (see Formulas 8, 9, 10, and 11). The simulation analysis additionally highlighted the necessity of a comprehensive approach to the group of variables: increasing X_5 (the number of keywords ranked in Top-3 positions) and X_1 (the URL Rating of a specific page) in order to achieve maximum traffic growth; reducing X_9 (the number of keywords ranked in positions 51-100), since growth in this variable has a negative effect; disregarding X_3 (the overall domain rank within the Ahrefs database) because of its lack of substantial influence and the negative nature of the relationship; and secondary efforts directed towards increasing X_4 (the total number of organic keywords), X_{12} (the number of referring domains with "nofollow" links), X_{15} (the total number of backlinks), X_{17} (the number of "nofollow" backlinks), as well as reducing X_7 (keywords ranked in positions 11-20), in order to support the overall effectiveness of the profile.

The results of the conducted study provided construction companies specialising in the construction of facilities for the agricultural sector with a specific, data-oriented toolkit for transitioning from intuitive or fragmented digital marketing towards a KPI-oriented strategy. The practical application of the results involves the clear prioritisation of SEO investments aimed at ensuring the fastest possible traffic

growth without the need for additional content. The highest priorities are keywords ranked in the Top-3 positions (X_5) and positions 4-10 (X_6), which exert the most substantial influence on organic traffic. To increase the number of such keywords, construction companies are advised to systematically develop a content strategy focused on "long-tail" queries reflecting the specific characteristics of the agricultural sector. Parallel priority should be given to backlink profiles (X_{10}, X_{11}, X_{13}, X_{14}). Domain authority should be strengthened through the acquisition of high-quality "dofollow" links from industry-related resources. To achieve this, construction companies may conduct regular informational and outreach activities on agricultural portals, farmers' forums, industry media, and the websites of equipment suppliers. Another parallel priority is the URL Rating of a specific page (X_1). To improve this indicator, construction companies should focus on optimising the internal structure of their websites by improving the technical performance of each page (speed, mobile optimisation, internal linking). Such a comprehensive approach enables not only the forecasting of traffic growth but also the optimisation of marketing expenditure, ensuring maximum return on investment in digital promotion.

From a strategic perspective, the results of the study enable construction companies to develop an annual KPI-oriented promotion programme in which organic traffic becomes the key measurable performance indicator. The use of empirical models makes scenario forecasting possible, allowing companies to estimate potential lead growth and conversions even before implementation measures begin, as well as to promptly adjust strategy based on the results of monthly monitoring. The implementation of the proposed recommendations is intended to contribute to reducing customer acquisition costs, increasing trust among agricultural producers, and ensuring a long-term competitive advantage within the market for construction services in agribusiness.

DISCUSSION

According to B2B statistics from 2025, 61% of marketers prioritised SEO and organic traffic as the main focus of inbound marketing, which delivered a high ROI through personalised content and highlighted the importance of digital metrics (First Page Sage Team, n.d.); 57% of companies believed that SEO generated more leads than any other channel, with 76% of web traffic coming from search engines (Shum, 2026); 68% of companies reported that organic traffic from search engines was their primary source of high-quality leads, whilst 54% of marketers planned to increase investment in SEO precisely because of the higher ROI compared to paid advertising, which is particularly important for sector-specific markets such as construction services for the agricultural sector (Bateman, 2025). 73% of B2B buyers considered SEO and organic search to be one of the most important sources of information during the supplier research phase, and companies that invested in quality content and SEO generated 55% more leads than those relying primarily on paid advertising (PBJ Marketing, n.d.). According to digital marketing data for the agricultural sector, agricultural companies that invested in SEO and content marketing received a steady stream of high-quality leads through organic search, as farmers and agribusinesses actively used online channels to search for service providers, equipment and solutions, making digital metrics key to building trust and competitive advantages in the B2B segment (Dombrowski, 2025). The effectiveness of promotion in segmented industries, such as construction for the agricultural sector, depended to a large extent on a comprehensive approach to content, technical optimisation and the quality of the backlink profile, which allowed for a steady flow of organic traffic even in the face of limited search demand and high customer acquisition costs (Romain, 2024), whilst strategic flexibility in shaping marketing strategies enabled companies to adapt effectively to changes in demand and the competitive environment, which was particularly important for sector-specific markets such as the construction of facilities for agricultural enterprises, where the long deal cycle required a rapid response to digital opportunities and precise measurement of effectiveness (Norouzi, 2025).

The agricultural sector, farmers and agricultural producers increasingly sought out

suppliers of services, equipment and solutions via social media and search engines, where brands that actively published useful content and optimised their profiles for key search terms significantly increased their visibility and trust among their target audience, making digital performance metrics critically important for construction companies focused on agribusiness (Baranowska, 2025), whilst agricultural companies that integrated SEO, content marketing and digital advertising with a clear focus on measurable KPIs (organic traffic, conversion, lead quality), achieved a significantly higher ROI than those relying solely on traditional channels or fragmented digital tools, which is particularly important for the B2B services segment, such as the construction of facilities for agribusinesses (Rhea + Kaiser, n.d.). In the agricultural sector, even with zero search volume for key queries, a comprehensive content marketing strategy, SEO optimisation and targeted information and awareness-raising efforts enabled significant growth in organic traffic and high-quality leads, demonstrating the potential of digital performance metrics for sector-specific construction companies operating with limited search demand in the agricultural segment (Sandyriev, 2025).

A review of the literature on digital marketing in agribusiness revealed significant academic interest in the role of digital performance metrics in shaping promotional strategies. Researchers S. Wang & R. Meng (2024) developed the "Zebra" optimiser model with a weighted random forest algorithm (ZO-WRF) to forecast marketing channels for agricultural products in Leshan and confirmed that machine learning based on social data achieves 95% accuracy in predicting media marketing effectiveness, significantly outperforming traditional methods. The issue of using digital performance indicators was addressed in studies by S. Hasnain & A. Kazmi (2015) on digital marketing, brand management and service promotion. Despite a significant body of scholarly work, most studies have focused on general agromarketing strategies, whilst the works of A. Mostova (2022) and Z. Lu (2023) focused on consumer markets, whilst the research by S. Hasnain & A. Kazmi (2015) concentrated on specific online communication tools.

The analysed studies confirmed that digital performance indicators form the strategic foundation for developing a marketing strategy in agribusiness. Researchers D. Nyangoma *et al.* (2024) highlighted the shift from an intuitive to a "data-driven" approach, where KPIs (reach, engagement, conversion, ROI) have become an essential tool for optimising resources and enhancing competitiveness. In particular, researchers S. Koberniuk *et al.* (2025) and I. Yatskevych (2024) emphasised the need to monitor digital metrics in SMM strategies. Researchers I. Gushcha (2023) and M. Sheeraz *et al.* (2023) focused on the role of data analytics and brand awareness. Author W. Shen (2024) investigated the power of machine learning predictions. Researcher A.S. Ajibola (2025) focused on KPIs for technology adoption among smallholder farmers. Researchers M. Braglia *et al.* (2022) focused on a structured Industry 4.0 KPI system. Authors U.S. Nwabekee *et al.* (2021) paid particular attention to the integration of digital marketing with financial metrics. The authors' findings were fully consistent with this paradigm, empirically confirming the strong influence of SEO metrics on organic traffic in the B2B segment.

Despite a shared methodological framework, the studies differ significantly in subject matter and approach. The studies by M. Sheeraz *et al.* (2023) and E.A. Inyommom *et al.* (2025) focused on general digital strategies (SMM, content marketing, "big data") in the agri-food industry or at the level of end consumers/smallholder farmers. The authors D. Nyangoma *et al.* (2024) proposed conceptual models, whilst the researchers M. Braglia *et al.* (2022) focused on universal Industry 4.0 KPI frameworks. The authors S. Wang & R. Meng (2024) paid particular attention to predictive ML models. In contrast, the author's work was purely empirical and econometric: it was based on a correlation and regression analysis of real-world data from Ahrefs (n.d.) for 17 Ukrainian construction companies and proposed specific quantitative models of the impact of SEO metrics on organic traffic specifically within the B2B segment of construction services. Thus, whilst most of the literature addressed the question "which tools and models to use", this study answers the question "which specific SEO metrics have the

greatest impact on results and how to optimise them quantitatively".

The analysed works highlighted additional aspects that significantly broaden the understanding of the role of digital performance indicators in shaping the strategy for promoting construction services in agribusiness. In particular, the works of A.S. Ajibola (2025) and D. Nyangoma *et al.* (2024) highlighted the specific characteristics of developing countries, resource constraints and the need to personalise strategies. Meanwhile, I. Yatskevych (2024), S. Koberniuk *et al.* (2025), and N.B. Zelisko & V.V. Maliuha (2025) highlighted the synergy of various digital channels (SMM, SEO, content marketing) to achieve a cumulative effect.

In turn, the author's work organically complemented this body of research, adding an empirical dimension specifically to the B2B segment of construction services: the high capital intensity of projects, the lengthy decision-making cycle, limited search demand, and the synergistic influence of SEO factors. Thus, the body of analysed sources formed a solid theoretical and methodological foundation, against which this study demonstrated scientific novelty – the quantitative verification of the role of digital performance indicators for the strategic planning of construction services promotion in agribusiness, using Ukrainian companies as a case study. The results obtained not only confirmed the general trends in the literature but also offered practical tools for construction companies operating in the agricultural sector, facilitating the transition from descriptive recommendations to predictive KPI-oriented strategies.

CONCLUSIONS

As a result of the conducted study, the decisive role of digital performance indicators in shaping the promotion strategy of construction services for agricultural enterprises was confirmed. The analysis demonstrated that, within a B2B market characterised by high-value contracts and long decision-making cycles, the website of a construction company serves as a key instrument of communication, trust formation, and support for the customer acquisition process. The correlation analysis confirmed the existence of strong direct relationships between the majority of digital website performance indicators and the resulting variables characterising the level of their presence within the digital environment. High values of correlation coefficients according to the Chaddock scale demonstrated that organic visibility in search engines, the structure and quality of keywords, as well as the characteristics of the backlink profile, exert a systematic influence on the effectiveness of the digital promotion of construction companies operating within the agricultural sector.

The constructed single-factor linear regression models confirmed the statistically significant influence of individual digital indicators on the resulting variable Y_1 (organic traffic), with coefficients of determination exceeding 0.7, indicating the high explanatory power of the models. This provided grounds for asserting that individual SEO indicators may be used as reliable measures of the effectiveness of construction service promotion strategies within the digital environment. The results of the multifactor regression analysis and sensitivity simulation analysis demonstrated the existence of a synergistic effect between digital performance indicators, whereby their combined influence substantially exceeded the influence of each individual factor. In particular, the greatest average increase in organic traffic resulting from a unit increase in the independent variables was observed for X_5 (the number of keywords ranked in positions 1-3) and X_6 (the number of keywords ranked in positions 4-10), which was confirmed by high positive coefficients. This indicated the priority of focusing specifically on these variables in order to achieve rapid and substantial traffic growth.

A secondary but still important direction identified in the study was work on variables X_{10} (the total number of referring domains), X_{11} (the number of referring domains with "dofollow" links), X_{13} (the total number of unique referring IP addresses), and X_{14} (the number of unique Class C subnets), where comprehensive optimisation of these factors would strengthen domain authority and improve positioning within search engines. The obtained results made it possible to consider digital website performance indicators not only as tools for the operational control of marketing activities, but also

as elements of strategic planning. Accordingly, for construction companies working with agricultural enterprises, systematic management of organic visibility, keyword structure, and the quality of digital content may serve as the foundation of a long-term competitive advantage in the market. Prospects for further research include expanding the sample of enterprises, analysing the dynamics of digital indicators over time, and incorporating additional factors into the models that characterise user behaviour and content quality. This would allow for a deeper understanding of the mechanisms through which digital indicators influence the strategic promotion of construction services within the agricultural sector and would improve the accuracy of forecasting marketing performance outcomes.

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Роль цифрових показників ефективності формування стратегії просування будівельних послуг в агробізнесі

Анотація. В умовах цифровізації економіки маркетингова діяльність будівельних компаній, орієнтованих на агробізнес, залежить від даних та аналітичних інструментів, які дозволяють приймати обґрунтовані рішення на основі кількісних показників. Метою статті було встановити кількісні залежності між основними SEO-показниками веб-сайтів та обсягом органічного трафіку, а також оцінити їх вплив на формування ефективної стратегії просування будівельних послуг для підприємств агробізнесу. Для досягнення мети сформовано вибірку із 17 українських будівельних компаній, що спеціалізуються на будівництві об'єктів для аграрного сектору. Дані отримано з сервісу Ahrefs станом на жовтень 2025 року. Використано кореляційний аналіз за шкалою Чеддока, однофакторні лінійні регресійні моделі, багатофакторні нелінійні регресійні моделі з елементами взаємодії, а також симуляційний аналіз чутливості. У результаті дослідження виявлено сильні прямі кореляційні зв'язки між органічним трафіком та ключовими SEO-метриками: кількістю ключових слів у позиціях 1-3 ($r = 0,87$) і у позиціях 4-10 ($r = 0,89$), загальною кількістю реферальних доменів ($r = 0,91$), кількістю «dofollow» – реферальних доменів ($r = 0,91$), кількістю унікальних IP-адрес реферерів ($r = 0,88$) та кількістю унікальних підмереж класу C ($r = 0,88$). Побудовано шість статистично значущих однофакторних лінійних регресійних моделей з коефіцієнтами детермінації R^2 від 0,7427 до 0,8126. Багатофакторні нелінійні моделі з елементами взаємодії показали вищу пояснювальну здатність (R^2 до 0,999). Симуляційний аналіз чутливості підтвердив, що найбільший приріст органічного трафіку забезпечує збільшення кількості ключових слів у топ-3 (+282 відвідування/місяць) та підвищення рейтингу сили URL-сторінки (+150-162 відвідування/місяць). Практичне значення дослідження полягає в тому, що отримані результати дозволяють будівельним компаніям формувати KPI-орієнтовані стратегії просування, оптимізувати розподіл маркетингових ресурсів та підвищувати ефективність взаємодії з клієнтами в аграрному секторі

Ключові слова: цифровий маркетинг; веб-аналітика; математичні моделі; органічний трафік; SEO-метрики; сільськогосподарські підприємства; B2B-стратегії

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Financial support of territorial communities under martial law: Challenges and prospects for the agricultural sector

Abstract. The aim of the article was to identify transformations of financial resources of territorial communities during martial law and determine the role of the agricultural sector in restoring the financial capacity. The methodology was based on the analysis of statistical indicators of local budget revenues of Ukraine in 2022-2024, structural and functional analysis of the role of the agricultural sector and forecast modelling of the restoration of the tax base in 2025-2030. The agricultural sector, which provides more than 30% of rural community budgets, suffered losses of about USD 59.8 billion. due to the destruction of infrastructure, mining of more than a quarter of land and a reduction in exports. The volume of international grant support from the World Bank, the Food and Agriculture Organization of the United Nations, the International Fund for Agricultural Development and the European Union increased from USD 385 million in 2022 to USD 650 million in 2024, which confirmed the importance of foreign aid. Forecast calculations showed that in 2025-2027, tax revenues from the agricultural sector will increase from UAH 54.9 billion to UAH 67.9 billion, while the annual needs for financing its restoration in 2025-2030 will remain at the level of USD 17-18 billion. with a reorientation to the modernisation of equipment and support for farmers. The combination of state, municipal, and international support mechanisms creates the basis for restoring the financial capacity of communities, and Ukraine's integration into the European market opens up new opportunities for strengthening the tax base. The practical significance of the study lies in the formulation of recommendations for the development of local agricultural funds, microcredit and preferential lending programmes. The results can be used by local governments, state institutions and international donors to develop strategies for the financial sustainability of territorial communities

Keywords: budget; revenues; grants; subventions; food security; forecast modelling

INTRODUCTION

The relevance of the study of the financial support of territorial communities under martial law is due to the sharp reduction in these communities' revenues, which was a consequence of the decline in economic activity and restrictions on access to the resource base.

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Significant losses of tax revenues, in particular from personal income tax and land payments, were accompanied by an increase in the dependence of local budgets on centralised transfers, which significantly weakened the financial autonomy. An additional challenge was the decline in the role of the agricultural sector, which traditionally was a key source of revenue for rural budgets, but suffered large-scale losses due to the destruction of infrastructure, mining of territories and reduction of production capacities. In such conditions, the search for effective mechanisms for restoring and diversifying financial resources that can ensure the sustainability of local budgets and create a basis for further economic reconstruction at the community level becomes particularly important.

In the study by L. Pronko *et al.* (2024), the authors showed that territorial communities during the martial law period underwent transformations in the direction of increasing dependence on inter-budgetary transfers and reducing the communities' tax sources. It was found that the key factor of financial instability was the reduction of income from labour and land use, which significantly reduced the financial autonomy of communities. In the work of O. Mohylnyi *et al.* (2022), the consequences of deregulation measures in the agricultural sector were analysed. Although the reduction of administrative burden and transaction costs had a positive effect on agricultural producers, these measures turned out to be insufficient in the context of large-scale destruction of logistics chains. The authors emphasised that it was the disruption of transport and warehouse infrastructure, as well as the decline in food security, that became key factors in the decline in economic activity of communities. E.S. De Dios *et al.* (2021), studying the experience of the Philippines during the martial law period, showed that long-term centralisation of financial flows leads to structural imbalances in investment processes. As a result, there was a gradual decline in the productivity of the regional economy, which limited the ability of local budgets to develop independently. This experience is relevant for Ukraine, as it demonstrates that without proper financial autonomy, communities become vulnerable to external shocks. M. Nehrey & R. Finger (2024) focused on the initial consequences of the military invasion for the agricultural sector of Ukraine. The authors emphasised that the decline in yields and the sharp increase in production costs were primarily due to the mining of significant areas and the loss of access to basic infrastructure. This directly affected the reduction in tax revenues at the local level, as agricultural enterprises could not maintain the previous level of production activity.

In a global review by R. Leonhardt *et al.* (2022), it was found that a combination of grant programmes, feed-in tariffs, and preferential lending contributed to the formation of sustainable local energy systems and strengthened the financial capacity of communities. J.K.L. Chan *et al.* (2021) using the example of ecotourism practices in Malaysia showed that the active participation of the population in tourism management ensured the creation of additional sources of income and stimulated the rational use of natural resources. In the study by M. Rosales *et al.* (2023), it was proven that the institutionalisation of grassroots governance increased the level of resilience of communities to emergencies and reduced the time to restore basic management functions. These results confirmed the importance of various instruments and citizen involvement in the formation of a sustainable financial and social basis for development, which demonstrates the universality of institutional practices across sectors and countries. An important emphasis is also placed on the intangible aspects of development. M.O. Edwards-Fapohunda (2024) demonstrated that adult learning and education programmes are directly correlated with employment growth. Educational initiatives not only strengthen human capital, but also stimulate citizens' financial participation in local processes, which ultimately forms a more stable tax base. In turn, A.V. Machado *et al.* (2022), analysing the functioning of community-controlled water supply systems, proved that long-term sustainability depends on quality management and financial discipline, as well as active participation of the local population in decision-making. This emphasises that institutional capacity and the human factor are as important as financial resources.

However, the literature review revealed a number of gaps. Integrated quantitative models that would combine data on agricultural losses, the scale of mining and the transformation of fiscal policy in the dimension of territorial communities of Ukraine were not sufficiently developed. Attention remained limited to spatial differences in the impact of wartime destruction on the tax base and to assessing the effectiveness of new financial instruments, in particular agricultural funds and microcredit. The consequences of Ukraine's integration into the European Union (EU) for local budget revenues in the medium term were also not comprehensively investigated. In addition, there was a lack of analysis of the differentiation of financial capacity between rural, urban and industrial communities, which necessitates further research. The purpose of the study was to determine the features of the transformation of the financial capacity of territorial communities during the war period and outline the role of the agricultural sector in restoring the revenue base. To achieve this goal, the following tasks were set: to analyse the dynamics of local budget revenues in 2022-2024, taking into account the reduction of personal income tax and the growth of inter-budgetary transfers; to assess the importance of agricultural production for the formation of tax revenues and the scale of its losses as a result of military actions; to explore mechanisms for supporting communities and agricultural producers from the state and international organisations, with further identification of prospects for restoring the tax base through the introduction of innovative technologies and the development of financial instruments at the community level.

MATERIALS AND METHODS

The study was applied in nature and was conducted as an analytical-descriptive study with elements of forecast modelling, which was due to the need for a comprehensive assessment of the transformations of the financial capacity of territorial communities during the war. It was this approach that made it possible to combine descriptive assessments of current trends with the construction of forecast scenarios. The chronological framework of the study covered the years 2022-2024, which provided the opportunity to trace changes in the structure of local budget revenues in the dynamics of martial law. To form forecasts for the restoration of the tax base, benchmarks for 2025-2030 were taken into account, which gave the study a strategic dimension and allowed assessing the prospects for financial sustainability in the medium term. Data collection was carried out by processing official statistical materials and reports using open state and international sources. For the analysis of budget indicators, data from the Portal "Decentralisation" (n.d.) were used, reflecting the dynamics of local budget revenues, the structure of tax revenues, and the volume of inter-budgetary transfers. The study of the impact of military actions on the agricultural sector was carried out based on official data from the Food and Agriculture Organization of the United Nations (FAO) (2023a; 2023b) and analytical reports from the KSE Institute (2023), which highlighted the scale of losses and key risks to production. Additional information was provided by materials from the European Commission (2022; 2023; 2024) and World Bank (n.d.), which contained estimates of recovery needs and the volume of financial assistance. To form a comprehensive picture, reports from the International Fund for Agricultural Development (IFAD) (2022) were also used, reflecting international approaches to supporting rural areas and long-term reconstruction scenarios.

The study used a statistical method that provided the opportunity to generalise and systematise data on the dynamics of local budget revenues in the period 2022-2024. It was used to analyse official indicators that reflected changes in revenues from the main tax and non-tax sources. The application of this method made it possible to identify patterns in the transformation of the revenue base of communities, assess trends in the ratio of own and external funds, and determine structural shifts in the financing of local budgets. The method of structural and functional analysis was used to study the role of the agricultural sector in ensuring the financial capacity of territorial communities. Revenues were distributed by key components related to agriculture, which made it possible to assess the share in the overall revenue structure. The use

of this method made it possible to determine the dependence of local budgets on agricultural production, trace the impact of war destruction on the functioning of economic units, and form an idea of the scale of financial losses in rural communities.

The comparative method was used to compare the instruments of financial support for the agricultural sector and territorial communities in Ukraine with the practices implemented by international organisations. This approach made it possible to identify common and distinctive features of these instruments and determine the directions of the adaptation to Ukrainian conditions, which created an analytical basis for recommendations on optimising financing mechanisms. In addition, a case method was used, which made it possible to analyse specific examples of territorial communities from different regions of Ukraine. Three communities were selected for the study – de-occupied (Izium, Kharkiv region), frontline (Orikhiv, Zaporizhzhia region) and rear (Tlumach, Ivano-Frankivsk region). The selection criteria were different security conditions for the functioning and use of different financial support instruments (budget funds, grants from international organisations, preferential financing).

Forecast modelling was used to identify possible scenarios for restoring the financial base of communities in the medium term, and it was based on the average annual rates of restoration of agricultural production, the expected growth in employment after the demining of agricultural land, and the expansion of the tax base through involvement in European Union support programmes, in particular the Ukraine Facility (European Commission, 2022), which provided long-term macro-financial assistance to Ukraine. Additionally, analytical materials by R. Neyter *et al.* (2024) were taken into account, which highlighted joint initiatives of the European Union and the Food and Agriculture Organization for the restoration of farms. The Common Agricultural Policy (European Commission, 2023) and the European Agricultural Fund for Rural Development (European Commission, 2024) approaches served as a reference for assessing future needs in financing the agricultural sector for 2025-2030, which identified key areas of investment in land demining, modernisation of machinery, restoration of infrastructure, and support for small and medium-sized farmers. For the forecast revenues to local budgets from the agricultural sector, the horizon 2025-2027 was chosen, which was due to the availability of reliable short-term macroeconomic indicators and the possibility of the correlation with current data from the Ministry of Finance of Ukraine (n.d.) and Open Budget (n.d.). For the needs of financing the restoration of the agricultural sector, a wider period of 2025-2030 was used, since infrastructure projects, modernisation of equipment and support for farms are of a long-term nature. Thus, the distinction between time horizons was due to the different nature of the indicators: tax revenues could be forecast with a higher degree of accuracy in the short term, while investment needs required a longer perspective.

Methodologically, the forecast was carried out using trend analysis (time-series forecasting) based on data from 2020-2024. A multiple regression model was used, where the dependent variable was tax revenues to local budgets, and the independent variables were the area of demined land, the amount of state and international financial support, the employment index in agriculture, and agricultural product export indicators. For the needs of financing the restoration of the agricultural sector, a scenario-based approach was used, which took into account three scenarios: baseline (slow recovery), optimistic (accelerated attraction of investments and international assistance), and pessimistic (delay in the demining and modernisation processes). The interpretation of the results obtained was based on a combination of quantitative analysis with a qualitative assessment of institutional mechanisms. This approach allowed not only to systematise the impact of war destruction on the financial capacity of communities, but also to identify key structural dependencies between the state of the agricultural sector and the possibility of forming a sustainable tax base. In addition, based on the methods used, practical recommendations were formulated that are practical in nature and aimed at developing compensatory mechanisms for the financial stabilisation of territorial communities.

RESULTS AND DISCUSSION

Transformation of local budget revenues under martial law

The financial resources of territorial communities during the martial law period underwent significant transformations, which directly affected the dynamics of the revenues. Tax and non-tax revenues, which in the pre-war period formed the basis of the financial autonomy of local self-government, gradually lost stability. The effect of transferring the military levy and personal income tax (PIT) to a special fund of the state budget was especially noticeable, which led to the loss of a significant part of the communities' own resources and increased dependence on centralised redistribution of financial flows (Ministry of Finance of Ukraine, 2024). A comparison of the main revenue items in 2022-2024 showed both structural shifts and multidirectional trends in the dynamics of key sources of budget funding. While local taxes demonstrated gradual growth, PIT during this period decreased, forming a negative trend for the financial base of communities. Instead, inter-budgetary transfers and other revenues, including administrative fees and fines, began to play a more significant role in supporting revenue. The summarised data on these changes are presented in Table 1, which reflects the dynamics of revenues of local budgets of Ukraine in 2022-2024 and makes it possible to trace structural changes in the sources.

Table 1. Dynamics of revenues of local budgets of Ukraine in 2022-2024 (general fund, billion UAH)

Year	Personal income tax	Local taxes	Transfers	Other revenues	Total
2022	300.5	126.4	150.2	42.1	619.2
2023	291.2	134.7	168.9	44.5	639.3
2024	259.3	142.5	187.9	61.4	651.1

Note: transfers – grants and subventions from the state budget; other revenues – administrative payments, fines, non-tax fees

Source: developed by the author based on data from the Ministry of Finance of Ukraine (n.d.), Open Budget (n.d.), Portal "Decentralisation" (n.d.)

The data in Table 1 showed that in 2022-2024 there was a steady reduction in the volume of personal income tax – from UAH 300.5 to 259.3 billion, which corresponded to a decrease of almost 14%. At the same time, local taxes increased by 12.7%, which confirmed the relative stability in the revenue structure. The most dynamic source was inter-budgetary transfers, which increased by UAH 37.7 billion and reflected the strengthening of the centralisation of the budget system. Other revenues also showed an increase of UAH 19.3 billion, but the share remained secondary. The overall results indicated a relative stability of the total volume of revenues, but with a significant change in the structure, which meant a decrease in the financial independence of territorial communities and an increase in the role of state mechanisms in ensuring the viability. A similar effect of centralisation of financial flows was described by B. Topić-Pavković (2024), emphasising that the concentration of resources without compensatory mechanisms makes local budgets vulnerable to external and internal shocks. The structure of local budget revenues in 2024 confirmed the trend towards redistribution of financial flows in favour of centralised resources. Despite the significant role of traditional tax revenues, the share of grants and subventions increased significantly, which together provided more than a quarter of the general fund. This indicates the formation of a model in which the sustainability of local finances increasingly depended on the state budget. The generalised proportions between the main sources of income are shown in Figure 1, which makes it possible to outline the key trends in the transformation of the revenue base of territorial communities during the war period.

Data analysis showed that 40% of local budget revenues in 2024 were provided by personal income tax, which remained the key source of formation of the financial base of territorial communities. At the same time, the share of grants and subventions in total exceeded 28%, which indicated a significant

dependence on state budget resources. This result correlates with the conclusions of K. Kluza & K. Wójtowicz (2025), who, in the study, proved that inter-budgetary transfers, on the one hand, strengthen the financial stability of communities, and on the other hand, increase the dependence on central government decisions. Local taxes formed more than a fifth of revenues, confirming the importance for maintaining communities' own financial capabilities. Other sources, in particular excise taxes and non-tax payments, were of an auxiliary nature and did not create a tangible impact on ensuring financial autonomy. This revenue structure demonstrates the strengthening of centralisation tendencies and the gradual limitation of communities' opportunities to implement independent financial policy.

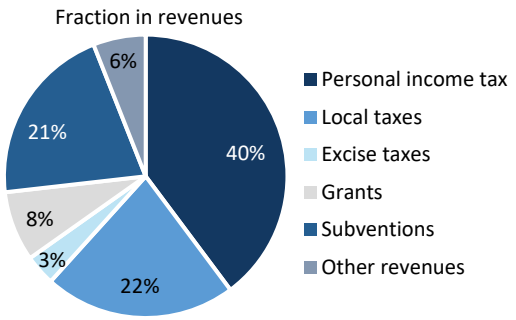

Figure 1. Structure of revenues of local budgets of Ukraine in 2024

Source: developed by the author based on Ministry of Finance of Ukraine (n.d.), Portal "Decentralisation" (n.d.)

An in-depth analysis showed a reduction in the share of personal income tax and local taxes in the general budget fund and an increase in the role of centralised financing. On the one hand, this guaranteed minimal stability during the period of military challenges, but on the other hand, it deprived communities of strategic development planning tools. A similar pattern was confirmed by G. Abuselidze (2021), pointing out that excessive centralisation in the processes of decentralisation reforms reduces the institutional capacity of local budgets and limits the autonomy. According to the Ministry of Finance of Ukraine (2024), in conditions of limited resources, most communities were forced to direct budget funds mainly to social protection and ensuring protected expenditure items. The change in the tax burden led to the fact that the financial resources of local governments became more dependent on the decisions of central authorities and international donors (Open Budget, n.d.). In fact, a significant part of the independence in the formation of the revenue part of the budgets was lost, which led to an orientation towards a centralised system of resource distribution. As C.I. Ojiako & O.C. Raphael (2025) showed, limiting the financial independence of local governments hinders the implementation of strategic development programmes and increases dependence on external sources of support. This situation created additional risks in the event of a state budget deficit or a reduction in the volume of external support.

In the systemic dimension, the transformation of revenues confirms the decrease in the role of local tax revenues and the increase in the centralisation of financial flows. Such a trend is typical for crisis conditions, but it contradicted the principles of budget decentralisation, which provided for strengthening the financial independence of territorial communities. The situation that developed highlighted the need to find compensatory mechanisms and alternative sources of income that can ensure the sustainable development of communities. One of these areas was the agricultural sector, the potential of which lies in the ability to form a stable tax flow and support the financial autonomy of communities in the medium term.

The agricultural sector as the basis of the financial capacity of rural communities

During the war period, the agricultural sector remained one of the key factors in the formation of the revenue base of rural communities. Its importance for local budgets was manifested through revenues from personal income tax, land tax, rent for the use of agricultural land, as well as other related sources (Open Budget, n.d.). An analysis of the dynamics of tax revenues in the agricultural sector in 2022-2024 made it possible to outline the scale of the reduction in the contribution of agricultural production to the formation of community income and showed how the war events

affected the sustainability of local finances. Studying the share of the agricultural sector in the income structure made it possible to determine the level of dependence of budgets on the functioning of agricultural enterprises. The comparative analysis demonstrated a gradual reduction in the share of primary sources due to a decrease in production capacities and loss of access to land resources in significant areas. As shown in Figure 2, this trend indicated a strategic risk to the financial capacity of territorial communities in the absence of compensatory mechanisms and alternative sources of filling local budgets.

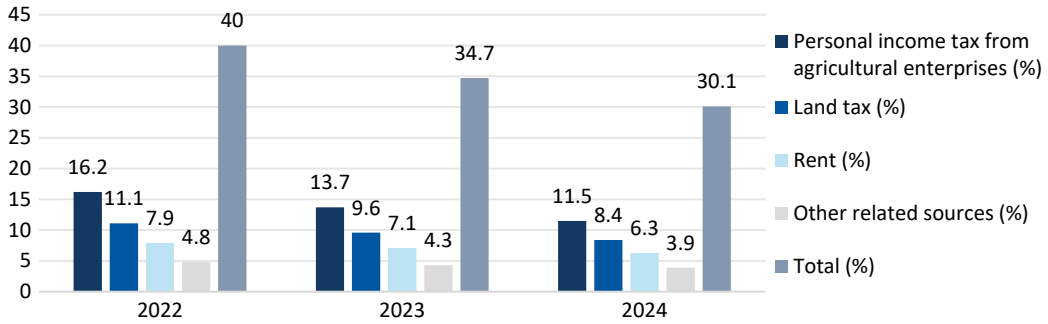

Figure 2. Share of the agricultural sector in the structure of local budget revenues of Ukraine in 2022-2024

Source: developed by the author based on FAO (2023b), A. Albaladejo Román (2024), Portal "Decentralisation" (n.d.)

Analysis of Figure 2 showed that in 2022-2024, there was a gradual reduction in the share of the agricultural sector in the structure of local budget revenues from 40.0% to 30.1%. The most significant decrease was observed at the expense of personal income tax from agricultural enterprises, which decreased by almost 5 percentage points. Land tax and rent also decreased: the share of land tax decreased from 11.1% in 2022 to 8.4% in 2024, and rent from 7.9% in 2022 to 6.3% in 2024. This directly reflected the loss of access to agricultural land and the decline in the activity of agricultural producers. Other sources remained relatively stable, but the share was insignificant for meeting the needs of local budgets. The overall dynamics confirmed the increasing dependence of territorial communities on external sources of financing and highlighted the need for income diversification in order to maintain the financial capacity. Similar conclusions were made by P.K. Ozili & P.T. Iorember (2024), who proved that long-term economic security is possible only with systematic investments in key industries, among which the agricultural sector plays a leading role in forming financial sustainability.

Direct financial losses of the agricultural sector are considered one of the key indicators of the impact of military actions on the economic base of territorial communities. These losses encompass both the destruction of production and logistics capacities, and limited access to land due to mining, as well as a decrease in export opportunities. The aggregate indicators for 2022-2024 made it possible to outline the scale of the problem and trace the trend towards its aggravation. The generalised results of these processes are shown in Figure 3, which reflects the structure and dynamics of direct financial losses of the agricultural sector in the period under study. Analysis of Figure 3 showed that in 2022-2024, the total direct losses of the agricultural sector increased from USD 41.7 to 59.8 billion, demonstrating a steady increase in the negative consequences of military operations. The largest losses fell on the category of destroyed infrastructure, which accounted for about half of the total losses. The destruction of warehouses, elevators, transport routes and logistics centres actually reduced the possibilities for storing and transporting products, which had a long-term effect on the economy of communities. An additional factor of destabilisation

was land mining, the scale of which grew every year: according to the KSE Institute (2023), as of 2023, about 30% of the territory of Ukraine was potentially contaminated with mines and explosive remnants of war, and in 2024 more than 5.2 million hectares of land remained unsuitable for agricultural use (FAO, 2023a). This made significant areas inaccessible for production and created risks for both economic activity and the safety of the rural population. At the same time, the reduction in exports remained an important factor that limited foreign exchange earnings and weakened the resource base of the state and local budgets. Taken together, these processes formed a multidimensional challenge that included the destruction of the material and technical base, loss of access to land, and restrictions on access to foreign markets. Similarly, V. Pernechele *et al.* (2021) showed that systematic investment in the agricultural sector creates long-term multiplier effects for local budgets and strengthens food security, which confirms the importance of restoring agriculture as a strategic resource.

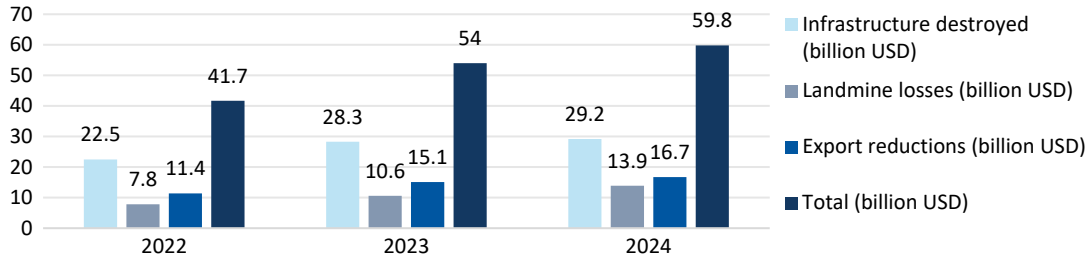

Figure 3. Direct financial losses of the agricultural sector of Ukraine in 2022-2024

Note: destroyed infrastructure refers to elevators, warehouses, transport facilities, logistics routes; losses from land mining include unreceived products and demining costs; reduced exports – reduced foreign exchange earnings from agricultural products exports

Source: developed by the author based on FAO (2023a), KSE Institute (2023), A. Albaladejo Román (2024

A critical element of financial losses was also the reduction in the number of people employed in agriculture due to the mobilisation of the working-age population: in 2022-2023, the number of workers in the agricultural sector decreased by 12-15% on average across the country (Nehrey & Finger, 2024), and in some frontline regions, losses exceeded 25% (Neyter *et al.*, 2024). The reduction in the workforce in the production process caused a drop in productivity and led to a decrease in tax payments to local budgets. Thus, the financial capabilities of territorial communities were directly dependent on demographic changes imposed on wartime circumstances. The loss of labour potential, combined with increasing infrastructure damage and land loss, increased the burden on the system of inter-budgetary transfers and international aid. As K. Kumar *et al.* (2025) showed, it is tax incentives and regulatory interventions that can restore the productive base of the agricultural sector and thereby support tax revenues at the local level. This confirmed that without external support, local governments would be unable to provide even a basic level of social and economic functions. Similar trends were described by K. Jansen *et al.* (2022), who emphasised that centralisation and the reduction of the role of local farms lead to the loss of economic subjectivity of rural areas, making these areas dependent on external resources.

The cumulative effect of infrastructure destruction, loss of access to land, reduced exports, and reduced labour resources determined strategic risks to the financial sustainability of rural communities. The accumulation of these factors led to the need to significantly expand the volume of state support and attract external financial resources, in particular through grant and loan programmes of international organisations. At the same time, long-term recovery could be ensured only by reviving agricultural production as a key basis of the tax base of local budgets. The identified trends confirmed

that the agricultural sector during the war period performed not only an economic, but also a system-forming function in shaping the financial stability of territorial communities. In this context, effective mechanisms for financing and attracting additional resources that can support the development of agriculture and the restoration of the revenue base of communities in the medium term became of paramount importance. A similar approach was demonstrated by M. Fetoui *et al.* (2021), who showed that the restoration of degraded lands is possible only through multi-level cooperation between state institutions, local communities and international organisations, which fully corresponds to Ukrainian realities.

The combination of direct and indirect losses to the agricultural sector during the war period significantly weakened the financial basis of territorial communities, making these communities more dependent on centralised transfers and foreign aid. The loss of infrastructure, land resources, labour potential, and export opportunities created a complex challenge for the economic stability of local governments. Under these conditions, the restoration of agricultural production is a key prerequisite for strengthening the tax base and ensuring the long-term financial sustainability of communities.

Mechanisms of financial support for territorial communities and agricultural producers

The financial stability of territorial communities during the martial law period was largely determined by the volume of resources received in the form of inter-budgetary transfers. Grants and subventions performed a compensatory function, since the communities' own revenues, in particular revenues from personal income tax and economic activity, were significantly reduced. The growth in the role of transfers reflected the adaptation of state financial policy to crisis conditions and demonstrated the level of support for local budgets in ensuring the solvency and performing socially significant functions. A. Bayrakçeken (2024) confirmed this logic, emphasising that the key condition for economic security in crisis situations is the creation of flexible legal mechanisms capable of ensuring the adaptability of financial systems.

An analysis of the dynamics of grants and subventions in 2022-2024 showed a steady increase in centralised financing, which confirmed the formation of a model of high dependence of communities on state resources. As shown in Figure 4, there was both an increase in the absolute volume of transfers and a change in the structure. The share of subventions was of particular importance, as these subventions were directed at specific areas of expenditure, in particular education, healthcare and social protection, while grants performed a more universal function of balancing budgets. The relationship between these forms of support made it possible to assess how rigidly the conditions for the use of centralised funds were determined and what opportunities communities retained for communities' own financial manoeuvring.

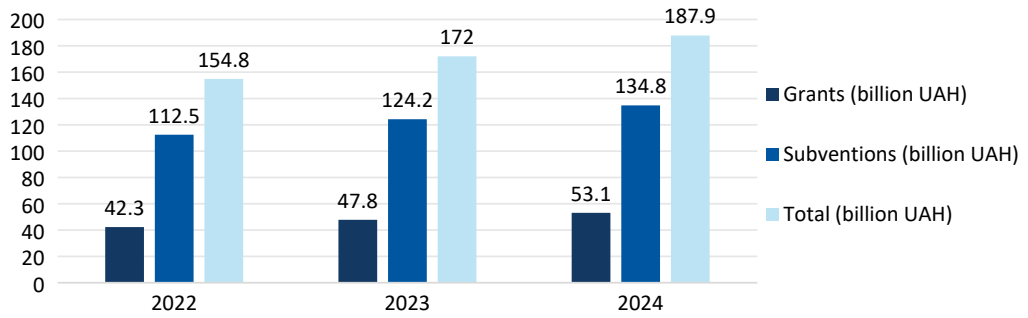

Figure 4. Dynamics of the volume of inter-budgetary transfers for territorial communities in 2022-2024

Note: grants – funds transferred to local budgets without specifying a specific target; subventions – inter-budgetary transfers from the state budget for specific purposes (education, healthcare, infrastructure)

Source: developed by the author based on the Ministry of Finance of Ukraine (n.d.), Portal "Decentralisation" (n.d.)

The data presented in Figure 4 showed a stable growth in the volume of inter-budgetary transfers in 2022-2024. If in 2022 territorial communities received UAH 154.8 billion, then in 2024 this figure increased to UAH 187.9 billion, which corresponded to an increase of almost 21%. The largest share in the structure of transfers was made up of subventions, which increased by UAH 22.3 billion over three years and confirmed the priority of targeted financing focused on the educational, medical and social spheres. Grants demonstrated slower growth rates, but retained a key role in balancing local budgets and ensuring the basic solvency. The overall dynamics of transfers confirmed the growth of centralised support as the main mechanism for compensating for losses of own revenues, which in conditions of martial law increased the dependence of communities on the state budget and narrowed the possibilities for strategic planning at the local level. Similarly, R. Svartzman *et al.* (2021) proved that a multi-level model of coordination of financial flows in crisis conditions allows reducing systemic risks and compensating for losses of income at the local level.

In this context, grant and preferential financing acquires particular importance, as it acts as an additional tool for increasing the financial sustainability of communities. To specify these trends, it is advisable to consider examples of three territorial communities from different regions of Ukraine: deoccupied, frontline, and rear (Table 2). The cases presented make it possible to trace how the combination of budget resources, international grants, and preferential lending programmes ensures the restoration of agricultural infrastructure, support for production processes, and the formation of the tax base of local budgets.

Table 2. Examples of financial support for territorial communities in 2022-2024

Community type	Name of community (region)	Support tool	Funding amount	Direction of use	Expected effect
Deoccupied	Iziumska (Kharkiv)	State budget + FAO grant	USD 4.2 million	Restoration of the grain elevator and logistics	Restoration of export flows and increase in PIT revenues
Frontline	Orikhivska (Zaporizhzhia)	World Bank ARISE Programme	USD 1.8 million	Purchase of mobile dryers and seed stock	Sowing campaign ensured and jobs preserved
Rear	Tlumatska (Ivano-Frankivsk)	Local budget + programme "5-7-9"	UAH 25 million	Construction of a modern dryer and expansion of the elevator	12% increase in land-related budget revenues lease

Source: developed by the author based on FAO (2023a), World Bank (2023), D. Poursina *et al.* (2024), Cabinet of Ministers of Ukraine (2025), Delegation of the European Union to Ukraine (2025), Ministry of Finance of Ukraine (n.d.), Portal "Decentralisation" (n.d.)

In the case of the deoccupied Iziumska community in Kharkiv region, funding was provided through a combination of the state budget and the FAO grant programme, which ensured the restoration of basic production capacities (FAO, 2023a). In addition to the restoration of the elevator, part of the funds were directed to the purchase of equipment for grain quality control laboratories, which allowed for the restoration of export supplies through the Black Sea corridors. A study by D. Poursina *et al.* (2024) confirmed the significant economic effect of the grain initiative in supporting international trade. Additionally, FAO and EU grant resources were used to train local farmers in risk management in the post-war period, which increased the human resources potential of the community (Delegation of the European Union to Ukraine, 2025). The cumulative effect was manifested in an increase in personal income tax revenues and the restoration of contracts with international traders.

The Orikhivska frontline community of Zaporizhzhia region received support under the World Bank's Ukraine Agriculture Recovery Inclusive Support Emergency (ARISE) programme, which provided funding for mobile grain dryers and seed stock restoration (World Bank, 2023). Thanks to this, the community was able to

conduct a full-fledged sowing campaign despite limited logistical capabilities and constant risks of hostilities. In addition, part of the funds were used to create a reserve seed stock for subsequent seasons, which increased resilience to possible future disruptions. The economic effect was manifested in the preservation of over 300 jobs and stabilisation of land lease revenues. In the Tlumatska rear community of Ivano-Frankivsk region, the use of the local budget in combination with the "5-7-9" programme made it possible not only to build a modern dryer and expand the elevator, but also to create a cooperative for small farmers. The affordable lending programme provided low interest rates, which stimulated additional investments in technical re-equipment (Cabinet of Ministers of Ukraine, 2025). As a result, the community received a 12% increase in land-related budget revenues lease and increased employment in the field of agricultural infrastructure services.

A critical additional factor of financial support was the activities of international organisations that provided a resource base for the restoration of the agricultural sector. In particular, the Ukraine Facility programme (European Commission, 2022) provided for the provision of long-term macro-financial assistance to Ukraine, including resources to support agricultural production and the development of local infrastructure. The Common Agricultural Policy (European Commission, 2023) was aimed at supporting the competitiveness of agricultural producers through the modernisation of technologies, the development of innovations and ensuring food security. The European Agricultural Fund for Rural Development (European Commission, 2024) provided funding for rural rehabilitation projects, including land demining, infrastructure construction and modernisation, and support for small and medium-sized farms. FAO (2023a) implemented grant programmes focused on the direct rehabilitation of farms, the purchase of seeds, equipment, and the restoration of production capacities in the affected areas. Data for 2022-2024 showed a gradual increase in the volume of international assistance, reflecting the increased interest of partners in stabilising the agricultural sector of Ukraine. This trend had not only socio-economic but also fiscal significance, as support for agricultural production directly influenced the formation of local tax revenues and served as an important element in ensuring the financial sustainability of territorial communities, which is clearly reflected in Figure 5.

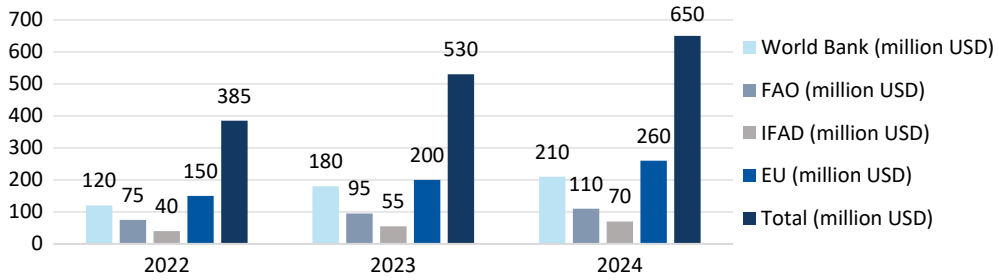

Figure 5. Volumes of grant support to the agricultural sector from international organisations in 2022-2024

Note: data reflect grant support in the form of financing programmes for the restoration, modernisation and support of agricultural production

Source: developed by the author based on International Fund for Agricultural Development (2022), FAO (2023b), World Bank (n.d.)

Analysis of Figure 5 showed a steady increase in the volume of international grant assistance to the agricultural sector of Ukraine in 2022-2024. The total amount of funding increased from USD 385 million in 2022 to USD 650 million in 2024, which corresponded to an increase of 69%. The largest share of assistance was provided by the European Union, which accounted for about 40% of the total. Resources provided by the World Bank

remained significant, while FAO and IFAD focused on supporting small farms and implementing food programmes. This dynamics indicated the growing role of international donors in stabilising the agricultural sector, which directly formed the tax base and financial sustainability of territorial communities. According to the Fund for Entrepreneurship Development (n.d.), state programmes to stimulate small businesses played an important role in supporting the agricultural sector, in particular the affordable loan programme "5-7-9". Expanding access of rural enterprises to cheap financial resources made it possible to maintain employment of the population, maintain production capacities and minimise the risk of complete loss of tax revenues. The combination of external and internal financing instruments created conditions for diversification of income sources and contributed to more sustainable development of communities even under military restrictions. A similar effect was described by S. Karim *et al.* (2022), showing that during the COVID-19 pandemic, adaptive mechanisms of the banking sector, in particular regulatory easing and targeted support programmes, made it possible to minimise the negative effect of the crisis on local economies.

At the same time, problems of efficiency of use of attracted resources persisted. Insufficient level of transparency and control mechanisms created risks of non-targeted spending of grant and subvention funds, in particular delays in the implementation of reconstruction programmes and cases of use of funds without clear reference to target indicators (KSE Institute, 2023; World Bank, n.d.). This reduced the effectiveness of financial support, as part of the funding did not provide the expected effect in restoring production capacities and developing local infrastructure. This problem correlates with the results of the study by A. Białek-Jaworska (2022), which found that the activation of municipal enterprises can reduce the debt burden and at the same time increase the efficiency of using financial resources at the local level. Therefore, the need to strengthen the institutional capacity of local governments for high-quality administration of external and internal financial flows became urgent, because it was this factor that determined the trust of international partners and further readiness for cooperation.

In general, the financial capacity of territorial communities in wartime was formed thanks to a combination of multi-level support from the state and international organisations. The development of effective schemes of interaction between communities, government structures and donors became a key prerequisite for minimising the consequences of war destruction and created the basis for further reconstruction of the economy at the local level. This trend determined the prospects for long-term restoration of financial stability through the restoration and development of the agricultural sector.

Prospects for restoring the financial capacity of communities through agricultural development

The restoration of the agricultural sector after the end of the active phase of hostilities is a key factor in rebuilding the financial base of territorial communities. It is this sector that determines the level of tax revenues, which are the basis of the revenue part of local budgets in rural regions. Forecasting its development makes it possible to assess the potential volumes of resources that will be formed in the medium term and will ensure the financial capacity of communities. Revenues from personal income tax, land tax and rent are of particular importance, since these revenues reflect both the level of economic activity and access to land resources, which directly affect budget planning.

Forecast calculations of revenues make it possible to determine guidelines for strategic financial planning of territorial communities (Fig. 6). The expected gradual restoration of agricultural production after land clearance and modernisation of production facilities will contribute to employment growth, labour productivity, and land use costs (Neyter *et al.*, 2024). This will generate a stable increase in tax and rental payments, which in the future will ensure not only the fulfilment of current social and administrative obligations, but also create opportunities for investment in the development of social and production infrastructure (World Bank, n.d.). Thus, the restoration of the

agricultural sector becomes not only an economic but also a socio-strategic factor capable of determining the trajectory of rural communities in the post-war period.

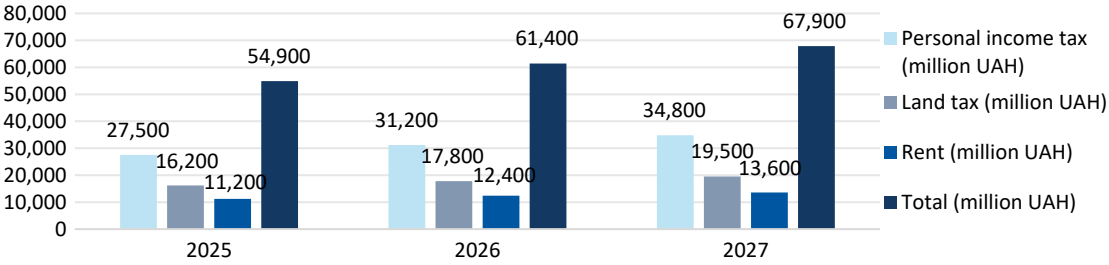

Figure 6. Forecast revenues to local budgets from the agricultural sector in 2025-2027
Note: land tax – mandatory payments for the use of land plots; rent – revenues for the use of agricultural land. Forecast data are calculated based on the average annual rates of recovery of agricultural production of 8-10%, the expected growth in employment in the sector after land clearance, as well as the expansion of the tax base through integration into support programmes of the European Commission and international donors
Source: developed by the author based on FAO (2023b), A. Albaladejo Román (2024), Ministry of Finance of Ukraine (n.d.)

Analysis of Figure 6 indicates a gradual recovery and growth of tax revenues from the agricultural sector in 2025-2027. The largest increase is expected due to the personal income tax, the volume of which increases from UAH 27.5 billion in 2025 to UAH 34.8 billion in 2027. This is due to the expansion of employment in agriculture and the gradual restoration of entrepreneurial activity in the liberated and restored territories. Land tax during this period shows an increase of UAH 3.3 billion, which is associated with the introduction into economic circulation of lands that were inaccessible due to mining or destruction of infrastructure. The rent for agricultural land also increases by UAH 2.4 billion, reflecting the increased interest of private and corporate investors in land use and the increase in rental costs. In total, local budget revenues from the agricultural sector increase from UAH 54.9 billion in 2025 to UAH 67.9 billion in 2027, confirming its key role as a budget-forming factor and the basis for the financial stability of territorial communities. Similarly, D.R. Hakim & S.R.S. Dewi (2021) showed that targeted tax revenues can strengthen the financial capacity of territories and ensure diversification of income sources.

Determining the needs for financing the restoration of the agricultural sector is the next important step in shaping post-war reconstruction strategies. The analysis of key areas showed that the largest resources in the medium term will be required for land demining, modernisation of the technical base and restoration of damaged infrastructure, while supporting farms is seen as a long-term investment in the development of the local economy. Forecast data for 2025-2030 indicate a gradual reallocation of financial flows from priority measures aimed at eliminating the consequences of the war to investments in technological renewal, increasing productivity, and ensuring sustainable competitiveness of the agricultural sector (Fig. 7). This approach forms the basis for balanced development of local budgets and creates opportunities for long-term strengthening of the financial capacity of communities. Analysis of Figure 7 shows that in 2025-2030, the largest expenditures will be required for infrastructure restoration and land demining, but the share in overall needs will gradually decrease. At the initial stage, these areas are critically important for returning agricultural land to production and restoring logistics links. Financing for demining decreases from USD 5.5 billion in 2025 to USD 3.4 billion in 2030, which is explained by the completion of key stages of territory clearance and the gradual reduction in the scale of the problem. This correlates with the conclusions of K.Q. Yaqub (2024), who, analysing the experience of Iraq, proved that excessive dependence on a single source of income (in particular, oil revenues) creates fiscal

vulnerability, which echoes the Ukrainian situation, where the dominance of certain income items requires compensatory mechanisms. In contrast, spending on equipment modernisation shows the opposite dynamics – growing from USD 3.0 to USD 4.8 billion, reflecting a strategic shift in emphasis from eliminating war consequences to increasing production productivity. This conclusion is consistent with the results of the study by A. Ahmad *et al.* (2024), which showed that the introduction of innovative technologies and artificial intelligence in the agricultural sector provides increased productivity, reduced costs, and the formation of stable tax revenues. Digitalisation of processes in production and logistics, as A. Ahmad *et al.* prove, creates the basis for strengthening the financial capacity of communities, since the introduction of innovative technologies and artificial intelligence in the agricultural sector provides increased productivity, reduced costs, and the formation of stable tax revenues. Forecast data developed based on materials from KSE Institute (2023), R. Neyter *et al.* (2024) and World Bank (n.d.), confirmed a similar role of modernisation of agricultural machinery, which was determined as one of the key factors in restoring the financial base in the medium term. Support for farms during this period also gradually increased, which indicates the growing role of small and medium-sized agricultural producers in restoring economic activity and ensuring sustainable development of the agricultural sector. The total annual financing needs according to forecasts for 2025-2030 remain stable and fluctuate at the level of USD 17-18 billion (Neyter *et al.*, 2024; World Bank, n.d.), which confirms the sustainability of financial obligations in the medium term and the need for long-term planning of relevant programmes. A similar pattern was noted by C. Challoumis (2024), who developed the concept of integrating the dynamics of the monetary cycle and economocracy, proving that the effectiveness of the financial system in crisis conditions depends on the ability to balance income and expenditure, taking into account cyclical fluctuations.

In the context of forming the financial stability of territorial communities after the end of the active phase of hostilities, an important task is not only to assess resource needs, but also to determine strategic guidelines for development. The predicted recommended solutions, summarised in Table 3, make it possible to outline the key areas of state, municipal and international support. These solutions reflect possible steps aimed at creating new financial instruments, restoring the tax base and stimulating agricultural development, which together form the basis for long-term strengthening of the financial capacity of local budgets and increasing the economic independence.

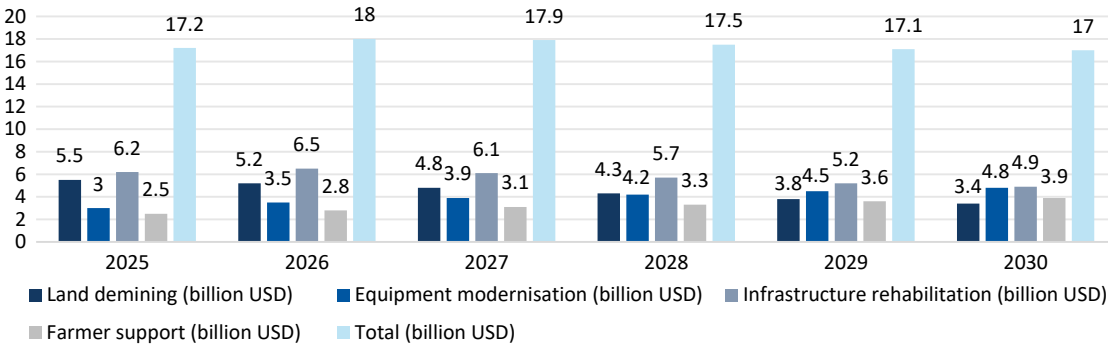

Figure 7. Financing needs for the restoration of the agricultural sector by areas in 2025-2030
Note: the forecast financing needs for the main areas of development of the agricultural sector are given: land demining – costs for clearing territories to return these territories to economic circulation; modernisation of equipment – investments in modern machinery and equipment; infrastructure restoration – reconstruction of warehouses, logistics facilities, irrigation systems; support for farmers – grants, loans, and subsidies for small and medium-sized producers
Source: developed by the author based on FAO (2023b), KSE Institute (2023), A. Albaladejo Román (2024)

Table 3. Predicted recommended solutions for restoring the financial capacity of territorial communities through agricultural development

Direction	The essence of the solution	Expected effect	Estimated implementation period
Integration into the European market	Participation in EU programmes – Ukraine Facility, CAP, EAFRD	Expansion of sales markets, increase in foreign exchange earnings, growth in local budget revenues	2025-2030
Technology modernisation	Introduction of modern agricultural technologies (precision farming, irrigation) and product storage systems (mobile dryers, elevators)	Reducing production costs, increasing competitiveness, increasing tax revenues	2025-2028
Development of microcredit	Creating affordable financing programmes for small farmers and personal farms	Diversification of production, preservation of jobs, stabilisation of the local economy	2025-2027
Creation of local agricultural funds	Pooling state, municipal, and donor resources to support farmers and restore land	Financing demining, supporting farmers, increasing the fiscal sustainability of communities	2025-2030

Note: local agricultural funds are special financial instruments created at the community level to support the agricultural sector and restore land resources; microcredit is a mechanism for providing small loans to small farmers and farms in order to maintain the activities
Source: developed by the author based on FAO (2023a), KSE Institute (2023), European Commission (2022; 2023; 2024)

The restoration of the tax base of territorial communities is possible thanks to Ukraine's integration into the European market and involvement in agricultural sector support programmes by the European Union, in particular the Ukraine Facility (European Commission, 2022), Common Agricultural Policy – CAP (European Commission, 2023) and European Agricultural Fund for Rural Development – EAFRD (European Commission, 2024). The implementation of these programmes involves the creation of new opportunities for export, the introduction of European production standards and an increase in the quality of products. It is assumed that this will not only ensure stable growth in farm incomes, but also expand the resource base of local budgets by increasing revenues from personal income tax, land payments and rent. In the medium term, such processes should contribute to the formation of a more predictable and diversified revenue part of local budgets. A similar conclusion was made by J. Zhang & Z. Shi (2025), who, based on the CGE model, proved that social capital and cultural interaction strengthen the economic base of rural areas and provide additional sources of income.

Modernisation of the agricultural sector through the introduction of modern technologies for production, storage, and processing of products is considered one of the most promising areas of recovery. The use of innovative solutions allows reducing the cost of production and increasing the efficiency of resource use: according to estimates, the use of precision agriculture technologies reduces fuel and fertiliser costs by 15-20%, which corresponds to savings of over USD 1.2 billion per year on a national scale (KSE Institute, 2023). At the same time, the introduction of irrigation systems increases the yield of grain crops by an average of 25-30%, providing additional tax revenues for local budgets at the level of UAH 4-5 billion per year (FAO, 2023a). According to World Bank calculations (n.d.), reconstruction and modernisation of storage infrastructure reduces post-harvest losses from 15% to 7-8%, which is equivalent to saving about 2.5 million tonnes of grain annually. The development of processing enterprises can increase the added value of products by 35-40% and bring communities an additional UAH 6-7 billion in tax deductions each year (FAO, 2023a). Taken together, such measures not only stabilise the production process and ensure competitiveness in international markets, but also contribute to the growth of tax revenues to local budgets, strengthen the financial capacity of territorial communities and create an attractive investment environment for

the long-term development of rural areas. The prospects for restoring the financial capacity of territorial communities through the development of the agricultural sector confirm the need to combine state, municipal, and international support instruments. A similar approach was proposed by T. Mallawaarachchi & D.B. Rahut (2023), emphasising that inclusiveness and diversification of income are key conditions for sustainable development of rural areas in the post-crisis period. Implementation of comprehensive measures to demine territories, expand access to financial resources and modernise production creates a basis for long-term restoration of the revenue base of local budgets. Such a strategy provides not only financial stabilisation, but also forms the basis for analysing social and economic effects that will determine the further trajectory of development of local finances in the post-war period.

Thus, the results of forecast calculations and analysis of the main areas of financing showed that the restoration of the financial capacity of territorial communities directly depends on the pace of revival of the agricultural sector and the effectiveness of the implementation of mechanisms for its support. The combination of modernisation of production, attraction of investments, integration into European programmes and development of local financial instruments creates a comprehensive basis for stabilising local budgets and creating prerequisites for long-term economic growth.

CONCLUSIONS

The results of the study showed that in 2022-2024, the financial base of territorial communities in Ukraine underwent significant changes. Personal income tax decreased from UAH 300.5 billion in 2022 to UAH 259.3 billion in 2024 (-14%), while inter-budgetary transfers increased by 21%, reaching UAH 187.9 billion. In the revenue structure of 2024, personal income tax accounted for almost 40%, and the share of grants and subventions exceeded 28%, which indicated an increase in centralised trends and a decrease in the financial independence of communities. The agricultural sector remained the leading factor in generating income in rural areas, but its share decreased from 40.0% in 2022 to 30.1% in 2024. The largest drop was observed in personal income tax from agricultural enterprises – from 16.2% to 11.5%. Direct losses of the industry in 2022-2024 amounted to USD 59.8 billion, of which about half was due to destroyed infrastructure. Additional negative factors were land mining and reduced exports, which increased fiscal risks for communities. At the same time, international support increased: grant funding increased from USD 385 million in 2022 to USD 650 million in 2024. Forecasts indicate that in 2025-2027 tax revenues from the agricultural sector will increase from UAH 54.9 billion to UAH 67.9 billion, while the needs for financing its recovery in 2025-2030 will remain at the level of USD 17-18 billion annually. The greatest resources will be required for the restoration of infrastructure and land demining, while costs for modernisation of equipment and support for farmers will gradually increase. At the same time, the long-term recovery strategy should be based on the implementation of the predicted recommended solutions, including integration into European markets, modernisation of agricultural technologies, development of microcredit and creation of local agricultural funds, which will ensure stability and diversification of sources of income of communities.

The limitations of the study are the dependence on official statistical data and reports of international organisations, which may not fully reflect the real scale of economic losses in communities, as well as the lack of unified methods for assessing the financial consequences of land mining and the destruction of agricultural infrastructure, which reduced the accuracy of long-term forecasts. Further research should be aimed at quantitatively assessing the socio-economic effects of restoring the agricultural sector, modelling regional disparities in community incomes, and analysing the effectiveness of Ukraine's integration into the financial and agricultural programmes of the European Union, which will allow for the formation of more comprehensive strategies for restoring and strengthening the financial sustainability of territorial communities.

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CONFLICT OF INTEREST

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Фінансове забезпечення територіальних громад в умовах воєнного стану: виклики та перспективи для аграрного сектора

Анотація. Метою статті було виявлення трансформацій фінансових ресурсів територіальних громад у період воєнного стану та визначення ролі аграрного сектору у відновленні їхньої фінансової спроможності. Методологія ґрунтувалася на аналізі статистичних показників доходів місцевих бюджетів України у 2022-2024 роках, структурно-функціональному аналізі ролі аграрного сектору та прогнозному моделюванні відновлення податкової бази у 2025-2030 роках. Аграрний сектор, що забезпечує понад 30 % бюджетів сільських громад, зазнав втрат на суму близько 59,8 млрд дол. унаслідок руйнування інфраструктури, мінування понад чверті земель і скорочення експорту. Обсяги міжнародної грантової підтримки від Світового банку, Продовольчої та сільськогосподарської організації ООН, Міжнародного фонду сільськогосподарського розвитку та Європейського Союзу зросли з 385 млн дол. у 2022 році до 650 млн дол. у 2024 році, що підтвердило вагомість зовнішньої допомоги. Прогнозні розрахунки показали, що у 2025-2027 роках податкові надходження від аграрного сектору зростуть із 54,9 млрд грн до 67,9 млрд грн, тоді як щорічні потреби у фінансуванні його відновлення у 2025-2030 роках залишатимуться на рівні 17-18 млрд дол. з переорієнтацією на модернізацію техніки та підтримку фермерів. Поєднання державних, муніципальних та міжнародних механізмів підтримки створює основу для відновлення фінансової спроможності громад, а інтеграція України до європейського ринку відкриває нові можливості для зміцнення податкової бази. Практичне значення дослідження полягає у формуванні рекомендацій щодо розвитку локальних аграрних фондів, мікрокредитування та програм пільгового кредитування. Результати можуть бути використані органами місцевого самоврядування, державними установами та міжнародними донорами для розробки стратегій фінансової стійкості територіальних громад

Ключові слова: бюджет; доходи; гранти; субвенції; продовольча безпека; прогнозне моделювання

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The state of efficiency of use and prospects for restoration of resource potential of agricultural enterprises of the Polissia zone of Ukraine in the post-war period

Abstract. The purpose of this study was to determine the features of the formation and effectiveness of the use of resource potential of agricultural enterprises of the Polissia zone of Ukraine in conditions of wartime transformations. The research methodology was based on the application of descriptive-statistical, structural, dynamic and comparative analysis, as well as the case study method on the example of the enterprises Galeks-Agro and Ritter Bio Agro LLC. The study found that the natural and climatic conditions of Polissia limited the efficiency of resource use: the pH level of soils was 4-5.5, the humus content was 0.8-1.5%, and annual losses were 0.3-0.5 tonnes/hectare. At the same time, an increase in grain crop yields by more than 40% and an increase in production volumes to UAH 258 billion in 2023 were found, which may indicate adaptation. Comparative analysis of enterprises showed significant differences in efficiency: at Galeks-Agro, revenue per hectare was UAH 41,780, profit – UAH 8,887, labour productivity – 1,530,392 UAH/employee, integral indicator – 0.75. At Ritter Bio Agro LLC, revenue per hectare was UAH 2,902, profit per hectare was UAH 631, labour productivity – UAH 196,927 per employee, integral indicator of efficiency – 0.25. At the same time, close profitability values (21.27% and 21.73%) indicate similar cost efficiency, while differences in overall results are due to the scale and intensity of resource use. In the post-war period, increasing the efficiency of resource potential use is associated with optimising land use, modernising the material and technical base, developing processing, diversifying production, and improving logistics and export activities. The practical significance of the study lies in the possibility of using the obtained results and substantiated approaches to increase the efficiency of resource potential use and forming management decisions regarding the restoration of agricultural enterprises in the post-war period

Keywords: productivity; land use; productivity; diversification; digitalisation; profitability

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INTRODUCTION

The functioning of agricultural enterprises in the Polissia zone of Ukraine in the conditions of military transformations is accompanied by a disruption of the processes of formation and resource potential use, which manifested itself in the loss of part of production resources, a decrease in the efficiency of land use and limited access to material, technical and financial resources. A full-scale war led to the destruction of infrastructure, loss of equipment, mining of agricultural lands and disruption of logistics chains, which directly affected the effectiveness of agricultural production. Violation of the effectiveness of the functioning of agricultural enterprises necessitates a review of approaches to the formation and use of the production and financial capabilities in the context of innovative transformations, which are accompanied by the influence of external and internal factors. The study by N.M. Sulima *et al.* (2024) found that agricultural enterprises concentrate a significant share of land, labour and financial resources, which determines the role in the formation of production potential. Increasing the efficiency is associated with the introduction of innovative technologies, the development of human capital, diversification of activities and the use of various sources of financing, which allows adapting to changes in the economic environment. The activities of small and medium-sized agricultural enterprises, as established by N.O. Avercheva & H.V. Kozak (2024), are accompanied by a decrease in the level of profitability, a decrease in employment and an increase in dependence on external sources of financing. A significant part of economic entities is on the verge of financial sustainability, and the restoration of the functioning in the post-war period requires improving management processes, implementing performance assessment systems and attracting state and international support.

The complexity of the processes of combining and using production factors in agricultural enterprises in the context of the transformation of the economic environment necessitates the clarification of the essence and structure of the resource capabilities. The resource potential of agricultural enterprises in the study of S.V. Stepanenko (2022) considered it as a complex system of interconnected elements, including land, capital, and labour with the further detailing in accordance with the peculiarities of the functioning of agricultural production. The author also proved that the efficiency of resource use is determined not only by the volume, but also by the proportionality and balance of the combination, with a special role played by intellectual and image capital, as well as the transformation of land relations and the growth of the importance of human capital in the conditions of innovative development. The agricultural sector of Ukraine, as established by I.V. Tomashuk & R.O. Horobchuk (2024), has significant potential, formed at the expense of natural resources, labour supply, infrastructure and technological capabilities. Its implementation is limited by an insufficient level of modernisation, investment difficulties and social challenges, in particular the ageing of the population in rural areas. The authors argued that increasing efficiency is possible through the introduction of innovative technologies, the development of cooperation, the digitalisation of production, and the expansion of processing, which will contribute to the growth of added value and the competitiveness of products.

Disruption of agricultural land use processes due to military actions, accompanied by a decrease in cultivated areas, deterioration of soil quality characteristics and complication of production and logistics processes, necessitates a rethinking of organisational and economic approaches to land use. The study found that military aggression caused significant losses of land resources due to mining, occupation and pollution, which, as noted by O.M. Dyachynska (2025), led to a reduction in sown areas and a decrease in yields. The researcher also substantiated that in conditions of limited access to resources and disruption of logistical connections, agricultural enterprises are forced to adapt the production structure, reduce costly crops and review approaches to the use of land resources, and also identified areas of state support, investment support and land use optimisation for the restoration of production processes in the post-war period. A. Shevchenko *et al.* (2025), in the study, determined that the resource potential of

agricultural enterprises includes land, material and technical, financial and human components that form the possibilities of the development and adaptation to changes in the economic environment. The authors also substantiated that innovative diversification of activities, in particular the introduction of niche crops, the development of new areas of production and the use of modern technologies, contributes to increasing financial stability, reducing risks and ensuring the stability of the functioning of agricultural enterprises in the post-war period.

Deterioration of the conditions for providing agricultural production with material and technical, financial and labour resources in conditions of economic instability is accompanied by a decrease in productivity and a complication of the processes of reproducing production capabilities. In the study of M.P. Martyniuk (2024), the resource availability of agriculture was characterised by significant limitations caused by the destruction of infrastructure, disruption of logistical connections, loss of part of the land and limited access to financing, which negatively affected the efficiency of the functioning of enterprises. The author also argued that increased efficiency is possible through the introduction of innovative technologies, in particular precision agriculture, production automation and digital solutions, as well as through diversification of financing sources, development of environmentally friendly practices and staff training. At the same time, R.M. Soloshenko (2023) found that the war caused complex negative consequences, in particular the destruction of logistics and production infrastructure, loss of up to 30% of agricultural land, shortage of financial resources and reduction of production by 30-40% compared to the pre-war period. The author also argued that recovery is possible on the basis of an integrated approach, which involves the reconstruction of infrastructure, modernisation of irrigation systems, attraction of international investments, state financial support, implementation of digital and agro-technological solutions, as well as the development of human capital and diversification of export markets.

Meanwhile, the issues of assessing the efficiency of resource use in a regional context remain insufficiently addressed, and there are no comprehensive approaches to restoring production potential, taking into account territorial conditions and the consequences of war-related impact. The purpose of this study was to study the processes of formation and efficiency of use of production resources of agricultural enterprises of the Polissia zone of Ukraine under the influence of military changes. To achieve this goal, the following tasks were defined: to analyse the composition and structure of resource endowment of agricultural enterprises of the Polissia zone of Ukraine, taking into account natural and climatic conditions and military changes; to assess the effectiveness of use of production resources; to substantiate the directions of restoration and improvement of the effectiveness of use of resources of agricultural enterprises in the post-war period.

MATERIALS AND METHODS

The study was empirical in nature and covered the time period of 2021-2025, which was due to the need to simultaneously take into account the pre-war state of the agricultural sector, the sharp transformation of the resource base as a result of full-scale military operations in 2022 and the stage of gradual restoration in 2023-2025, which made it possible to trace the dynamics of changes in the use of the resource potential of agricultural enterprises. The object of the study was agricultural enterprises of the Polissia zone of Ukraine and the resource potential, which was formed under the influence of natural and climatic, economic and military factors. The Polissia zone was considered as a spatial environment for the functioning of enterprises, which determined the specifics of resource use. To clarify the territorial boundaries of the study, the method of regional and spatial analysis was used, which made it possible to outline the composition of the relevant regions (Resolution of the Cabinet of Ministers of Ukraine No. 2068, 1998) and take into account the natural and geographical features. To identify the factors that affected the efficiency of resource potential use of agricultural enterprises in the Polissia zone of Ukraine, the study used a descriptive-analytical method. Using this method, the characteristics of the soil cover were

analysed, in particular, soil acidity (Soil fertility models..., 2022; Soil pH and..., 2025), as well as the humus content and its dynamics (One of the biggest..., 2018). Special attention was paid to the peculiarities of the structure of agricultural production and its transformation (Zosymchuk, 2022). The obtained data were used to identify natural, climatic and resource factors that determined the conditions for using the resource potential of agricultural enterprises in the region (Nechyporenko *et al.*, 2025).

Within the framework of the study of the resource potential of agricultural enterprises of the Polissia zone of Ukraine, the case study method was applied on the example of the enterprises Galeks-Agro (n.d.) and Ritter Bio Agro LLC (n.d.). The choice of these enterprises was due to the need to compare different models of production organisation within the same natural and climatic zone. The study of the enterprise Galeks-Agro was carried out using structural and descriptive-analytical methods to characterise the components of the resource potential, in particular land, biological, material, and technical and innovative resources, as well as determining the features of the combination in the production process. The assessment of the organisational and production model and the level of integration was carried out using a functional-structural approach, which made it possible to analyse the relationships between crop production, livestock farming and processing. The study of innovative and environmental components of the resource potential was based on the analysis of the enterprise's compliance with international standards of organic production: Regulation (EU) 2018/848 (2018), Bio Suisse (2023). Additionally, for a generalised assessment of the efficiency of resource use, elements of financial analysis were used based on the reporting of Galeks-Agro (n.d.), which allowed correlating the structure of resource availability with the results of economic activity.

The study of Ritter Bio Agro LLC (n.d.) was conducted using a similar methodological approach, taking into account the specifics of its production model. The characteristics of land resources and production specialisation were carried out using structural and descriptive-analytical methods to determine the structure of crops and the features of the use of land potential in organic production: Regulation (EU) 2018/848 (2018), Ritter Bio Agro LLC. Information on the organic orientation of the enterprise's activities was taken into account based on the availability of relevant organic production certificates, in particular Organic Standard (n.d.), Naturland (n.d.) and Bio Suisse (2023). The assessment of the material and technical support and production model was carried out using a functional-structural approach based on information on the enterprise's activities. Additionally, elements of financial analysis were used based on open reporting data, which allowed correlating resource support with the results of economic activity.

To generalise approaches to resource potential use, a comparative method was applied by comparing the activities of Ritter Bio Agro LLC (n.d.) and Galeks-Agro (n.d.) according to the following indicators: revenue per hectare, UAH/ha, profit per hectare, UAH/ha, profitability, %, revenue per 1 employee, UAH, integral efficiency indicator. The calculation of revenue per hectare was carried out according to the formula (1):

$$D_1 = \frac{D}{S}, \tag{1}$$

where D – net revenue from sales of products, UAH; S – the area of agricultural land, ha.

This indicator was used to assess the economic return on land resources and allowed comparison of the efficiency of enterprises. The calculation of profit per hectare was carried out according to the formula (2):

$$P_1 = \frac{P}{S}, \tag{2}$$

where P – net profit, UAH.

The indicator characterised the efficiency of land resource use taking into account costs and reflected the level of financial result formation per unit of area. The level of profitability was determined as (3):

$$R = \frac{P}{D} \times 100\%. \tag{3}$$

This indicator enabled assessing the efficiency of enterprise costs and determining the

ratio of profit received to the volume of products sold. The calculation of labour productivity (revenue per employee) was carried out according to the formula (4):

$$L = \frac{D}{N}, \quad (4)$$

where N – the average number of employees, people.

The indicator was used to assess the efficiency of using labour resources and reflected the volume of products created per employee. In order to ensure the comparability of indicators that have different units of measurement, the normalisation was applied using the minimax method (5):

$$(x - x_{min})/(x_{max} - x_{min}). \quad (5)$$

Normalisation made it possible to bring heterogeneous indicators to a single scale and provided the possibility of the further generalisation. The integral indicator of the efficiency of using resource potential was determined as the arithmetic mean of the normalised indicators (6):

$$I = (x_1 + x_2 + x_3 + x_4)/4. \quad (6)$$

The use of the integral indicator allowed for the aggregation of partial indicators of efficiency and the formation of a generalised assessment of the level of use of the resource potential of enterprises. Based on the generalisation of the obtained results, directions for the restoration and improvement of the efficiency of resource use in the post-war period were formed using the method of generalisation and systematisation, which provided a justification for approaches to increasing the operational efficiency of agricultural enterprises, taking into account the identified trends and limitations.

RESULTS AND DISCUSSION

The state and dynamics of agricultural production development in the Polissia zone of Ukraine

The Polissia zone of Ukraine covers the northern and partly western regions of the country and is characterised by the predominance of sod-podzolic soils of sandy and sandy loam mechanical composition, as well as a significant share of waterlogged and swampy lands. It includes the territories of Volyn, Rivne, Zhytomyr, Kyiv, Chernihiv, Sumy, Lviv, Ternopil and Khmelnytsky regions (Resolution of the Cabinet of Ministers of Ukraine No. 2068, 1998). The total area of the zone is over 113 thousand km² (about 20% of the territory of Ukraine), and in some regions, in particular the Rivne region, the share of Polissia territories exceeds 73% (about 1.5 million hectares). The natural environment of the region is characterised by an excess water balance: the average annual rainfall is 600-650 mm (in some areas over 700 mm) with evaporation of 400-450 mm. The temperature regime ranges from -4.5...-8°C in winter to +17...+19°C in summer, and the duration of the frost-free period is 160-180 days. The functioning of agricultural enterprises in the Polissia zone of Ukraine is determined by specific natural resource conditions that directly affect the efficiency of resource potential use. One of the keys limiting factors is the properties of soils characterised by high acidity and low natural fertility. The predominance of sod-podzolic soils with a pH level of 4-5.5 causes the formation of an acidic environment, which leads to the accumulation of toxic forms of aluminium, inhibition of the development of the plant root system and a decrease in the availability of nutrients (Soil pH and..., 2025). As a result, the efficiency of fertiliser use decreases by 20-40%, which increases production costs and reduces resource efficiency (Soil fertility models..., 2022).

The natural and climatic conditions of Polissia also determine the structure of agricultural production and the choice of economically viable crops. The most adapted are grain and leguminous crops (winter wheat, rye, triticale, maize), as well as crops traditional for the region – potatoes, flax, buckwheat, and fodder grasses. Under conditions of proper land reclamation and technological support, individual crops can provide a high level of yield, in particular maize – up to 10-12 t/ha. At the same time, the structure of production is gradually transforming from traditional specialisation to a more diversified model, which includes the expansion of areas under soybeans, rapeseed, and sunflower (Zosymchuk, 2022). Along with

natural limitations, the development of agricultural production is affected by the processes of resource base degradation. One of the characteristic features of the soils of the Polissia zone is the low humus content, which in light mineral soils is mostly 0.8-1.5%. Under conditions of intensive land use, annual humus losses due to mineralisation are estimated at 0.3-0.5 t/ha, which requires the compensation to maintain the initial level of soil fertility (One of the biggest..., 2018). These processes, combined with erosion phenomena and land drainage, lead to a decrease in the productive potential of agricultural landscapes.

Despite the above limitations, the region was experiencing positive dynamics in the development of agricultural production. Over the last decades, the yield of major agricultural crops increased, which is associated with the introduction of modern technologies, the use of new varieties and the development of land reclamation. In particular, the yield of grain crops increased by more than 40%, which was accompanied by an increase in production indicators despite existing natural limitations. At the same time, the increase in production volumes was accompanied by a change in the structure of crops and the expansion of the use of more productive crops. The dynamics of production was growing: the volume of agricultural production increased to UAH 258 billion in 2023, with the share of the Polissia zone accounting for about 10% of the total production in Ukraine, with a high specialisation in the production of individual crops, in particular oats and buckwheat. At the same time, despite the soil degradation processes, the region maintains a tendency to maintain the achieved levels of yield, which may be associated with the adaptation of agricultural production to existing resource constraints (Nechyporenko *et al*., 2025). Thus, agricultural production in the Polissia zone operates under conditions of a combination of natural constraints and gradual technological adaptation. The specifics of soil and climatic conditions, the degradation of the resource base and the transformation of the production structure determine the features of the formation of the resource potential of agricultural enterprises and necessitate the need to increase the efficiency of its use through the introduction of adaptive technologies, diversification of production and optimisation of land use.

Assessment of the efficiency of resource use of agricultural enterprises of the Polissia zone of Ukraine

The agricultural enterprise Galeks-Agro (n.d.) is an example of the formation and effective resource potential use in the conditions of the Polissia zone of Ukraine, based on the model of vertically integrated production. The enterprise functions as a comprehensive system that covers all stages of agricultural production – from the cultivation of organic crop and livestock products to the processing and sale to the end consumer on the principle of "from field to table". Such an organisation of activities ensures the closure of the production cycle, an increase in the level of added value and more efficient use of available resources. The enterprise's land resources constitute over 10 thousand hectares of agricultural land certified as organic. Production is carried out in the conditions of the Polissia zone, which is characterised by less fertile soils and increased humidity, which necessitates the adaptation of agricultural technologies. The specialisation of crop production is represented by the cultivation of grain and leguminous crops, in particular wheat (including spelt), rye, barley, oats, buckwheat, millet, maize, soybeans, as well as legumes (peas, beans, vetch). Fodder crops provide the internal needs of livestock farming, which indicates a rational combination of industries and the closure of resource flows. The livestock sector is represented by the breeding of Simmental cattle of the meat and dairy production. The total livestock population is about 4.7 thousand heads, of which approximately 1.7 thousand are dairy cows. The average annual productivity is about 7,000 litres of milk per cow, which corresponds to a high level of efficiency in the use of biological resources. The development of livestock farming is ensured by the presence of modern dairy complexes operating according to European standards, as well as its own feed base formed at the expense of crop production. The material and technical base of the enterprise includes production infrastructure that ensures

the implementation of basic technological processes in crop and livestock farming, in particular soil cultivation, sowing, harvesting and animal husbandry. It includes dairy farms, fattening complexes, an elevator with a capacity of about 12 thousand tonnes of storage, as well as processing enterprises. The presence of its own infrastructure ensures the possibility of implementing a full production cycle and reducing losses at individual stages of production.

A feature of the resource potential of Galeks-Agro (n.d.) is the development of processing, which allows transforming raw materials into products with high added value. The enterprise has its own dairy plant with a capacity of up to 30 tonnes per day, which produces over 120 types of organic dairy products, including the production of organic beef and pork, as well as a wide range of processed products, in particular sausage products (boiled, semi-smoked, raw smoked), sausage products, thick sausages, meat pâtés and lard products. Additionally, grain crops are processed into flour, cereals and other products, which indicates a deep integration of production processes and effective use of the raw material base. The enterprise's resource potential includes innovative and environmental elements that are implemented through organic production and the corresponding certification system. All products of the enterprise are certified in accordance with international standards of organic production: Regulation (EU) 2018/848 (2018), Bio Suisse (2023), which confirms compliance with environmental requirements and increases the competitiveness of products. The organic management model involves the rational use of land resources, preservation of soil fertility and minimisation of negative impact on the environment.

The economic results of the Galeks-Agro enterprise (n.d.) can be characterised using generalised financial indicators. In particular, in 2025, net revenue from sales of products amounted to UAH 417.8 million, and net profit – UAH 88.9 million, which exceeds the indicators of the same period of the previous year. The enterprise is partially focused on foreign markets, exporting organic products, in particular grain, cereals and flour. About 30% of the products produced are sold outside Ukraine, while the rest is used for internal processing and ensuring the production cycle. The main export destinations are the countries of the European Union (in particular, Germany, Switzerland, Italy, the Netherlands, the Czech Republic), as well as the USA and Canada, which indicates the integration of the enterprise into the international markets of organic products. Thus, the resource potential of Galeks-Agro is formed on the basis of a combination of land, material and technical, biological and innovative resources that operate within a vertically integrated production system. The state of efficiency of its use is characterised by ensuring a closed production cycle, a rational combination of crop and livestock industries, as well as the development of its own processing, which contributes to increasing the return on resources and reducing losses at individual stages of production. Additionally, the effectiveness of the resource potential use is manifested in the stable dynamics of production indicators, in particular livestock productivity and volumes of raw material processing, which reflects the adaptation of the enterprise to the natural and climatic conditions of the Polissia zone.

Ritter Bio Agro LLC (n.d.) is an agricultural enterprise operating within the Polissia zone of Ukraine (Rivne region, Goshchansky district) and specialising in organic crop production with an orientation towards external markets. The production activity of the enterprise is based on the use of land resources, which form the basis of its resource potential, and is characterised by the absence of a livestock direction, which determines a clear industry specialisation. The enterprise's land bank consists of about 3.8 thousand hectares of agricultural land located within the Rivne region. A significant part of the land (approximately 3.2 thousand hectares) is certified as organic, while about 600 hectares are in the transition period to organic production. This structure of land resources indicates the gradual expansion of the organic segment and the transformation of traditional agriculture in accordance with environmental requirements. The production specialisation of the enterprise is focused on growing grain, leguminous and oil crops. The basis of the sown areas is formed by wheat, maize, rye and buckwheat, which are

the basic crops for organic production in the conditions of Polissia. In addition, soybeans are grown as a representative of leguminous crops, as well as oil crops – sunflower and rapeseed. The structure of the enterprise's production includes niche and industrial crops, in particular buckwheat as an export-oriented organic product, as well as sugar beets, the cultivation of which in the organic segment is a relatively new direction for Ukraine. The crop structure is characterised by the dominance of grain crops with the inclusion of oil and niche crops in the crop rotation, which ensures compliance with the principles of organic farming. Organic production is a key component of the enterprise's resource potential. The company was operating in this segment since its foundation (2013) and is certified in accordance with international standards, in particular Organic Standard (n.d.), Naturland (n.d.) and Bio Suisse (2023). Products sold as organic are produced in compliance with the established requirements, which ensures access to external markets, primarily the countries of the European Union.

The material and technical base of the enterprise is formed in accordance with the scale of its activities and includes modern agricultural machinery necessary for soil cultivation, sowing and harvesting. Although open sources do not contain detailed information on specific technologies of precision agriculture, the scale of production and export orientation of the enterprise are consistent with the use of modern technological solutions, which is indirectly confirmed by the need for products to comply with the requirements of international quality standards and certification, in particular Regulation (EU) 2018/848 (2018), ISO 22000:2019 (2019), HACCP (2022). Infrastructure includes warehouses for storing products, while information on the availability of own elevator capacities in open sources is not detailed, which may indicate partial use of leased logistics infrastructure. Assessment of the effectiveness of the resource potential use can be partially illustrated by generalised financial indicators. In particular, in 2025, the company's revenue was about UAH 58 million, while a negative financial result was recorded (loss of more than UAH 10 million), which is accompanied by a decrease in profitability to -18.25%. At the same time, in the previous period (2024), the enterprise demonstrated positive financial results (profit of UAH 27.8 million, profitability of 23.87%), which indicates the variability of the efficiency of resource use depending on market and production conditions. Thus, the resource potential of Ritter Bio Agro LLC is formed mainly at the expense of land and material and technical resources with the dominance of the crop production specialisation and the lack of integration with livestock breeding and processing. The state of its use efficiency is characterised by an orientation towards organic production and export of products, a gradual expansion of certified areas, as well as the dependence of efficiency on external market conditions and crop structure. In order to assess the efficiency of the resource potential use of agricultural enterprises of the Polissia zone, a comparative analysis of the activities of Galeks-Agro and Ritter Bio Agro LLC was conducted using a system of relative indicators characterising the effectiveness of the use of land and labour resources. The results of the calculations are given in Table 1.

Table 1. Comparative assessment of the efficiency of using the resource potential of agricultural enterprises of the Polissia zone

Indicator	Galeks-Agro	Ritter Bio Agro LLC
Revenue per hectare, UAH/ha	41,780	2,902
Profit per hectare, UAH/ha	8,887	631
Profitability, %	21.27	21.73
Revenue per employee, UAH	1,530,392	196,927
Integral efficiency indicator	0.75	0.25

Source: calculated by the author based on Galeks-Agro (n.d.), Ritter Bio Agro LLC (n.d.)

Analysis of the indicators calculated in Table 1 according to formulas (1-6) enabled revealing differences in the effectiveness of using the resource potential of the studied enterprises. In particular, Galeks-Agro demonstrates significantly higher values of revenue and profit per hectare, UAH/ha, which indicates a more intensive use of land resources and a higher level of the economic return. Additionally, the enterprise is characterised by significantly higher labour productivity, which reflects a more efficient use of labour resources and a higher level of organisation of production processes. At the same time, the level of profitability of both enterprises is comparable (21.27% in Galeks-Agro and 21.73% in Ritter Bio Agro), which indicates a relatively close cost efficiency per unit of revenue received. This means that in terms of cost profitability, both enterprises operate in similar economic conditions, despite differences in the scale of activity and the level of resource availability. The value of the integral indicator for this enterprise is 0.75, while for Ritter Bio Agro it is 0.25, which indicates a higher level of generalised efficiency of resource potential use. The results obtained can be explained by differences in the scale of production, the level of diversification of activities and the availability of processing capacities. In particular, the integrated structure of Galeks-Agro, which combines crop production, livestock farming and processing, creates the prerequisites for the formation of added value and more efficient use of resources. In contrast, Ritter Bio Agro functions mainly as a producer of raw materials, which limits the possibilities of increasing the economic return on resource potential.

The analysis of the resource potential of agricultural enterprises in this study was formed taking into account military transformations, which determined its focus on identifying the features of resource use at the enterprise level and determining the possibilities of the restoration and adaptation to changed operating conditions. In this context, a comparison with H. Luo *et al.* (2025) reflects a difference in approaches to the interpretation of resources: if in this study the main attention is paid to the use under conditions of limitations and the need for restoration, then in the work by H. Luo *et al*., resources are considered as a factor in the formation of economic value within the framework of rural development policy. Common to both approaches is the orientation towards increasing the efficiency of resource use, but the difference lies in the focus of the study. Further comparison with S. Seifert *et al*. (2024) makes it possible to expand the understanding of the efficiency of resource use from the enterprise level to the level of agrolandscapes. In this study, the emphasis is on the analysis of production systems of specific enterprises and the ability to adapt to changes, while S. Seifert *et al.* investigate eco-efficiency within broader spatial systems using quantitative approaches. Thus, the difference lies in the scale of analysis and the level of generalisation of results.

Comparison with K.P. Pawłowski & G. Sołtysiak (2024) demonstrates a different nature of resource use constraints. In this study, these constraints are associated with wartime conditions and the transformation of the resource base, while in the aforementioned study, such constraints are associated with environmental policy and regulatory requirements. At the same time, both approaches combine the need to adapt agricultural production and find ways to increase resource efficiency. Comparison with Y. Yuan *et al.* (2025) makes it possible to shift the emphasis towards internal factors of increasing efficiency. In this study, attention is focused on the organisational features of resource use and various production models, in particular vertically integrated and specialised, while Y. Yuan *et al.* consider digitalisation as a key tool for increasing efficiency. The approach of considering resources as the basis for enterprise performance remains common.

Another approach is presented in the study by P.K. Sarangi *et al*. (2024), where resources are considered in the context of the reuse and the formation of closed production cycles. In this study, attention is focused on combining existing resources and increasing the efficiency of the use within enterprises, which differs from the approach focused on circularity. A comparison with C.J. Watson *et al.* (2024) summarises different approaches to resource analysis. While in this study the analysis is carried out at the level of individual enterprises and the

production models, C.J. Watson *et al.* consider the use of resources in a broader interdisciplinary context. Thus, the results of the study complement existing scientific approaches, specifying the features of the resource potential use at the level of agricultural enterprises of the Polissia zone and the adaptation to changed operating conditions. Thus, the analysis of the activities of the studied enterprises shows that the efficiency of the resource potential use in the conditions of the Polissia zone is largely determined by the model of production organisation. The vertically integrated Galeks-Agro model ensures a more complete and balanced use of land, biological and material and technical resources by combining industries and developing processing. In contrast, the specialised model of Ritter Bio Agro is characterised by an orientation towards organic crop production and external markets, which makes the effectiveness dependent on market conditions. The results obtained confirm that increasing the efficiency of resource potential use is associated not only with the volume of resources, but also with the level of the integration, the structure of production and the development of processing activities.

Directions of restoration and improvement of efficiency of use of resources in the post-war period

The conducted research enabled establishing that the formation and resource potential use of agricultural enterprises of the Polissia zone of Ukraine during the war period took place in conditions of significant limitations associated with the reduction of the resource base, the complication of production processes, the disruption of logistical connections and the increase in the risks of economic activity. The identified features of the functioning of the enterprises Galeks-Agro and Ritter Bio Agro indicate a different level of resistance to external influences, which determines a differentiated approach to determining directions of restoration and improvement of efficiency of use of resources in the post-war period. One of the directions is the restoration and optimisation of the use of land resources. In the conditions of the Polissia zone, where soils are characterised by increased acidity, low fertility and excessive humidity, increasing the efficiency of land use is associated with the introduction of adapted cultivation technologies, improving the agrochemical condition of soils and rationalising the structure of crops. For enterprises operating in the organic production segment, it is important to expand the area of certified land and complete the transition period for some land, which allows for an increase in the level of use of land potential and ensure the stability of production. The second direction is the development of the material and technical base and the modernisation of the production infrastructure. It was established that under the conditions of war-related impact, some enterprises suffered losses of equipment and restrictions in access to resources, which negatively affected the efficiency of production processes. In the post-war period, the renewal of the technical fleet, the introduction of modern technologies for soil cultivation, sowing and harvesting, as well as the development of warehouse and logistics infrastructure are relevant. For enterprises with a vertically integrated structure, such as Galeks-Agro, this also involves the support and modernisation of processing capacities, which ensure the formation of added value within the enterprise.

Increasing the efficiency of the use of labour resources and adapting production to weather conditions is one of the directions of recovery in the post-war period. A study of the activities of agricultural enterprises in the Zhytomyr region confirms the presence of practical limitations in the use of resource potential. In particular, during the harvesting process, difficulties are noted associated with adverse weather conditions, in particular excessive rainfall, which complicates field work. At the same time, one of the production factors is labour resources, the shortage of which significantly limits the efficiency of land potential use. The shortage of workers in combination with wartime conditions complicates the implementation of production operations and reduces the effectiveness of agricultural activities. In the post-war period, increasing the efficiency of labour potential use is associated with the automation of production processes, the introduction of digital management technologies and an increase in the level of mechanisation (RuportZT, 2023).

The next direction is the development of processing and increasing the level of integration of production. The analysis showed that vertically integrated enterprises have a higher level of efficiency in the resource potential use due to a closed production cycle and the formation of added value. In the post-war period, the development of processing infrastructure, in particular the production of dairy, meat and grain products, allows reducing dependence on external markets, increasing profitability and ensuring a more complete use of the raw material base. For specialised enterprises in the crop sector, the gradual expansion of participation in value-added chains is relevant, including through cooperation or partnership. Diversification of production and development of niche crops is one of the areas of recovery in the post-war period. In the production structure of enterprises in the Polissia zone, along with traditional crops, niche and technical crops are represented, which provide for the expansion of the possibilities of using land resources and sales markets. The development of such production helps reduce the risks associated with fluctuations in yields and price conditions.

A separate area is increasing the efficiency of resource use through the development of export activities and logistics. Enterprises focused on external markets face significant logistical constraints and dependence on a limited number of sales markets. In particular, about 60% of exporters of organic products experience difficulties in transportation, especially at border crossings, and 45% of enterprises depend on 2-3 main markets, which increases the risks of the activities. Additionally, 29% of producers noted increased competition in international markets, and 28% – increased requirements for product quality. In these conditions, increasing the efficiency of resource potential use is associated with the optimisation of logistics chains, diversification of sales markets, as well as improving product quality in accordance with international standards (The main challenges..., 2025). Increasing the efficiency of resource potential use takes into account the implementation of innovative and environmental approaches. The development of organic production, compliance with international quality standards and the use of modern technologies contribute to increasing the competitiveness of products and the efficiency of resource use. In the post-war period, the innovative transformation of the agricultural sector is one of the key factors in its restoration and development. Thus, increasing the efficiency of using the resource potential of agricultural enterprises in the Polissia zone in the post-war period is associated with the comprehensive implementation of measures covering the restoration of land resources, modernisation of the material and technical base, development of labour potential, adaptation of production to natural and climatic conditions, expansion of processing, diversification of activities and improvement of logistics. This creates the prerequisites for increasing the efficiency of resource use and ensuring sustainable development of the agricultural sector.

The analysis of the resource potential of agricultural enterprises in this study was formed under the influence of war losses, which determined its focus on restoring production capabilities and adapting to the limitations of the resource base. In this context, a comparison with the work by Y. Li *et al.* (2024) made it possible to expand the vision of efficiency factors: if in this study the restoration of resources remained key, then Y. Li *et al.* associated increased efficiency with technological innovations and the diffusion through patent activity. Thus, both approaches overlapped in the systemic understanding of agricultural production, but diverged in determining the sources of its development. This difference in the interpretation of resources was even more pronounced when compared with the work by S. Wunder *et al.* (2025), where resources were interpreted as natural capital that can be included in market mechanisms through biodiversity credits. If this study was about restoring the production potential of enterprises, then in the work by S. Wunder *et al.*, the emphasis shifted to the economic assessment and preservation of natural systems. The common orientation remained the efficiency of resource use, but the tools for achieving it differed significantly.

Further comparison with L. Biagini *et al.* (2026) logically transferred the analysis to the plane of resource interaction. In this study,

efficiency was considered as the restoration of lost opportunities, while L. Biagini *et al.* analysed it through the relationships between food, water, energy and environmental components, identifying trade-offs between these components. This means a transition from a regenerative logic to assessing the balance of the resource system. Another perspective was presented in the study by M.R. Marcone (2025), where efficiency was formed not only at the level of enterprise resources, but also through interaction within supply chains. While this study focused on internal constraints and the overcoming, M.R. Marcone considered interorganisational connections as a factor in the transformation of the agricultural sector. Thus, the systematic nature of the analysis was maintained, but the level of its implementation changed. Comparison with A. Muska *et al.* (2025) made it possible to expand the scope of the study to the inter-country level. While this study assessed the resource potential of enterprises in a specific region, A. Muska *et al.* analysed the "green competitiveness" of EU countries based on integrated environmental indicators. This emphasised a common focus on resource efficiency, but demonstrated different levels of generalisation and methodological approaches. Comparison with A. Serrano *et al.* (2024) made it possible to summarise the difference between approaches to changes in the resource base. While this study focused on its reduction and restoration due to war-related impact, A. Serrano *et al.* analysed the opposite process – the expansion and intensification of resource use through the development of irrigation, which formed regional specialisation and production growth.

The disruption of the functioning of agricultural enterprises in this study was associated with military losses of resources, which determined its focus on the analysis of internal resource potential and opportunities for the restoration of production. In this context, a comparison with J. Du *et al.* (2024) demonstrated a shift in focus from internal transformations to external economic processes: the authors studied the efficiency and potential of China's agricultural exports using econometric models. Despite the difference in objects, both approaches combined multifactor analysis and took into account the structural heterogeneity of the agricultural sector, although methodologically both approaches were implemented through different tools – from structural analysis to modelling of trade flows. Further comparison with the study by M.-L. Huang *et al.* (2025) made it possible to trace the transition from problems of restoration to assessing the efficiency of resource use in a broader systemic dimension. If in this study resource losses determined the logic of adaptation of agricultural production, then in the work by M.-L. Huang *et al.*, the efficiency was analysed through the concept of "food – energy – water" using quantitative models, which reflected a different level of generalisation and different research tools.

This difference in approaches was even more clearly manifested when compared with Y. Chen *et al.* (2024), where the agricultural sector was considered as a system of sustainable development through the Driver – Pressure – State – Impact – Response model. While this study focused on the restoration of the resource base after losses, Y. Chen *et al.* in the study assessed the state and dynamics of sustainability based on an indicator approach. Both studies combined a systemic vision of agricultural production, but the analytical goals differed: restoration versus sustainability assessment. A logical continuation of this line of comparison was the analysis of A. Saxena *et al.* (2024), where the emphasis was shifted to the technological transformation of the agricultural sector. In contrast to this study, which described adaptation to resource constraints, A. Saxena *et al.* considered tools for increasing efficiency through digital technologies and the Internet of Things. At the same time, the common focus remained on optimising resource use, although the context of the application differed significantly. A similar trend was observed in the study by C. Che *et al.* (2024), where digitalisation was considered as a factor in increasing agricultural eco-efficiency. While in this study, efficiency was limited to military losses and degradation of the resource base, C. Che *et al.* analysed the positive impact of the development of the digital economy using econometric models. Thus, the common focus on efficiency was combined with

a different economic environment of operation. Comparing this study with the work of B. Liao *et al.* (2025) made it possible to expand the context to the level of integration of energy and agriculture. In this case, the studies were close in terms of the systemic approach and consideration of resource relationships, but differed in the focus: this study focused on restoring production potential, while the work by B. Liao *et al.* – on the development of "PV+" models and increasing the efficiency of land use in the context of energy transition.

During the war period, the functioning of agricultural enterprises in the Polissia zone was accompanied by a limitation of the resource base, the complication of production processes and the disruption of logistical connections, which affected the efficiency of resource potential use. The study showed that the adaptation of enterprises occurred through changes in organisational and production models, the development of the material and technical base, the improvement of logistics and the expansion of processing activities. It was established that the impact of war factors was differentiated: for vertically integrated enterprises this was manifested in the transformation of the production structure and the maintenance of a closed cycle, while for specialised enterprises – in increased dependence on external markets and logistical restrictions. In the post-war period, increasing the efficiency of resource use is associated with the restoration and optimisation of land use, modernisation of the material and technical base, development of processing, diversification of production, improvement of logistics, and the implementation of innovative and digital solutions.

CONCLUSIONS

The study showed that the efficiency of using the resource potential of agricultural enterprises of the Polissia zone of Ukraine in 2021-2025 was formed under the influence of natural and climatic constraints and military transformations, which led to changes in the structure of production, resource supply and financial results. In particular, the functioning of enterprises in the region takes place in conditions of low natural fertility of soils, characterised by increased acidity (pH 4-5.5), low humus content (0.8-1.5%) and its annual losses at the level of 0.3-0.5 t/ha, which limits the efficiency of using land resources and requires additional costs to maintain the productivity. Despite these limitations, positive dynamics of agricultural production are observed in the region. In particular, the yield of grain crops increased by more than 40%, and production volumes increased to UAH 258 billion in 2023, which indicates the adaptation of the agricultural sector to existing resource constraints and a gradual increase in the efficiency of using resource potential.

At the enterprise level, it was found that the efficiency of resource potential use significantly depends on the production organisation model. In particular, Galeks-Agro, which cultivates over 10 thousand hectares of land, demonstrates higher efficiency indicators: revenue is UAH 417.8 million, net profit is UAH 88.9 million, which corresponds to UAH 41,780 of revenue and UAH 8,887 of profit per hectare, UAH/ha. Labour productivity is UAH 1,530,392 per employee. At the same time, Ritter Bio Agro LLC with a land bank of 3.8 thousand hectares is characterised by significantly lower indicators of resource use intensity: revenue per 1 ha is UAH 2,902, profit is UAH 631, and labour productivity is UAH 196,927 per employee. Calculation of the integral indicator of resource potential use efficiency confirmed these differences: its value is 0.75 for Galeks-Agro and 0.25 for Ritter Bio Agro. This indicates a higher level of generalised efficiency of resource use in enterprises with a vertically integrated production model. At the same time, a comparable level of profitability (21.27% and 21.73%, respectively) indicates a similar cost efficiency, which indicates the influence of external market conditions on the results of enterprises. The generalisation of the results shows that increasing the efficiency of resource potential use in the conditions of the Polissia zone is associated not only with the volume of resources, but also with the level of the integration, diversification of production and development of processing. In the post-war period, the key areas are land use optimisation, modernisation of the material and technical base, development of logistics and export diversification, which creates the prerequisites for

increasing the effectiveness of the functioning of agricultural enterprises.

The limitation of the study is the limited access to complete and representative statistical data in a regional context, which is due to war conditions and partial loss of information on the functioning of agricultural enterprises. Prospects for further research are related to expanding the analytical base through the use of micro-level data from enterprises, as well as the use of economic and mathematical modelling to assess the efficiency of resource use and predict scenarios for the recovery of the agricultural sector.

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CONFLICT OF INTEREST

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Стан ефективності використання та перспективи відновлення ресурсного потенціалу аграрних підприємств Поліської зони України у післявоєнний період

Анотація. Метою даного дослідження було визначення особливостей формування та результативності використання ресурсного потенціалу аграрних підприємств Поліської зони України в умовах воєнних трансформацій. Методологія дослідження ґрунтувалася на застосуванні описово-статистичного, структурного, динамічного та порівняльного аналізу, а також методу кейс-стаді на прикладі підприємств Galeks-Agro та Товариство з обмеженою відповідальністю «Ріттер Біо Агро». У результаті дослідження встановлено, що природно-кліматичні умови Полісся обмежували ефективність використання ресурсів: рівень pH ґрунтів становив 4-5,5, вміст гумусу – 0,8-1,5 %, а щорічні втрати – 0,3-0,5 тонн/гектар. Водночас виявлено зростання урожайності зернових культур більш ніж на 40 % та збільшення обсягів виробництва до 258 млрд грн у 2023 році, що може свідчити про адаптацію. Порівняльний аналіз підприємств показав суттєві відмінності в ефективності: у Galeks-Agro дохід на 1 гектар становив 41 780 грн, прибуток – 8887 грн, продуктивність праці – 1 530 392 грн/працівника, інтегральний показник – 0,75. У ТОВ «Ріттер Біо Агро» дохід на 1 гектар становив 2902 грн, прибуток на 1 га – 631 грн, продуктивність праці – 196 927 грн на одного працівника, інтегральний показник ефективності – 0,25. Водночас близькі значення рентабельності (21,27 % та 21,73 %) свідчать про подібну ефективність витрат, тоді як відмінності в загальних результатах зумовлені масштабами та інтенсивністю використання ресурсів. У післявоєнний період підвищення результативності використання ресурсного потенціалу пов'язується з оптимізацією землекористування, модернізацією матеріально-технічної бази, розвитком переробки, диверсифікацією виробництва та удосконаленням логістики й експортної діяльності. Практичне значення дослідження полягає в можливості використання отриманих результатів і обґрунтованих підходів для підвищення ефективності використання ресурсного потенціалу та формування управлінських рішень щодо відновлення діяльності аграрних підприємств у післявоєнний період

Ключові слова: продуктивність; землекористування; врожайність; диверсифікація; цифровізація; рентабельність

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Labour motivation in agricultural enterprises: Theoretical foundations and the state of development in Ukraine

Abstract. The relevance of this study stems from the fact that, despite the decisive role of motivation in ensuring labour productivity and socio-economic stability in rural areas, its level at Ukrainian agricultural enterprises remains low due to insufficient remuneration, seasonal work, and unstable employment. The aim of the study was to analyse the relationship between wages and employment in the agricultural sector of the economy and to determine the significance of economic and non-economic factors in employee motivation. The study employed structural and comparative methods, as well as statistical analysis. The research demonstrated that the components of labour motivation include incentives and interests, which may be influenced by employers or the state in order to motivate employees. At the same time, incentives may be both material and non-material. The approaches of various scholars to the study of labour motivation were also examined. An analysis of wage dynamics showed that during 1995-2024, nominal wages in agricultural enterprises increased by more than 120 times, while real wages rose by 9.7 times, indicating an improvement in material working conditions. Nevertheless, the wages of agricultural workers remained below the national average: in 1995 the gap amounted to -30%, while by 2024 it had narrowed to -16%. In the field of employment, a steady downward trend was observed: the share of employees in the agricultural sector within the overall employment structure decreased by 20.3%, driven by technological modernisation, seasonality, and demographic changes in rural areas. At the same time, the trends observed in the agricultural sector were more favourable compared with other sectors, namely construction and industry. Overall, the findings indicate that, despite improvements in financial and social conditions, labour motivation requires a comprehensive approach combining economic, social, and psychological factors. The obtained results are of practical significance for the development of

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effective motivational mechanisms capable not only of increasing labour productivity but also of ensuring the sustainable socio-economic development of Ukraine's rural areas

Keywords: wages; employment; unemployment; agricultural sector of the economy; incentives; labour efficiency

INTRODUCTION

The relevance of the study is determined by the need to identify effective mechanisms of labour motivation in Ukraine's agricultural sector, which is characterised by low wage levels, seasonal production, and a high dependence of outcomes on natural, climatic, and market factors. Under current conditions of increasing competition for labour resources and growing migration processes, it is important to establish a comprehensive motivational system combining economic, social, and psychological factors influencing employees. In addition, the development of market relations, Ukraine's integration into the global economic environment, and the introduction of innovative technologies in agriculture impose new requirements on personnel management, particularly regarding approaches to labour incentives. Effective staff motivation is becoming a key factor in increasing labour productivity, strengthening enterprise competitiveness, and ensuring sustainable development. Thus, the study of labour motivation mechanisms in agricultural enterprises is timely and carries significant theoretical and practical importance for improving human resource management systems under modern economic challenges. The issue of labour motivation is of particular relevance within the context of strategic management in agribusiness. Modern agricultural enterprises operate under conditions of intensified competition in the labour market, the introduction of digital technologies, and the automation of production processes, all of which transform the requirements for personnel management. The establishment of effective motivational mechanisms is becoming an integral component of agribusiness strategy, as the level of employee engagement and productivity directly determines the competitiveness of an enterprise and its ability to adapt to market changes.

Z. Lyschenko (2024) investigated the motivational aspect of human resource management in agricultural enterprises. It was found that effective motivation helps to overcome difficulties and adapt to changes, particularly climatic, market and personnel-related ones. A.V. Herasymenko (2023) investigated the influence of socio-economic motivational factors on labour productivity within an effective agribusiness system. It was noted that labour productivity in Ukrainian agriculture is showing positive growth: in 2020, livestock production volumes exceeded those of crop production. However, wage growth is outpacing labour productivity growth, which may negatively impact the sector's economic potential. A.D. Chikurkova & Yu.M. Hray (2020) investigated improvements in the development of motivational policies at agricultural enterprises. They drew attention to the role of the individual and intellect in the economy, and consequently, to labour motivation. At the same time, the approach of enterprises and the state to this issue is often ineffective, resulting in a decline in the effectiveness of measures aimed at labour motivation. The researchers consider the study of factors influencing labour motivation in the agricultural sector to be particularly relevant. O.M. Bachynska (2024) assessed improvements in staff motivation methods. She noted that increased motivation contributes to the achievement of strategic goals and strengthens competitiveness in the market, helping to attract skilled workers and increase employee loyalty. K.A. Tkachenko & G.M. Kopteva (2023) demonstrated that a successful motivation system must be flexible, differentiated and tailored to the individual needs of employees, which vary depending on their stage of life, professional level and personal values. They also noted that in the current context of digitalisation and the intellectualisation of work, incentive systems must be based on knowledge, innovation and the development of employees' creative potential.

L.I. Zastavnyuk (2022) studied staff motivation as a factor in enhancing a company's competitiveness. The author noted that a company's

competitiveness depends on the level of motivation among its staff, as it is motivated employees who ensure the effective functioning and development of the organisation. An effective motivation system increases labour productivity, facilitates the realisation of employees' labour potential and provides competitive advantages. To enhance the effective utilisation of human potential, it is necessary to develop a company policy aimed at motivating staff. O.S. Mykhaylova *et al.* (2020) studied the use of software products to enhance work motivation in the dairy cattle sector. The researchers noted that to enhance the motivational impact on staff at dairy farms, a combination of material and non-material incentives is required, which will ensure a sustained motivational impact on production outcomes. It was proposed to create an organisational and economic mechanism for fostering employee motivation, based on the evaluation of specific motivational tools according to defined criteria and levels of their implementation.

Previous studies, despite a thorough analysis of motivational factors in agriculture, have mainly focused on individual aspects – economic or organisational – whilst neglecting the complex influence of social and psychological factors. Furthermore, the relationship between wage levels, employment and labour productivity in the agricultural sector of the economy has not been sufficiently investigated. The aim of this study was to identify patterns in the influence of wage levels on employment and unemployment indicators. To achieve this aim, the following objectives were set: to conduct an empirical analysis of the relationship between wage levels, unemployment and employment; to assess the effectiveness of economic factors in stimulating labour activity among agricultural workers; and to summarise theoretical approaches to the role of social and psychological factors in labour motivation.

MATERIALS AND METHODS

The study employed a structural method to analyse the internal structure of phenomena related to labour motivation. In particular, it was applied to study the structure of the motivation system, namely the relationship between material and non-material incentives and their functions in labour behaviour, as well as the classification of incentives by type (material/non-material, individual/collective, internal/external). Various approaches to labour motivation by scholars such as A. Smith (1776), A.H. Maslow (1954) and D. McGregor (1960) were also examined. Attention was also paid to the theories of motivation developed by F. Herzberg *et al.* (1959), V. Vroom (1964) and J.S. Adams (1965). The period used for the analysis was 1995-2024; at the time of writing, data for this period alone were available for analysis. For the level of employment in the agricultural sector of the economy, the period was from 2000 to 2021 due to the lack of relevant information on the website of the State Statistics Service of Ukraine (Ukrstat, n.d.) for the period after 2021 (following the outbreak of the war, the State Statistics Service of Ukraine began publishing less information freely available), which ceased publishing separate data from 2022 onwards due to the start of Russia's full-scale invasion. Data from 2022 onwards is presented excluding information from the temporarily occupied territories. Based on data regarding the number of employed persons, the figures for 2024 have been estimated, taking into account demographic changes resulting from the Russian-Ukrainian war.

As part of the study, a statistical analysis was conducted of indicators characterising wages and employment levels in Ukraine as a whole and in the agricultural sector of the economy in particular. The study analysed the level of employment in the agricultural sector, the dynamics of real wages in Ukraine and in specific sectors – agriculture, industry and construction – as well as the difference and ratio between wages in the agricultural sector and the national average and other sectors. Real wages were calculated from nominal wages, adjusted for inflation, based on data from the State Statistics Service of Ukraine (Ukrstat, n.d.). The approach to calculating real wages is shown in formula (1):

$$w_{r_N} = \frac{w_{n_N}}{I_N}, \quad (1)$$

where w_{rN} – the real wage level in period N; w_{nN} – the nominal wage level in period N; I_N – the cumulative inflation rate in period N. The initial value was the wage for 1995, whilst all other

values were adjusted for the cumulative inflation rate, calculated as the product of all inflation rates in the current and previous years (up to and including 1996). The ratio of the sector's average wage to the national average was calculated as the ratio of the sector's average wage to the national average wage, minus one, as shown in the formula (2):

$$w_{AT} = (\frac{w_T}{w_A} - 1) \times 100\%, \quad (2)$$

where w_{AT} – the ratio of the sector's wage level to the national average wage for the period; w_A – the sector's average wage level for the period; w_T – the level of the average wage in Ukraine during the period.

This indicator was assessed dynamically, as was the change in the employment level. A comparison of the data for these two indicators was used to evaluate the influence of the economic component on employee motivation. Within the framework of the study, the change in the ratio of wage levels in the sector was also calculated by comparing the values for 2024 and 2000. This was carried out using formula (3):

$$w_{\Delta} = \frac{w_{AT2024} - w_{AT2000}}{w_{AT2000}} \times 100\%, \quad (3)$$

where w_{Δ} – the indicator of change in the ratio of wage levels in the sector; w_{AT2024} – the ratio of the wage level in the sector to the average wage level in 2024; w_{AT2000} – the ratio of the wage level in the sector to the average wage level in 2000.

A comparative method was also used to analyse differences and dynamics in the key indicators of labour motivation across various sectors of the economy (agriculture, industry, and construction). This method was applied to compare nominal and real wage levels, deviations of sectoral wages from the national average, the dynamics of employed persons and their share within the structure of the economy, as well as the relationship between changes in wages and changes in the share of employees in the selected sectors.

RESULTS

Labour motivation is one of the key components of the personnel management system, as it determines the effective utilisation of labour potential and directly influences the results of the enterprise's activities (Poór *et al.*, 2025). It represents a combination of internal and external incentives for work that determine an employee's behaviour, the form, direction and intensity of their work, thereby directly influencing the enterprise's performance. In agricultural enterprises, the application of work motivation theories requires consideration of sector-specific factors that influence the effectiveness of staff incentives (Kanas & Steinmetz, 2021). Due to seasonality and the low capital intensity of the agricultural sector, wage levels here are lower than in industry or the information technology sector; therefore, financial incentives alone are insufficient. A comprehensive approach combining material and non-material motivators is required. The seasonal nature of the work leads to uneven workloads and the risk of underemployment, which requires flexible incentive systems – short-term contracts, seasonal bonuses, performance-related bonuses for production cycles, and social support (Manoharan *et al.*, 2023a). It is also important to retain skilled staff capable of working with machinery and natural resources. As results depend on external factors (weather, soil, prices), the link between workers' efforts and outcomes is weak. Thus, collective motivation based on shared responsibility is effective, as is the development of non-material incentives – a sense of belonging, professional pride, stability and opportunities for development (Johari & Jha, 2020; Westerman, 2020).

Theories of work motivation distinguish between incentives and interests. Incentives are material or non-material factors used by an organisation to influence employees' work behaviour with the aim of increasing their productivity and the efficiency of economic activity. An employee's interests, in turn, represent the sum of their needs, values and expectations, which determine their motivation to work and their level of engagement in work activities. These encompass material, social, psychological and professional development interests. Incentives are classified according to several criteria. By nature of their impact, they are divided into material (monetary and non-monetary) and non-material. Material monetary incentives include wages,

bonuses, allowances and profit-sharing. Material non-monetary incentives include benefits packages, perks, housing, meals and insurance. Non-material incentives include recognition, praise, career progression, professional training and improved working conditions. By level of application, a distinction is made between individual incentives (personal bonuses, pay rises), collective incentives (team bonuses, shared profit-sharing) and organisational incentives (corporate programmes). Based on the source of motivation, a distinction is made between external (extrinsic) incentives, which are based on material rewards and social guarantees, and internal (intrinsic) incentives, which are linked to job satisfaction, self-fulfilment and a sense of the significance of one's work (Ghasemi & Shakerian, 2025).

An employee's interests form the basis of their intrinsic motivation, influence their perception of incentives and determine their behavioural guidelines, in particular their drive for performance, willingness to take on responsibility and long-term loyalty to their employer. In agricultural enterprises, labour motivation is characterised by seasonality, high levels of physical exertion, and the dependence of work outcomes on natural and climatic conditions and fluctuations in agricultural market conditions. Consequently, the development of an effective labour motivation mechanism in agricultural enterprises has not only an economic but also a social dimension, as it concerns ensuring a decent standard of living for workers and the stable development of rural areas. The theoretical and methodological foundations of labour motivation have evolved through the development of economic thought and socio-psychological approaches. Classical economics, as exemplified by the work of A. Smith (1776), linked motivation primarily to material incentives and wages; however, this approach did not take into account the psychological and social multidimensionality of labour behaviour. Further development was driven by humanistic concepts, notably A.H. Maslow's hierarchy of needs (1954), the models of D. McGregor (1960) and F. Herzberg *et al.* (1959), which emphasised the importance of non-material incentives and intrinsic needs. Contemporary approaches integrate economic, behavioural and social factors, drawing on V. Vroom's expectancy theory (1964), J.S. Adams' equity theory (1965) and B.F. Skinner's reinforcement model (1953). The evolution of ideas about motivation reflects a shift from a purely materialistic to a comprehensive understanding of labour activity, encompassing interests, values, social ties and the need for self-actualisation.

The methodology for studying labour motivation in agriculture combines economic, sociological and psychological approaches (Xu *et al.,* 2022). The economic approach focuses on wages, bonuses and social security, establishing a direct link between work outcomes and remuneration whilst accounting for seasonality and collective forms of incentives (Nikolova & Cnossen, 2020; Manoharan *et al*., 2023b). The sociological approach views motivation as a result of social relations, norms and values, emphasising the importance of collective culture, trust and team spirit (McCollum & Findlay, 2019; Hyggen & Vedeler, 2021). The psychological approach focuses on internal behavioural factors – needs, values, recognition, development and comfort – taking into account the individual characteristics of employees. Such a comprehensive approach enhances emotional engagement, professional pride and resilience to seasonal challenges. Table 1 summarises the key features of these approaches.

Table 1. Approaches to understanding labour motivation

Approach to labour motivation	Examples of incentives in the agricultural sector	Purpose / effect on the employee
Economic	Wages, performance-related bonuses, incentives for exceeding targets, profit-sharing schemes (for managers), and social guarantees (insurance, housing, meals)	Increase in labour productivity, stimulation of performance through material rewards, and income stability
Social	Recognition within the team, support from colleagues and management, corporate events, development of team spirit, and participation in community life	Strengthening loyalty, cohesion, and a sense of belonging, as well as enhancing social stability

Table 1, Continued

Approach to labour motivation	Examples of incentives in the agricultural sector	Purpose / effect on the employee
Psychological	Opportunities to influence processes, recognition of achievements, professional development, training, self-realisation, and a sense of the significance of one's work	Enhancement of intrinsic motivation, emotional engagement, independence and responsibility, and satisfaction with work and its results

Source: compiled by the authors based on D. McCollum & A. Findlay (2019), M. Nikolova & F. Cnossen (2020), C. Schultz *et al.* (2020), C. Hyggen & J.S. Vedeler (2021), Y. Xu *et al.* (2022), K. Manoharan *et al.* (2023b)

As shown in Table 1, an effective motivational system in the agricultural sector requires an integrated approach combining economic, social, and psychological incentives. Economic instruments ensure employees' material interest and income stability, social incentives contribute to strengthening the workforce, loyalty, and social cohesion, while psychological incentives satisfy employees' internal needs, increase their emotional engagement, and enhance their sense of the significance of work. Thus, labour motivation in agricultural enterprises has a comprehensive nature and should be based on a combination of material and non-material incentives, the provision of social protection for employees, and the creation of conditions that increase the prestige of agricultural work. In Ukraine, the formation of a modern labour motivation system in agricultural enterprises remains at a stage of development characterised by the search for optimal incentive mechanisms capable of simultaneously ensuring production efficiency and improving employees' welfare.

From the perspective of strategic management in agricultural enterprises, an effective labour motivation system is not merely an instrument of personnel policy but also a key element of the overall entrepreneurial strategy. Agricultural enterprises implementing innovative approaches to employee incentives – including flexible wage systems linked to production cycle outcomes, competency development programmes, and employee participation in managerial decision-making – demonstrate greater adaptability to market fluctuations. The digitalisation of agricultural production and the implementation of precision farming are transforming the structure of labour functions, increasing the share of intellectual and technologically complex work, which requires a revision of traditional motivational models towards strengthening non-material and developmental incentives. Consequently, the management of labour motivation in modern agricultural enterprises is both an operational management task and an element of an innovative entrepreneurial strategy.

Given the key role of material motivation in shaping employees' labour activity, particular attention should be paid to the analysis of wages as the principal economic incentive. In the context of Ukraine, wage levels and their structural characteristics vary significantly across sectors and regions, which affects employees' perceptions of financial incentives and, consequently, their motivation and productivity. Agriculture is characterised by lower average wages compared with industry or the service sector, as well as by high seasonality and the dependence of income on natural, climatic, and market factors. This necessitates a statistical analysis of wage levels, their dynamics, and structural characteristics both nationally and within the agricultural sector in particular. Figure 1 presents nominal wages in Ukraine during the period 1995-2024 overall, as well as specifically in the agricultural sector, industry, and construction. As shown in Figure 1, the average wage in Ukraine during 1995-2024 increased hyperbolically. In 1995, the highest-paid sector was construction, while the lowest-paid was agriculture. During this period, wages in the agricultural sector increased from UAH 52 to UAH 18,012; in construction from UAH 103 to UAH 16,928; in industry from UAH 89 to UAH 23,150; while the national average wage increased from UAH 73 to UAH 21,473. The overall trend is characterised by steady growth with temporary slowdowns associated with the

financial crisis of 2008-2009, the COVID-19 pandemic, and the full-scale invasion in 2022. Despite the overall increase in nominal incomes, the agricultural sector remained throughout the entire period the sector with the lowest-paid labour, indicating the persistence of a significant wage gap between agriculture and the more capital-intensive sectors of the economy. An assessment of real wages during this period is presented in Figure 2, based on formula (1):

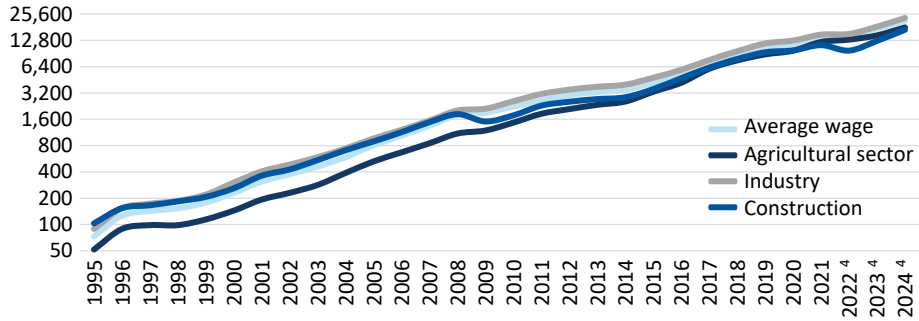

Figure 1. Dynamics of the average nominal wage in Ukraine by main sectors of the economy, 1995-2024, UAH

Note: [4] – excluding information from temporarily occupied territories

Source: compiled by the authors based on data from Ukrstat (n.d.)

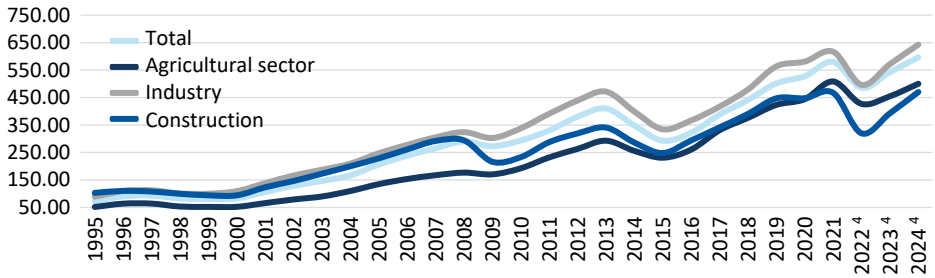

Figure 2. Real average wages in Ukraine by sector, 1995-2024, UAH

Note: [4] – excluding information from temporarily occupied territories

Source: compiled by the authors based on data from Ukrstat (n.d.)

The data presented in Figure 2 provide a clearer understanding of the extent to which each sector became better remunerated. Thus, the average real wage in Ukraine increased by 8.2 times, in industry by 7.2 times, in construction by 4.6 times, while in agriculture it increased by 9.7 times. The overall upward trend changed only in 2009 (a decline in the overall real wage by 6%, in the agricultural sector by 4%, in industry by 7%, and in construction by 27%) and in 2014-2015 (a decline in the overall real wage by 16%, in the agricultural sector by 10%, in industry by 16%, and in construction by 13%): in the first case, this was related to the global financial crisis, while in the second case it was associated with the occupation of Crimea and part of Donbas. Thus, although the average wage in agriculture in Ukraine remains below the national average wage, a positive trend can be observed in terms of the convergence of agricultural wages towards the national average. It should be noted that among the selected sectors, such a trend is observed only in the agricultural sector of the economy. It is also worth considering the indicator showing the extent to which wages in agricultural enterprises differ from the average wage in the country. Its dynamics are presented in Figure 3, calculated on the basis of formula (2):

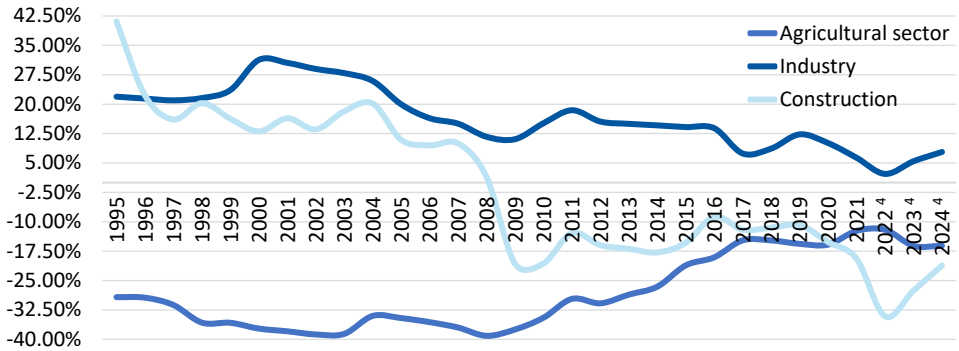

Figure 3. Deviation of the real average wage by sector from the national average in Ukraine, 1995-2024

Note: [4] – excluding information from temporarily occupied territories

Source: compiled by the authors based on data from Ukrstat (n.d.)

As can be seen from Figure 3, the gap between the average wage in the agricultural sector and the overall average wage narrowed from -30% to -16%, whilst in industry and construction it widened from 22% to 8% and from 41% to -21% respectively. A significant decline in construction occurred in 2008-2009 (from 1.44% to -20.72%), which was linked to the global financial crisis. The agricultural sector of the economy, on the other hand, began to grow from that point onwards. Another metric characterising labour motivation in agricultural enterprises is the level of employment in the real economy sectors. Thus, the absolute figures for the number of employed persons are shown in Figure 4:

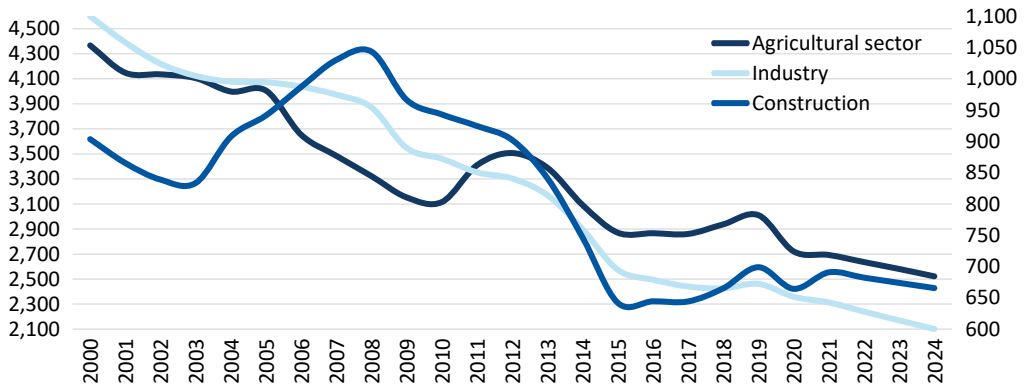

Figure 4. Dynamics of the number of employed persons in selected sectors of the Ukrainian economy during the period 2000-2021, thousand persons

Note: values for the construction sector correspond to the scale on the right-hand side, whereas values for the agricultural and industrial sectors correspond to the scale on the left-hand side

Source: compiled by the authors based on data from Ukrstat (n.d.)

As can be seen from Figure 4, the number of employed persons in Ukraine gradually declined in each of the sectors. In the agricultural sector, employment decreased from 4,367 thousand persons to 2,692.7 thousand persons (by 38.3%); in industry, from 4,598.3 thousand persons to 2,313.2 thousand persons (by 49.7%); and in construction from 903.6 thousand persons to 690.8 thousand persons during the period from 2000 to 2021 (by 23.6%). Nevertheless, this was largely

associated with the decline in Ukraine's overall population. The working-age population decreased by 4,565 thousand persons, or 23.6%. At the same time, the total population decreased by 5,258.06 thousand persons, or 10.61%. This indicates that the majority of the population decline involved economically active individuals, which may be associated with labour migration abroad. However, there are other explanations for this phenomenon, including technological development and automation, as well as structural changes in the economy (an increasing role of the service sector). Information for 2022, 2023, and 2024 is unavailable due to the limited release of statistical data by the State Statistics Service of Ukraine. Nevertheless, there are estimates regarding the overall population decline and general trends in these sectors, on the basis of which forecasts for 2022-2024 were made. According to these forecasts, the number of employed persons in the agricultural sector decreased by 20% during 2021-2024, in industry by 27.7%, and in construction by 30%. However, a more detailed analysis of these data will only be possible if official statistics are published by the State Statistics Service after the end of the full-scale invasion.

Thus, it is also worth considering the share of employed persons in each sector relative to the total number of employed persons during the analysed period. The share of employment in all three sectors generally declined, although the rates of decline differed, with the highest decline observed in industry. The share of employment in industry decreased from almost 23% to 14.8%; in the agricultural sector from 21.6% to 17.2%; while the situation in construction remained more stable, with 4-5% of all employed persons in the country working in this sector annually. This decline is associated not only with the overall decrease in the country's population but also with the reorientation of the economy towards the tertiary sector, which generally offers higher wages to employees. According to forecast data for the period 2022-2024, the share of employment in the agricultural sector decreased from 17.2% to 16.1%; in industry from 14.8% to 12.5%; and in construction from 4.4% to 3.6%. Data on employment shares were calculated on the basis of employment figures in each sector (Figure 4) and the total number of employed persons; all information was obtained from the official website of Ukrstat (n.d.). Although official data are unavailable, an increase in the share of employment would likely have occurred in the defence sector (due to an increase in the number of military personnel). The role played by changes in wages in such trends can be assessed by comparing changes in the share of employment with changes in the difference between average wages in the sectors and the national average. These data are presented in Table 2:

Table 2. Comparison of indicators of changes in the share of employment and the average wage

Indicator	Change in the share of employment	Change in the ratio of the sector's average wage to the national average wage
Agricultural sector	-25.6%	56.72%
Industry	-45.0%	-75.05%
Construction	-19.6%	-262.27%

Note: calculated on the basis of formula (2) and formula (3)
Source: compiled by the authors based on data from Ukrstat (n.d.)

As can be seen from Table 2, it is difficult to identify a clear relationship between changes in the ratio of average sectoral wages to the national average and changes in the share of employed persons. In construction, the average wage in the sector became significantly less attractive for employees, yet the decline in the share of employment amounted to only -1.2%, which was the smallest among all selected sectors of the real economy. At the same time, the change in agriculture reached -20.3%, despite the fact that the situation regarding average wages improved. The situation in industry was the worst in terms of employment, while remaining moderate in terms of wages. This indicates that other factors must play a role in the absence of a direct correlation, including both the social and psychological factors mentioned

above and those specific to each sector in relation to specialisation (the transition to a more highly paid field may be more difficult in some sectors than in others).

Thus, work motivation is a key factor in the effectiveness of human resource management, combining material and non-material incentives that determine employees' work behaviour. In the agricultural sector of the economy, due to seasonality and dependence on natural conditions, an integrated motivation system that combines economic, social and psychological approaches is effective. Statistical analysis for the period 1995-2024 showed an increase in real wages, particularly in agriculture; however, employment levels in the sector declined, highlighting the importance of non-material factors – self-fulfilment, social support and trust – in fostering sustainable employee motivation. Alongside the economic factors of labour motivation, which have traditionally remained the focus of academic research, social, psychological, and specific non-material aspects of labour motivation are becoming increasingly significant under the conditions of modern transformations in the agricultural sector. For agricultural enterprises, these aspects are of particular importance because the sector is characterised by seasonal production processes, increased levels of physical workload, dependence of labour outcomes on natural and climatic conditions, and relatively lower material remuneration compared with other sectors of the economy. Under such conditions, non-economic incentives are capable of ensuring the stability of labour behaviour, long-term employee engagement, and loyalty to the employer. All of the characteristics of labour motivation described above can be summarised in the form of a diagram (Fig. 5):

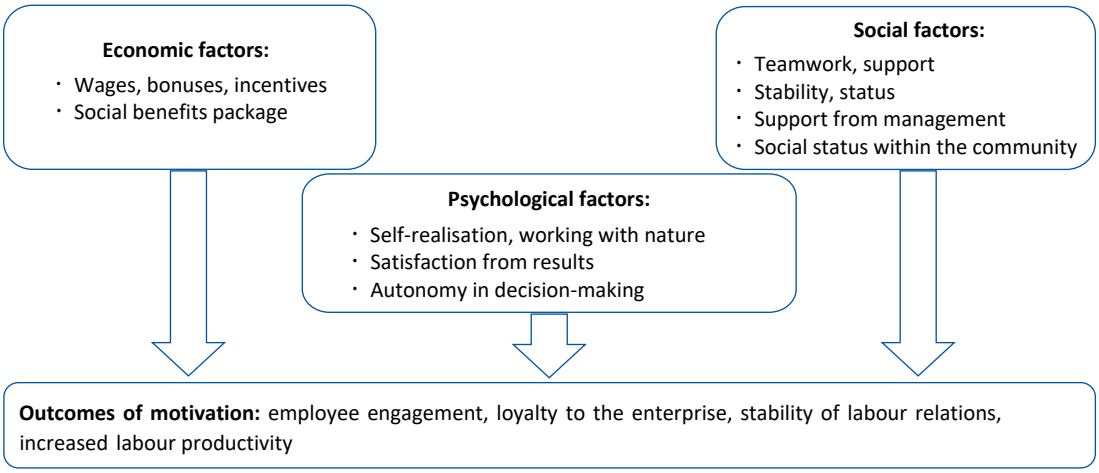

Figure 5. A model of labour motivation in agricultural enterprises
Source: compiled by the authors

The deepening of the theoretical foundations of labour motivation in agricultural enterprises requires moving beyond the traditional economic approach, which focuses primarily on wages and material incentives. The sector-specific nature of agricultural production limits the effectiveness of exclusively financial motivators, since labour outcomes largely depend on natural and climatic conditions, seasonality, and fluctuations in market conditions, while the relationship between an employee's individual efforts and the final result is weakened. Under such conditions, the role of social, psychological, and specific non-material factors increases, as they shape employees' intrinsic interest, ensure the stability of labour behaviour, and support long-term engagement in the production process. The social approach to labour motivation in agricultural enterprises is based on the specific organisation of work in the agricultural

sector, where production activities are carried out within relatively stable workforces closely connected with local communities. For employees, not only wage conditions are important, but also social recognition, support from colleagues and management, a sense of fairness, employment stability, and the opportunity to combine professional activity with family life. In rural areas, labour often has a pronounced social dimension, as it forms part of a way of life and an element of social identity, thereby strengthening the motivational effect of non-material social incentives. The psychological approach to labour motivation in the agricultural sector has a clearly defined sectoral specificity associated with the nature of work objects and the duration of production cycles. A significant proportion of agricultural workers demonstrate intrinsic motivation driven by the desire to work with plants and animals, care for them over an extended period, and observe the results of their own labour in the form of crop yields or livestock productivity. Achieving planned outcomes creates a sense of professional pride, job satisfaction, and self-realisation, which strengthens intrinsic interest in fulfilling work responsibilities regardless of fluctuations in material rewards.

Under modern conditions, the system of psychological and specific non-material motivational factors in agricultural enterprises should also include institutionally determined interests associated with the possibility and guarantee of exemption from military conscription during mobilisation. For male employees of working age, this factor acquires particular significance, as it directly influences their sense of personal security, employment stability, and ability to engage in long-term career planning. The existence of legally established mechanisms for reserving employees of agricultural enterprises recognised as critically important for maintaining the functioning of the economy and ensuring the state's food security creates an additional non-material motive for maintaining employment relationships and increases staff loyalty. From a motivational perspective, this factor combines institutional and psychological dimensions because, on the one hand, it is based on legal norms, while on the other hand it transforms into an employee's intrinsic interest in remaining within the agricultural sector and fulfilling professional duties under conditions of heightened social responsibility.

DISCUSSION

Thus, labour motivation in agriculture is a complex process incorporating economic, social, and psychological factors. Particular importance is attached to a sense of fairness, trust in management, corporate culture, and opportunities for professional development. An effective motivational system combines material and non-material incentives in order to increase loyalty, cohesion, and employees' intrinsic engagement. An analysis of wage and employment dynamics in the sector during 1995-2024 demonstrates a 9.68-fold increase in real wages and a reduction in the gap with the national average from -30% to -16%; at the same time, the share of employed persons decreased by 20.3%, indicating the significance of non-material factors. Thus, although wage increases are important, they are insufficient on their own, and the sustainable development of the agricultural sector requires a combination of economic, social, and psychological motivational mechanisms. From the perspective of agribusiness management, the establishment of an effective labour motivation system constitutes a strategic objective of the enterprise. Managers of agricultural enterprises who apply modern management approaches – including differentiated motivational programmes focused on individual and collective performance, the implementation of innovative HR tools, and transparent systems for evaluating labour efficiency – achieve higher levels of staff loyalty and reduce employee turnover. The obtained results indicate that entrepreneurial decisions in the field of personnel management should be considered comprehensively: from establishing competitive remuneration to developing an organisational culture that supports the engagement and development of every employee.

In Ukraine, social and psychological factors play a significant role in labour motivation. Although the situation in the agricultural sector has improved over time, unlike the two other sectors used for comparison – namely manufacturing and construction – wage levels remain

below average. S.S. Maican *et al.* (2021) conducted a study on a small sample of farmers and demonstrated the following pattern: worker motivation is a key factor in increasing the productivity and economic efficiency of agricultural enterprises. In the Romanian model, farmer motivation has both a direct and an indirect impact on economic outcomes through increased job satisfaction, which ensures the stability of production processes. This approach is fully consistent with the findings of the Ukrainian analysis, where wage levels are an important but not the sole determinant of stable employment. This points to a trend common to Central and Eastern European countries – a gradual shift from a purely economic to a comprehensive approach to motivation management, combining material, social and psychological factors. Thus, the empirical results of both studies confirm the validity of an integrated approach to the development of a labour motivation system in agriculture, which takes into account the interaction of material and non-material factors.

The results of this study confirm that economic factors remain a fundamental, but not exhaustive, element of the labour motivation system in Ukraine's agricultural sector. It was shown that wages are not the primary cause of changes in the country's employment levels, indicating the presence of other factors, particularly social and psychological ones. In turn, M. Heřmanová *et al.* (2024) investigated the motivational factors of Generation Z in agriculture and demonstrated a common trend towards a shift in emphasis from material incentives to non-material factors aligned with the values of the new generation of workers. Whilst the Ukrainian model demonstrates the predominance of economic motivational mechanisms, research on Generation Z shows that for young people, the key determinants of engagement are work-life balance, autonomy, flexible working hours, personal development and social support. This indicates a fundamental shift in the perception of work: for the new generation, it ceases to be merely a source of income and becomes a space for self-fulfilment and psychological well-being.

This study has shown that economic incentives remain a key driver of employment and labour productivity in Ukraine's agricultural sector. In particular, it has been established that an increase in real wages and the share of agricultural income in the overall national wage structure contributes to a reduction in unemployment and a strengthening of labour motivation. C. Schaffer *et al.* (2024), in turn, investigated farmers' motivation and perceptions of the benefits and challenges of agroforestry in Northern Europe, particularly Sweden. It was shown that the multifunctionality of agroforestry stems from farmers' diverse motivations: income generation, environmental sustainability, climate adaptation and landscape management. Farmers deliberately design their systems to provide a range of ecosystem services (provisioning, regulating, supporting and cultural). They demonstrate innovation, strategic thinking and adaptability, which are influenced by dispositional, social and cognitive factors. Many combine several agroforestry systems to optimise land use, increase productivity, diversify income and strengthen resilience to market changes. However, challenges include management complexity, a lack of appropriate technologies, limited plant materials and insufficient practical knowledge. Comparing these findings with current research reveals that in both countries, the understanding of work in the agricultural sector is viewed through the prism of multifunctional activities that combine economic, environmental and social objectives. This approach forms an integrated model of motivation, in which behavioural, cognitive and ethical factors are no less important than material incentives.

The current study demonstrated that the primary driver of labour motivation in Ukraine's agricultural sector remains the economic factor, particularly the level of wages and social-labour guarantees. V. Marinoudi *et al.* (2024) examined adaptation to the agricultural labour market shaped by robotisation. It was shown how automation and digital technologies are transforming the agricultural labour market and redefining the skills required for future work; automation not only replaces repetitive tasks but also reshapes labour roles towards more complex, intellectual, and socially oriented activities. This shift increases demand for higher-order cognitive and soft skills, such as

critical thinking, problem-solving, adaptability, and collaboration, while simultaneously reducing the demand for physical labour and increasing wage inequality between skilled and unskilled workers, thereby contributing to economic polarisation.

J. Ognjanović *et al.* (2023) demonstrated that the efficiency of human capital significantly improves the financial performance and productivity of agricultural enterprises, in particular by increasing net profit, operating profit and labour productivity per worker. However, this does not have a significant impact on value added per employee. This indicates that investment in employees' knowledge, skills and development is a key factor for success and competitiveness in agriculture, particularly when combined with modern technologies and favourable working conditions. The findings of this and the current study are consistent in recognising human capital as a central factor in the efficiency of agricultural production, yet they approach this issue from different academic perspectives. This article focuses on motivational mechanisms in the workplace as the basis for improving productivity and sustainability in agriculture, whereas the Serbian study analyses the effectiveness of human capital utilisation in financial terms – net profit, operating profit and labour productivity per employee. The similarity between the two works lies in the recognition that investment in human capital – through skills enhancement, motivation and competence development – has a direct positive impact on the performance of agricultural enterprises. Both studies demonstrate that effective human resource management contributes to increased labour productivity and the competitiveness of the sector. At the same time, the Serbian article empirically confirms the impact of human capital on enterprise profitability, whilst the Ukrainian study emphasises the socio-psychological aspects of motivation.

Thus, labour motivation in agriculture is shaped by a combination of economic, social and psychological factors. Material incentives remain important, but their effectiveness is significantly enhanced when complemented by non-material forms of encouragement – recognition, support, opportunities for development and a supportive social environment. A comparison of the agricultural sector with other industries has shown that, despite a gradual improvement in working conditions, it is precisely non-material factors that often determine staff engagement and retention. Thus, improving work performance in agricultural enterprises requires a comprehensive labour motivation system that combines financial incentives with the development of corporate culture, support for employees and the building of trust in the employer.

CONCLUSIONS

Labour motivation in agricultural enterprises is a key factor in the effective utilisation of labour potential and the development of the sector. The evolution of theoretical approaches demonstrates a transition from classical models focused primarily on material incentives to integrated concepts combining economic, social, and psychological factors. Within the motivational system of agricultural enterprises, an important role is played not only by incentives – material and non-material, individual and collective – but also by employees' interests, which determine their engagement and attitude towards work. The combination of economic, sociological, and psychological approaches makes it possible to create a balanced motivational model capable of increasing productivity, loyalty, and staff resilience to the specific challenges of agricultural production.

An empirical analysis of wage dynamics and employment levels in Ukraine's agricultural sector during the period 1995-2024 revealed a positive trend in the growth of real wages in the agricultural sector by 9.68 times, which reduced the gap with the national average wage from -30% to -16%. In industry, wages also increased, though at a slower rate (by 7.22 times in real terms from 1995 to 2024), resulting in the persistence of significant disparities between individual subsectors. In the construction sector, the dynamics were stable but less pronounced compared with the agricultural sector, indicating lower elasticity to changes in market conditions. The rate of wage growth in the agricultural sector was the highest among the analysed sectors. At the same time, the share of employment in the sector decreased by 20.3%, indicating the significance of non-ma-

terial motivational factors and the specific nature of the sector; moreover, such a decline was also characteristic of both industry and construction. The research findings demonstrate the need to implement flexible motivational systems combining material incentives (wages, bonuses, social guarantees) with collective forms of encouragement, seasonal bonuses, non-material incentives, opportunities for professional development, and social support for employees. Such a comprehensive approach makes it possible to increase productivity, strengthen staff loyalty, retain qualified personnel, and contribute to the socio-economic stability of rural areas. For entrepreneurs and managers in the agricultural business, this means a practical need to move from reactive personnel management to proactive strategic planning of the motivational system as a competitive advantage of the enterprise under conditions of the digital transformation of the agricultural sector.

The limitation of the study lies in the fact that economic models explain only part of the changes in employment, while other factors, predominantly socio-psychological, determine the need to establish an effective labour motivation system in the agricultural sector as a key condition for improving labour productivity, enterprise stability, and the welfare of the rural population. Further research may focus on integrated motivational models taking into account regional characteristics, employee qualifications, and seasonal production cycles, as well as on assessing the effectiveness of incentives through labour productivity, job satisfaction, and social stability within communities and the state as a whole.

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Мотивація праці в сільськогосподарських підприємствах: теоретичні засади й стан розвитку в Україні

Анотація. Актуальність дослідження зумовлена тим, що попри визначальну роль мотивації у забезпеченні продуктивності праці та соціально-економічної стабільності сільських територій, її рівень на аграрних підприємствах України залишається низьким через недостатню оплату, сезонність і нестабільну зайнятість. Метою роботи було проаналізувати взаємозв'язок між оплатою праці та зайнятістю в аграрному секторі економіки й визначити значення економічних і неекономічних факторів у мотивації працівників. У рамках дослідження було використано структурний та порівняльний методи, а також метод статистичного аналізу. У процесі дослідження було показано, що складовими мотивації праці є стимули та інтереси, вплив на які можуть здійснювати роботодавці чи держава для того, щоб мотивувати працівника. При цьому стимули можуть бути як матеріальними, так і нематеріальними. Було також розглянуто підходи різних учених щодо дослідження мотивації праці. Аналіз динаміки заробітної плати показав, що у 1995-2024 роках номінальна зарплата в сільськогосподарських підприємствах зросла більш ніж у 120 разів, а реальна – у 9,7 раза, що свідчить про поліпшення матеріальних умов праці. Попри це, заробітна плата працівників сільського господарства залишалася нижчою за середню по країні: у 1995 році розрив становив -30 %, а у 2024 році скоротився до -16 %. У сфері зайнятості спостерігалася стійка тенденція до скорочення: частка працівників аграрного сектору економіки в загальній структурі зайнятості зменшилася на 20,3 %, що зумовлено технологічною модернізацією, сезонністю та демографічними змінами у сільській місцевості. При цьому тенденції, що спостерігалися в аграрному секторі економіки, були найкращі порівняно з іншими секторами, а саме будівництвом та промисловістю. Загалом отримані дані свідчать, що, попри поліпшення фінансових і соціальних умов, мотивація праці потребує комплексного підходу, який поєднує економічні, соціальні й психологічні чинники. Отримані результати мають практичне значення для розроблення дієвих механізмів мотивації, здатних не лише підвищити продуктивність праці, а й забезпечити сталий соціально-економічний розвиток сільських територій України

Ключові слова: заробітна плата; зайнятість; безробіття; аграрний сектор економіки; стимулювання; ефективність праці

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Methodological approaches to the management of retail and leisure centres in conditions of uncertainty: Crisis-resilient and adaptive strategies

Abstract. The study aimed to identify effective management models for shopping and entertainment centres based on an analysis of the interaction between the asset, tenant and visitor flow subsystems. The methodology included a comparative analysis of management strategies for shopping and entertainment centres, a systematic approach, and conceptual modelling. The main findings of the study are the formation of a comprehensive interpretation of the shopping and entertainment centre as an open, adaptive socio-economic system, the functioning of which is determined by the interaction of three key subsystems: asset management, tenant management and visitor flow management. During the study, the system of factors influencing shopping and entertainment centres was structured for the first time into five interrelated groups – macroeconomic, behavioural, urban, technological and social – which made it possible to substantiate the multidimensional nature of the environment in which they operate. It was found that the defining trend in their development is the transformation of their function from predominantly retail to a comprehensive one – with a focus on experience, leisure and services. As a result of a comparative analysis of management strategies, three basic types have been identified – traditional, adaptive and anti-crisis – and their fundamental differences have been established in terms of management logic, level of flexibility, rental policy and ability to respond to changes in the environment. The study demonstrated that the operational effectiveness of shopping and entertainment centres depends not on the use of a single strategy, but on the ability to combine strategies depending on the level of uncertainty. Within the scope of the study, conceptual models for managing the subsystems of shopping and entertainment centres have been developed, in particular an asset management model based on a combination of occupancy, profitability and spatial efficiency indicators; a tenant management model, which involves forming a balanced tenant structure taking into account their role in generating footfall; a visitor flow management model that takes into account consumer behaviour patterns and the spatial organisation of the facility. The practical significance of the study lies in the possibility of using the developed approaches and models to optimise the management of shopping and entertainment

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centres, particularly in the areas of formulating rental policy, managing tenant mix, spatial planning and analysing visitor behaviour

Keywords: letting policy; visitor behaviour; tenant mix; spatial layout; cost-effectiveness

INTRODUCTION

In an unstable economic environment, characterised by shifts in consumer behaviour, security risks and intense competition, the management of shopping and entertainment centres (SECs) requires flexible and effective decision-making approaches. Uncertainty affects footfall, financial performance, tenancy relationships, logistics and the organisation of service processes, requiring a swift response to external and internal challenges. Anti-crisis and adaptive strategies aimed at maintaining operational stability, retaining customer loyalty, improving resource efficiency and securing competitive advantages are becoming increasingly relevant. Research into methodological approaches to the management of shopping and entertainment centres makes it possible to identify effective tools for strategic development and to formulate practical solutions for the operation of enterprises in a changing environment. The management of retail and leisure centres in times of uncertainty is increasingly focused on combining economic performance, flexible service and the ability to respond quickly to changes in consumer behaviour. In this regard, A. Khalifavi *et al.* (2023) investigated the success indicators of commercial centres in the process of organising leisure-shopping spaces. The authors analysed the functional characteristics of retail properties and demonstrated that combining shopping and leisure enhances the centre's appeal, the length of visitors' stays and revenue levels. The effectiveness of management decisions also depends on a focus on the needs of a family audience, as highlighted by M. Junaid *et al.* (2024), who analysed the components of the family shopping experience and the principles for creating family-friendly shopping centres. The study demonstrates that easy navigation, safe rest areas and services for children enhance visitor loyalty and encourage repeat visits. Alongside service solutions, the indoor environmental parameters of buildings are substantial. This assertion was confirmed by X. Zang *et al.* (2023), who investigated the impact of different functional zones on customer thermal comfort in shopping centres in Northern China. Optimising the microclimate within specific zones of the centres will allow for the improvement of the perception of the space and of the experience of the visitors themselves. Such approaches to management include issues related to partnership and territorial development models. For example, R. Kirk (2023) examined how lifestyle centres are the new stage in the evolution of retail property. His work investigated the governance of these retail properties and the role of partnerships between public and private entities. He found that aligning the interests of business, government and the community increased the resilience of retail properties in the face of market fluctuations. Furthermore, the ability to accurately forecast sales during periods of economic crisis is crucial for such properties. H.-J. Kim *et al.* (2023) investigated models for forecasting offline sales during the pandemic, using a South Korean shopping centre as a case study. The use of analytical models can be used for the timely adjustment of marketing activities, stock levels and financial planning. Adaptive management also involves optimising the operating costs of facilities. G. Ramkumar *et al.* (2025) investigated improvements to the thermal management of multi-zone air-conditioning systems in a shopping centre. The application of intelligent control algorithms reduces energy consumption and improves operational efficiency. Optimisation was achieved through the automated analysis of temperature readings in various functional areas of the building, the forecasting of thermal loads, and the dynamic adjustment of cooling settings following visitor numbers, the time of day, and the intensity of use of the premises.

Despite the arguments put forward by the authors mentioned above, there remain gaps in the academic literature regarding a comprehensiv

justification of methodological approaches to the management of retail and leisure centres in conditions of uncertainty. The mechanism for combining anti-crisis measures with long-term adaptive strategies remain insufficiently explored, as do the tools for rapid response to changes in consumer behaviour, security risks and market fluctuations. Models for integrating digital analytics, scenario planning, resource optimisation and customer-centric management require further development to ensure the sustainable operation of such centres. The aim of the study was to examine how asset-related, tenant-related and visitor-related components interact within retail and entertainment centres and to define management approaches capable of adapting to changing market and functional conditions. The objectives of the study were to summarise theoretical approaches to analysis of shopping and entertainment centres and their structural organisation; to compare management strategies for shopping and entertainment centres and identify their differences under various operating conditions; and to substantiate models for managing key subsystems of shopping and entertainment centres and their interrelationships.

MATERIALS AND METHODS

The methodological framework of the study comprises systems analysis, comparative analysis, the structural-functional approach, and the method of conceptual modelling. The combination of these methods was used for a comprehensive examination of shopping and entertainment centres as complex open socio-economic systems operating in a multidimensional and dynamic external environment and characterised by an internal multi-level structure. Within the framework of systems analysis, a decomposition of shopping and entertainment centres as open dynamic systems has been carried out. Attention was paid to identifying external and internal interrelationships, as well as the mechanisms of their mutual influence. The system's external environment was structured using factor classification. This classification made it possible to systematise the sources of uncertainty affecting the functioning of shopping centres, prioritise different types of risks, and fully account for the specifics of martial law in Ukraine, in particular the risks of physical destruction of facilities, logistical disruptions in the supply of goods, supply chain disruptions, and demographic shifts caused by internal and external population migration. A systematic analysis of the shopping centre was conducted based on the principle of decomposing the integrated socio-economic system into interrelated subsystems (asset management, tenant management and visitor flow management), followed by an examination of their functions, interrelationships and feedback loops within a single management mechanism. A comparative analysis was used to classify management strategies for shopping centres. The strategies were categorised into three main types: traditional, adaptive and crisis-response. The criteria for this classification were the level of stability of the external environment and the degree of adaptability of the management system. The criteria for the comparative analysis included management logic, letting policy, tenant mix, visitor behaviour and spatial planning, as these parameters reflect the interconnection between the economic, spatial and behavioural levels of shopping centre operation. Their selection is justified by the fact that they directly determine the shopping and entertainment centre's adaptability to changes in the external environment, the effectiveness of revenue generation, and the stability of visitor flows. This approach made it possible to identify differences between strategies, determine the conditions for their effective application, and justify the need for the combined use of different management models depending on the level of uncertainty. A structural-functional approach was used for a detailed analysis of the internal organisation of the shopping and entertainment centre. The internal structure of the system was decomposed according to criteria of functional interaction into three key subsystems, namely asset management, tenant management and visitor flow management.

The conceptual model of shopping centre management was operationalised through a system of quantitative indicators for the three subsystems: assets, tenants and visitor flows. For the asset subsystem, the key indicators are

defined as the occupancy rate (%) = (occupied area/total area) × 100, income per m² (Net Operating Income (NOI)/m², in monetary terms) and the vacancy rate (%) = (vacant area/total area) × 100; occupancy rates of ≥90%, vacancy rates of ≤5% and stable NOI were considered normal, whilst a drop in occupancy below 80% or a vacancy rate exceeding 15% triggered a review of rental rates and optimisation of space utilisation. For the tenant subsystem, the following indicators were used: tenant mix structure (% share of tenant categories), average lease term (months) and rental income per tenant; a single category's dominance of ≤40% was defined as the acceptable norm, whilst exceeding 50% required a rotation of the tenant mix, the introduction of new formats and a review of the commercial strategy. For the visitor flow subsystem, the following metrics were applied: throughput (people/hour), conversion rate (%) = (buyers/visitors) × 100, and average spend (in monetary units); a conversion rate of ≥25-30% was considered the standard, whereas a drop below 20% or a decline in traffic of more than 30% required adjustments to circulation routes, marketing incentives and the reorganisation of zones. Functional dependencies of both direct and cascading types exist between the subsystems: changes in visitor flows directly affect tenants' profitability, which in turn determines the occupancy rate of the assets and the need to review the letting policy; Similarly, an imbalance in the tenant mix alters the structure of demand and transforms behavioural patterns, requiring the spatial layout of the shopping centre to be adapted. The conceptual modelling method has become the primary tool for formalising the management subsystems of shopping centres.

The modelling process analysed key aspects of shopping centre operations, namely: asset management, tenant mix and visitor flows, which together form an integrated system of spatial, commercial and behavioural interactions. The expected outcome of the modelling is to identify mechanisms for transitioning between management strategies and to justify adaptive and anti-crisis tools for ensuring the sustainability of shopping centres under conditions of varying levels of uncertainty. The mechanisms of interaction between the shopping centre's subsystems were based on a system of feedback loops between asset management, tenant structure and visitor flows, where changes in one element triggered chain reactions in the others. External factors (macroeconomic, behavioural, urban and security) were integrated into the models as environmental variables that influenced the parameters of each subsystem and determined the level of adaptability of management decisions. Thus, the chosen methodological toolkit ensures the necessary systematic approach, comprehensiveness and scientific rigour of the analysis conducted.

RESULTS

Shopping and entertainment centres are among the most complex elements of urban commercial infrastructure, having emerged as a result of the evolution of the retail sector and the transformation of consumption patterns. The emergence of shopping and entertainment centres is linked to the shift from traditional shops to multi-functional spaces that cater to economic, recreational, social and cultural functions. In Ukraine in particular, these spaces have taken on additional functions and are transforming into multifunctional hubs of urban life (Nesterova & Brynzylo, 2024). The specific management of shopping and entertainment centres in Ukraine is influenced by the state of war in the country. The war has created a drastic level of uncertainty for the region and introduced a series of unique risks to these shopping and entertainment spaces. These risks include the threat of physical damage or destruction of these facilities due to shelling, the need to organise the evacuation of visitors during air raid alerts, the disruption of supply chains for logistics and the shift of the region's demographics due to population migration (Brynzylo, 2025). Due to these factors, traditional management methods have been proven to be insufficiently effective in managing these spaces, instead focusing on methods and strategies that aim to ensure the safety of individuals visiting the shopping and entertainment centres, the ability to restructure the activities occurring within the facilities and to preserve their economic viability. In order to address these challenges, it is necessary to diversify the

functions of shopping centres and to transform them into multi-functional hubs. According to S. Büyükşahin (2023), a multi-functional hub includes various functions beyond shopping and entertainment, such as commercial, social, cultural, educational, recreational and even humanitarian functions. Such a hub will become a site for social interaction, temporary accommodation, psychological relief and even educational and voluntary initiatives. The transformation of shopping centres into multifunctional hubs will provide them with a stabilising function during the crisis (Sepe, 2025). This will enhance their social significance for society and provide them with stability during difficult periods, as well as provide additional sources of income for these shopping and entertainment centres. Thus, shopping and entertainment centres in Ukraine are transitioning from a function that provides primarily economic benefits to a facility that serves a variety of social and security functions for the community, requiring new approaches to managing these spaces.

Beyond the concentration of various types of business within these centres is the interaction between those businesses, creating a synergistic effect in the attraction of visitors to the shopping and entertainment centre. The retail component of these shopping and entertainment centres contributes to the turnover of the centre and creates rental income for those who own the shopping and entertainment centre. The retail component is established upon the principles of commercial efficiency in that the main function of retail spaces within these shopping and entertainment centres is to create rental income through the letting of the commercial space. The entertainment component of these shopping and entertainment centres is established with the intention of creating emotional and behavioural engagement of the consumers of those spaces and products. Examples of these entertainment spaces include cinemas, children's entertainment zones, play areas, restaurants, food courts and other areas established for the provision of leisure activities for the visitors of the shopping and entertainment centre (Saidi *et al.*, 2026). While the main economic function of these areas is indirect, the entertainment component of these shopping and entertainment centres influences the length of the visit of the consumers of those spaces. Thus, these shopping and entertainment centres are not merely real estate developments but contain a socio-economic system that includes the commercial interests of the owners of the shopping and entertainment centre, the business interests of the tenants of the shopping and entertainment centre, and the behavioural system of the visitors of that location. The combination of these systems is what necessitates the study of these shopping and entertainment centres.

Furthermore, a shopping and entertainment centre is understood as an open, dynamic system, in constant interaction with its external environment. This environment includes macro-economic conditions, household income levels, demographic changes, development of e-commerce, urbanisation processes and changes in consumer habits. All these factors contribute to a high level of uncertainty that directly affects the operational efficiency of the shopping and entertainment centre (Ruth, 2024). The internal structure of the shopping and entertainment centre is multi-layered, and can be divided into three key subsystems: asset management, tenant management and visitor flow management. Such a decomposition transforms the analysis from a complex and holistic entity to a structured set of interrelated elements, each of which has a distinct functional role (Baghaee *et al.*, 2021). Asset management is the system for organising and using the centre's spatial and physical resources. This includes commercial premises, infrastructure facilities, logistics sites, car parks and common areas. As noted by M. Heptig (2023), the main function of this subsystem is to optimise the utilisation of space in terms of profitability, accessibility and investment value. Tenant management refers to the process of forming, structuring, and maintaining the commercial mix of a shopping and entertainment centre. This involves selecting the tenants that will operate within the shopping and entertainment centre, creating an optimal mix of such tenants, and regulating and maintaining the tenancy relationships within the shopping and entertainment centre (Chantarayukol, 2019). The tenant management subsystem determines the commercial profile

of a shopping and entertainment centre. Visitor flow management relates to the behavioural dimension of the operations of a shopping and entertainment centre. This subsystem involves analysing the number of visitors to a shopping and entertainment centre, the movements of these visitors within the shopping and entertainment centre, and the reactions of the visitors to the changes that occur within the shopping and entertainment centre. This management subsystem determines the operational effectiveness of the shopping and entertainment centre. According to S. Baghaee *et al.* (2021), the management of shopping and entertainment centre subsystems are interrelated. Each of these subsystems is interconnected with each of the others. For instance, changing the mix of tenants operating within a shopping and entertainment centre will impact the visitor patterns within that shopping and entertainment centre, which can impact the efficiency of the utilisation of the assets of that shopping and entertainment centre. These interrelationships between the different management subsystems create a single functioning mechanism within the shopping and entertainment centre that has numerous feedback loops that impact its development. Based on this approach, a transition is made to the analysis of management strategies for retail and leisure centres, which can be categorised according to their degree of stability and adaptability to the external environment. To this end, a comparative analysis was conducted, enabling a comparison of different types of management models; the results are presented in Table 1.

Table 1. A comparative analysis of management strategies for shopping centres

Parameter	Traditional strategy (stable environment)	Adaptive strategy (unstable environment)	Crisis management strategy (crisis environment)
Level of uncertainty and transition criteria	Occupancy rate ≥90%; footfall fluctuation ≤5%; stable external environment with no significant shocks	Occupancy rates of 75-89%; footfall fluctuations of 10-20%; changes in consumer behaviour and some volatility in demand	Occupancy rate <75%; drop in footfall >30%; disruption to operations or security threats
System status indicators (control signals)	Footfall is stable (±5%); vacancy rate ≤5%; NOI is stable; the tenant mix is balanced (no single category accounts for more than 40%)	Fluctuations in footfall of 10-25%; vacancy rates of 5-15%; changes in average spend of ±10-15%; dominance of a single category up to 45%	A drop in footfall of >30-50%; a vacancy rate of >20%; a decline in NOI; a single category accounting for >50% of the total
Leasing policy of the shopping centre	Long-term leases (3-5 years), fixed rents, low tenant turnover	Flexible contracts, a hybrid model (fixed fee + percentage of turnover), shorter terms (1-3 years)	Temporary agreements (up to 12 months), rent relief, and bespoke anti-crisis rates
Spatial layout of the shopping centre	Consistent functional zoning (retail/food/entertainment)	Partial conversion of areas (up to 20-30%), pop-up formats, temporary reconfiguration	Conservation or closure of areas (up to 40-60%), repurposing for core functions
Visitor flow management	Static flow planning, basic traffic zoning	Dynamic traffic management (heat maps, route analytics), traffic redistribution	Restricted access to certain areas, controlled traffic routes, safety first
Marketing tools for shopping centres	Mass advertising campaigns, standard loyalty schemes	Personalised digital marketing, audience segmentation, promotional campaigns	Crisis communication, information support, maintaining core demand
Tenant mix	Diversified structure: no category >40%	Partial concentration: up to 45-50% of a single category	Dominance of essential services (pharmacies, groceries): >50%
Key management tools for shopping centres	Planned yield management, strategic budgeting	Operational, data-driven, scenario-based planning	Crisis management, cost minimisation, liquidity protection

Source: compiled by the author based on S. Burnaz & Y.I. Topcu (2011), C.Y. Yiu & S.Y.S. Xu (2012), Y. Xu *et al.* (2022), Z. Wu *et al.* (2023)

A comparative analysis of management strategies for retail and leisure centres has shown that the traditional model operates in a stable environment, where occupancy rates exceed 90%, footfall fluctuations do not exceed 5%, and the tenant mix remains balanced (the share of any single category of tenants does not exceed 40%). Under such conditions, long-term lease agreements, fixed rates and a stable spatial layout without significant changes to functional zoning are applied. The adaptive strategy is implemented in conditions of heightened uncertainty, when occupancy rates fall to 75-89%, footfall fluctuations range from 10-20%, and individual tenant segments may account for up to 45-50% of the mix. This strategy involves flexible lease agreements, the transformation of retail areas to better suit the requirements of retail entrepreneurs (up to 20-30% of the retail space), pop-up formats for retail entrepreneurs, and the use of analytics to determine where visitors go in order to redistribute them across retail spaces to maximise commercial occupancy. This strategy is effective in striking a balance between the profitability of retail spaces and the need to adapt to changes in the retail market. The crisis management strategy is the most radical form of management. In this strategy, there is a complete overhaul of the leasing policy of retail spaces, the purpose of certain retail zones, and a change in the management of the property to ensure that the property can survive the crisis. The effectiveness of this management strategy is determined by how quickly the property management company can roll out this strategy and reduce losses caused by the crisis affecting the commercial property. Overall, the results of the analysis demonstrated that none of these strategies can be applied universally to commercial properties. The effectiveness of shopping and entertainment centre management is determined by the ability to combine different approaches depending on the level of economic and behavioural uncertainty. In stable conditions, it is advisable to use traditional models; in dynamic environments, adaptive ones; and in crises, anti-crisis management mechanisms. Thus, the key conclusion is that a shopping and entertainment centre functions as a system requiring multi-variant management capable of ensuring a balance between stability, flexibility and resilience to external influences.

The operation of shopping and entertainment centres is determined by a combination of external and internal factors that shape the conditions for their development, economic efficiency and the behavioural dynamics of visitors. Shopping and entertainment centres cannot be viewed as isolated commercial entities, as they are in constant interaction with the economic, social, technological and urban environment. This is precisely why analysing influencing factors is an essential step in analysis of the reasons behind the transformation of management models and changes in approaches to organising their operations. The most fundamental level of influence is provided by macroeconomic factors, which shape the general conditions for the functioning of the consumer market. C.I.-C. Lan & C.-J. Lee (2021) argued that these include the inflation rate, changes in household income, the unemployment rate, currency fluctuations and overall economic stability. Changes in these indicators directly impact the purchasing power of the population, which in turn impacts the footfall and spending in shopping and entertainment centres. During periods of economic instability, consumers tend to visit shopping and entertainment centres less frequently, spend less money within these centres, and shift their focus towards purchasing goods and services that are deemed as essential for their operations. In addition to the economic factors that impact the population's spending within shopping and entertainment centres, there are also behavioural factors to consider in relation to the shift in the technology industry. For instance, many consumers have changed their shopping habits and the way in which they make purchasing decisions due to the growth of the technology industry and its related technologies. Consumers are increasingly combining physical and digital shopping channels, using online platforms to compare prices, select goods and make purchases. This is leading to a decline in the role of traditional retail as the sole channel for consumption and is forcing shopping and entertainment centres to compete not only with one another but also with digital platforms. At the same time, the

structure of shopping centre visits is changing; it is not the purchase itself that is becoming increasingly relevant, but the experience of being there, leisure and social interaction (Ameen *et al.*, 2021). During the period of full-scale war in Ukraine, there was a decline in footfall at shopping and entertainment centres, with a drop in footfall of approximately 30-40% in 2022 compared to pre-war levels, followed by a partial recovery to a level that remained 8-16% lower than the figures for 2019-2021, even in 2024-2025. At the same time, a decline in operational efficiency has been recorded due to security restrictions and air raid alerts, leading to a loss of approximately 11-18% of shopping centres' operating hours across various regions of Ukraine (Attendance at Ukrainian shopping..., 2024). Structural changes in consumer behaviour are reflected in the redistribution of spending across product categories: the fashion, entertainment and discretionary spending segments saw a decline of approximately 10-20%, whilst the share of spending on essential goods increased, confirming the shift in the function of shopping centres as spaces for purpose-driven rather than recreational visits (Tyupka, 2026). At the same time, even during the market recovery phase in 2025, footfall at shopping centres remained on average 10-16% below pre-crisis levels, indicating the long-term impact of the crisis on consumer behaviour and the retail infrastructure (Budhouse Group, 2025).

A separate category is formed by urban factors that determine the spatial and territorial environment in which shopping and entertainment centres operate. These include urban density, transport accessibility, the development of public infrastructure, the level of car ownership among the population, and the overall organisation of urban space. Shopping and entertainment centres located in areas with high transport accessibility and heavy pedestrian traffic have greater potential to attract visitors. At the same time, changes in urban infrastructure, such as the development of new residential areas or transport hubs, can redistribute consumer flows between different venues. Technological factors, which have become systemic, are also substantial in the structure of these influences. The development of e-commerce, marketplaces, mobile apps and delivery services has transformed the competitive environment for shopping centres. Some consumer functions, which were previously conducted exclusively in physical retail spaces, have moved into the digital sphere. This has led to a reduction in the role of shopping centres as the sole venue for shopping and has strengthened their function as spaces for experience, leisure and social interaction (Borrallo-Jiménez *et al.*, 2020). At the same time, information and communication technologies have also made it possible to manage the shopping and entertainment centres themselves, as the technology can allow managers to analyse visitor flows and behaviours within the centres, and the efficiency of the utilisation of the space within the shopping and entertainment centres.

Another of the factors that is shaping the changing role of shopping and entertainment centres is the impact of social factors on those centres. Shopping and entertainment centres have, in many cases, become the places where individuals interact with others, participate in various leisure and recreational activities, engage in cultural interactions, and communicate with others. Changes in the lifestyles of individuals, the growth of the service economy, and a shift in the motivations of consumers towards experiencing activities rather than simply purchasing goods is contributing to the transformation of shopping and entertainment centres into spaces in which the social component of the shopping and entertainment centres is just as important as the economic component of those centres (Krey *et al.,* 2022). Thus, each of these factors interact with each other, and each of which has contributed to the development of the shopping and entertainment centre as it exists today. Each of these factors can be divided into groups of themselves, with the macroeconomic impacts on the shopping and entertainment centre, the behavioural factors that relate to consumers within the shopping and entertainment centre, the urban factors that impact the shopping and entertainment centre, the technological factors that impact the shopping and entertainment centre, and the social factors that impact the purpose and motivations of the shopping and entertainment centre. Each of these factors, however, has a combined impact

upon the shopping and entertainment centre that helps to create the necessity for the transformation of the management of those shopping and entertainment centres.

Consideration of a shopping and entertainment centre as a management object requires a preliminary systematic analysis of its internal organisation and external links. This approach involves interpreting the shopping and entertainment centre as a holistic, open socio-economic system that operates in constant interaction with its environment and is in a state of continuous adaptation. Systemicity in this case means that a shopping and entertainment centre is not the sum of its individual elements (tenants, floor space, visitors), but rather an integrated structure where each component performs a specific function yet simultaneously depends on the functioning of other elements (Zhou *et al*., 2024). Consequently, any change in one part of the system inevitably triggers transformations throughout its entire structure. The open nature of the shopping and entertainment centre system is manifested in the constant exchange with the external environment of three main types of resources: economic (cash flows, rental payments, investments), information (consumer behaviour analytics, market trends, marketing signals) and behavioural (visitor flows, changes in consumer preferences, migration of demand between sales channels). This tripartite structure of flows determines the complexity of shopping centre management. The external environment for a shopping and entertainment centre is multifaceted and volatile. It is shaped by macroeconomic conditions, household income levels, inflationary trends, the development of e-commerce, urban transformations, as well as changes in the social behaviour of the population. None of these factors can be controlled by the shopping centre's management system, which creates a state of constant uncertainty.

A key feature of this phase is that the external environment becomes not only unstable but also non-linear. This means that even minor changes in individual factors can lead to disproportionately significant consequences for the operation of a retail and leisure centre. For example, a change in consumer habits can sharply reduce footfall in certain categories of shops, triggering a chain reaction of changes in the tenant mix and profitability. The internal structure of a shopping and entertainment centre is characterised by the presence of interrelated subsystems that form its functional architecture (Eroglu *et al.*, 2005). These subsystems do not exist autonomously but are in a state of constant interaction, where every change generates corresponding adaptive responses in other elements of the system. In the most general terms, three basic levels of internal organisation can be identified, namely the spatial-material level, which is determined by the structure of assets; the commercial-economic level, which is shaped by tenancy relationships; and the behavioural-consumer level, which reflects visitor activity. The spatial-material level determines the physical configuration of the shopping and entertainment centre. It includes the architectural structure of the building, spatial zoning, engineering infrastructure and the logic of movement within the facility. This level is fundamental, as it creates the physical conditions for the implementation of all other processes.

The commercial and economic level reflects the structure of the relationship between the centre's owner and the tenants. It determines which businesses operate within the shopping centre, how the retail space is allocated, what financial flows are generated, and how stable the economic model underpinning the facility's operation is. It is this level that ensures the transformation of spatial resources into financial results (Berezko, 2021). The behavioural and consumer level is the most dynamic and sensitive to external changes. It reflects the actual activity of visitors, their movement patterns, consumer preferences, level of engagement, and reaction to changes in the structure of the retail space. This level is the source of the economic efficiency of the entire system. A characteristic of the shopping centre system is the presence of complex feedback loops between all levels of its organisation. These links are non-linear in nature and form cyclical processes of mutual influence. For example, a change in spatial structure affects visitor behaviour, which alters profitability, which in turn influences the tenant mix and subsequent decisions regarding

asset utilisation. Thus, the system functions as a self-regulating mechanism in which there is no single centre of causality. Instead, there is a network of interdependent processes that constantly adjust one another (Krey *et al.*, 2022). This property determines the complexity of managing retail and entertainment centres and the need for a systematic approach. It is worth noting that a systematic analysis of shopping centres can cause a shift from describing individual elements to analysis of the logic of their interactions (Uscher-Pines *et al.*, 2013). This is a key prerequisite for the subsequent modelling of management subsystems, as models can only be constructed correctly provided there is a set interpretation of the system's structure and the nature of its internal relationships.

Further consideration of a retail and leisure centre as a management entity requires interpreting it not as a collection of separate commercial spaces, but as a single integrated system operating based on interdependent subsystems. Such a system is open, as it constantly interacts with the external environment, responds to market changes and adapts internal processes to new conditions. Notably, any retail and entertainment centre are not a static entity, but a dynamic structure that is constantly being reshaped by economic, social and behavioural factors. This is precisely why its effective functioning is only possible through the synchronised management of several interconnected subsystems. The asset management subsystem forms the foundational level of a shopping and entertainment centre's operation, as it defines the physical and spatial basis of the entire system. Assets are defined not only as physical property, but as the entire complex of resources capable of generating economic value: commercial spaces, infrastructure, communal areas, logistics spaces, and the architectural and functional organisation of the building. In fact, this subsystem determines how effectively the space is utilised and how it translates into financial returns. It is the key level that shapes the property's base capitalisation and its investment appeal. To systematise the elements of asset management and determine their functional role within the structure of a retail and leisure centre, the key components of this subsystem, their interrelationships and performance indicators have been summarised (Table 2).

Table 2. An expanded conceptual model for the management of a retail and leisure centre

System component	Contents and description	Functional role in a shopping centre	Interactions with other subsystems	Assessment criteria	Vulnerability issues
Retail space	Physical retail spaces used for business premises	Form the basis for generating rental income	Depend on the tenant mix and visitor flows	% occupancy, vacancy rate	High dependence on the quality of the tenant mix; a hidden issue is the risk of "nominal occupancy" coupled with low tenant yields
Infrastructure assets	Lifts, escalators, car parks, service areas	Ensure accessibility and ease of movement	Influence visitor behaviour	Bandwidth	Vulnerability to overcrowding during peak hours; a trade-off between visitor comfort and maintenance costs
Spatial organisation	Planning of zoning and traffic flow	Determines the efficiency of space utilisation	Related to visitor traffic	Conversion to purchases	Typical conflict between commercial density and safety/ evacuation considerations; the risk of inefficient "dead zones"
Investment value	Market valuation of the centre as an asset	Determines the long-term stability of the system	Depends on the tenants and the return on investment	Return on Investment (ROI), capitalisation	High sensitivity to external shocks (war, migration, falling demand), which sharply reduces market capitalisation

Table 2, Continued

System component	Contents and description	Functional role in a shopping centre	Interactions with other subsystems	Assessment criteria	Vulnerability issues
Space efficiency	Profit per unit of floor area	Reflects the efficiency of asset utilisation	Depends on the tenant mix	NOI, revenue per square metre	Hidden problem of short-term "overlapping" of returns due to unreliable tenants; the risk of income volatility

Note: all indicators in this model are measured in percentages (%), monetary units, profitability metrics (in particular NOI), turnover and vacancy rates, capacity units (persons/hour or m2/person), and time intervals (months, years), depending on the nature of the relevant parameter
Source: compiled by the author

An analysis of this model concluded that asset management cannot be viewed as an isolated technical function, as it directly determines the economic rationale of the entire retail and leisure centre. In particular, the occupancy rate is not a sufficient indicator of performance, as it does not reflect the quality of tenants and their ability to generate a steady flow of visitors. Moreover, it is the spatial structure that determines consumer behaviour; the location of entrances, anchor tenants, leisure areas and services shapes movement patterns, which directly influence the level of commercial activity. A summary of vulnerability issues indicates that the operational efficiency of a shopping centre is dependent on the quality of the tenant mix and the system's capacity to maintain a balance between commercial efficiency, operational safety and visitor comfort. high formal occupancy rate may conceal a decline in real profitability. Attention to short-term financial results increases the risk of income instability in the long run. These further increases sensitivity to external shocks and operational overloads which together reduce resilience and capitalisation appeal of the shopping and entertainment centre. Assets therefore serve an economic as well as a behavioural function. The tenant management subsystem is central to the development of a shopping and entertainment centre's commercial ecosystem. The tenants create the substance of the space and determine its market appeal. Tenant management involves not only the placement of businesses, but also the formation of a balanced tenant mix that ensures synergy between different categories of tenants. Such synergy lies in the mutual reinforcement of footfall; large anchor brands generate a flow of visitors that is distributed among smaller tenants, thereby increasing their sales. Furthermore, the systematisation of the tenant structure and an analysis of their role in shaping the commercial ecosystem of a shopping and entertainment centre are presented in Table 3.

Table 3. An expanded conceptual model for managing tenants in shopping centres

System component	Contents and description	Functional role	Interaction with other subsystems	Key effects	Signs of imbalance
Tenant mix	Mix of tenants of varying sizes	Develops the commercial profile of the shopping centre	Affects visitor traffic	Sales synergy	Dominance of a single category of tenants; a loss of balance between retail and services; a decline in diversity
Anchor tenants	Major retail brands	Generate most traffic	Other shops are boosting sales	Increase in visitor numbers	Risk of becoming dependent on 1-2 brands; significant loss of traffic should they withdraw; asymmetry in bargaining power
Small and medium-sized enterprises	Specialist shops and services	Increase diversity	Maintain the system's balance	Steady income	Displacement during crises; instability of rental payments; sensitivity to fluctuations in demand

Table 3, Continued

System component	Contents and description	Functional role	Interaction with other subsystems	Key effects	Signs of imbalance
Small renters	Local outlets	Ensure the system's flexibility	Depend on traffic	High adaptability	High turnover; unstable income; low resilience to external shocks
Retention policy	Tenant management system	Reduces vacancy rates	Related to profitability	Income stability	Formal nature of retention; underlying conflicts with tenants; a decline in the quality of the tenant mix when retention is artificial

Source: compiled by the author

An analysis of this model demonstrates that the tenants of shopping centres are not passive participants in the commercial real estate of these centres, but active participants in their economic dynamics. The type of tenants that populate these shopping centres have a direct impact upon the behaviour of the visitors to those shopping centres. Finding the right balance between stability and flexibility in the tenant population of shopping centres is crucial to ensuring the long-term success of those shopping environments. While too much stability among the tenants of shopping centres can create positive effects for those commercial properties, too much stability can also prevent those shopping centres from adapting to changes in the marketplace. Signs of imbalance in the shopping centre's tenant management system collectively reflect a disruption of the structural and functional equilibrium of the tenant mix, manifested in the dominance of certain categories of tenants, a reduction in diversity, and an imbalance between retail and services. Additionally, there is a critical dependence on a limited number of key brands, which increases the risk of losing footfall and exacerbates bargaining asymmetry, as well as the instability of medium and small tenants during periods of crisis and fluctuations in demand. The result is a decline in the overall resilience of shopping centres, accompanied by high tenant turnover, unstable income, hidden conflicts and a deterioration in the quality of lease portfolio management in the long term. Therefore, effective tenant management is a compromise between these two extremes. The visitor flow management subsystem is the most dynamic and behaviour-oriented component of a shopping and entertainment centre. It reflects the actual level of interaction between the system and the end consumer. Visitors not only generate demand but also determine the efficiency of space utilisation, as their movement patterns influence conversion rates in commercial areas. Accordingly, visitor flow management involves analysing traffic intensity, concentration zones and behavioural patterns. To summarise the behavioural characteristics of visitors and their impact on the efficiency of the shopping and entertainment centre, a conceptual model of this subsystem has been developed (Table 4).

Table 4. Extended conceptual model for managing visitor flows in shopping centres

System component	Contents and description	Functional role	Interrelationships	Economic impact	Risks in a time of war
Visitor traffic	Total number of visits to the shopping centre	Determines the baseline demand for space	Depends on the tenants and the security situation	Profitability, sales figures	Substantial decrease in visitor numbers due to air raid alerts, shelling and population displacement
Behavioural patterns	Typical visitor routes	Can be used for prediction of consumer behaviour	Relating to spatial structure and safety	Sales optimisation and zone allocation	Changes to routes through evacuation zones and restricted access to parts of the shopping centre

Table 4, Continued

System component	Contents and description	Functional role	Interrelationships	Economic impact	Risks in a time of war
Concentration zones	Places with the highest concentration of people	Identification of key selling points	Affect tenants and vice versa	Increasing conversion rates	Increased risk of casualties during air raid alerts, the need to disperse crowds
Time series	Breakdown of visitor traffic by time	Determines the load on the infrastructure	Relating to assets and security protocols	Space utilisation efficiency	Interruptions during emergencies, reduction in "peak" hours
Spatial routes	Layout of the shopping centre	Optimises interaction between visitors and tenants	Depends on the design and safety routes	Growth in sales and engagement	Traffic restrictions, closure of certain areas, and changes to logistics due to sheltering
Security scenarios (military component)	Provision of shelters, evacuation routes and alarm signals	Ensures the physical safety of visitors	Integrates with all shopping centre subsystems	Maintenance of visitor numbers even in times of crisis	Direct risks of physical harm, damage to infrastructure, operational disruption

Source: compiled by the author

An analysis of this model concluded that visitors are not a passive element of the system, but an active factor that shapes the economic efficiency of a shopping and entertainment centre. It is through their behaviour that the link between spatial structure, letting policy and financial results is realised. Through reviewing each of the models for shopping and entertainment centres it becomes apparent that each centre comprises three main levels: spatial (assets), commercial (tenants) and behavioural (visitors). Each of these elements has a function within the shop or entertainment centre, but the effectiveness of the shopping and entertainment centre relates solely to the interaction of each of these components. Thus, the management of the shopping and entertainment centre should relate to the balance between spatial elements, business structure and consumer behaviour, as any alteration to any of these elements will have a transforming effect on the entire system of the shopping and entertainment centre. The war in Ukraine has contributed to a sharp drop in footfall in shopping and entertainment centres, as confirmed by official market research. According to research by the Ukrainian Trade Guild (UTG), footfall in shopping and entertainment centres in the capital city of Kyiv dropped to 291 visitors per 1,000 m^2 in 2022, compared to 506 visitors per 1,000 m^2 in the pre-war period. This represents a drop of 40-45% in footfall in shopping and entertainment centres (The vacancy rate..., 2023). Another indicator of the changes resulting from the war is the vacancy rate for retail space within shopping and entertainment centres. At the end of 2023, the vacancy rate for operating shopping centres in Kyiv reached 14.2%. If temporarily closed retailers are also accounted for, the vacancy rate increased to 19.7%. This means that 1 in 5 retail spaces in Kyiv were unused. For regional shopping and entertainment centres, the vacancy rate was even higher, reaching over 27%. In 2024, shopping and entertainment centres began to experience a recovery of their retail space. The vacancy rate in shopping centres in the capital of Ukraine dropped to 13.1% (Vacancy rate of operating..., 2024). However, there are still the consequences of the war in Ukraine visible within the retail and entertainment sector. For example, the footfall in shopping and entertainment centres is even throughout the country. Additionally, the rental income for these retail spaces has become increasingly unstable, as have the shopping and entertainment centres' sensitivities to external factors. As a result, changes in the management models of these retail spaces have developed in reaction to the war.

DISCUSSION

The findings of this study confirm that the management of shopping and entertainment centres in conditions of high uncertainty, particularly during martial law in Ukraine,

requires fundamentally new methodological approaches. The effectiveness of shopping and entertainment centres is determined not only by the commercial component, but also by the centres' ability to transform into multifunctional hubs, optimise internal subsystems (assets, tenants, visitor flows) and adapt quickly to external shocks. The findings are consistent with international research analysing anti-crisis strategies, resilience and the transformation of shopping centres in an unstable environment. The results of this study indicate that, in conditions of high uncertainty and crisis, the effective management of shopping and entertainment centres requires a shift from traditional to adaptive and anti-crisis strategies. The study determined that a balanced and well-thought-out tenant mix increases footfall, average spend, visitor dwell time and the centre's overall commercial performance. This is consistent with T. Kariya *et al.* (2023). Researchers have developed a tenant portfolio selection model for the risk-aware management of shopping centres. They have demonstrated that strategically selecting a tenant mix, considering risk correlations, can reduce revenue volatility and enhance the overall resilience of the property in times of economic uncertainty. Methodological aspects of optimising the tenant mix are also discussed by G.K.M. Alegría (2025). The author proposed multi-objective integer programming for the synergistic optimisation of the tenant mix. The study demonstrated that the use of mathematical optimisation methods can provide a balance between maximising rental income and creating commercial synergy among tenants. Algorithmic approaches to tenant management confirm the need for quantitative methods. This is consistent with H. Sawazaki *et al.* (2026). The authors developed a mechanism for allocating tenants in shopping centres based on a deferred acceptance algorithm. They demonstrated that the algorithmic approach ensures a fairer, more efficient and optimised allocation of tenants compared to traditional expert methods. The issue of the transformation and adaptation of shopping centres in a dynamic environment is examined by M. Hänninen & L. Paavola (2021). The authors conducted a case study of the management of organisational transformations at the large Itis shopping centre. The study identified key managerial, spatial and marketing changes necessary for the centre's successful adaptation to new market realities. One avenue for enhancing resilience is the use of artificial intelligence. This is consistent with D. Garanin *et al.* (2025). The authors analysed in detail the potential of artificial intelligence in the management of shopping and entertainment centres. They noted that the implementation of AI can improve demand forecasting, personalised offers, optimisation of retail space, and enhanced operational efficiency in shopping and entertainment centres. The study's findings also align with approaches to assessing resilience. This is consistent with an analysis by J. Zhang *et al.* (2025), based on partial least squares structural equation modelling (PLS-SEM) and machine learning tools to investigate the complex mechanism by which locational factors influence the resilience of retail properties. They found that different location attributes affect the long-term resilience of retail spaces in different ways, and that consumer attachment is one of the factors.

The socio-cultural role of shopping and entertainment centres in the urban environment is also significant. This is consistent with M.J. Grzegorzewski (2025). The author investigated the phenomenon of the "shopping mall city" and escapism in Jakarta's shopping centres. The study showed that shopping centres become spaces of private comfort and psychological relief, particularly in conditions of high urban density and social tension. The impact of e-commerce on the sustainability of commercial properties confirms the need to strengthen the agglomeration effect. This is consistent with the findings of X. Pan *et al.* (2024), who analysed the impact of e-commerce on the spatial resilience of large warehouse clusters. They found that the retail agglomeration effect mitigates the negative impact of online trade and helps to maintain the competitiveness of physical premises. General processes of transformation in the commercial property sector are also reflected by G. Wiejak-Roy (2025). The author examined the state of disequilibrium in the retail property sector. The study emphasises that the existing crisis is creating conditions for the

structural transformation of retail properties, which requires new management models. This is consistent with C. Oluigbo *et al.* (2025). The authors examined the issue of sustainable development of shopping and entertainment centres. They noted that the integration of sustainability principles into management strategy is becoming a prerequisite for the long-term viability of shopping and entertainment centres. Finally, a promising methodological approach to the redevelopment and modernisation of centres is the life cycle of facilities. This is consistent with J. Tamburić *et al.* (2025). The authors developed a model for the redevelopment of shopping centres based on the life cycle approach. The study proposes a systematic toolkit for planning service life design, which is particularly relevant for the crisis-response modernisation of shopping centres under conditions of limited resources. The non-linear nature of the interaction between shopping centre subsystems, with cascading effects of change, is partly illustrated by studies of the impact of external disturbances on commercial systems. In particular, D.G. Mogale *et al.* (2023), using the example of online retail, showed how simultaneous disruptions (changes in demand, closures of premises, supply chain disruptions) create a high level of uncertainty and require the development of adaptive response mechanisms.

The distinction between the spatial, commercial and behavioural levels of shopping centre operation is partly consistent with Y.-H. Fang & C.-Y. Li (2025). In omnichannel retail, the authors, drawing on Uncertainty Reduction Theory, demonstrated how consumers interact with different levels of the retail system and attempt to reduce transactional uncertainty, which is relevant to the management of multichannel interaction in shopping centres. Shaping a shopping centre's commercial profile through its tenant mix is a key element of resilience. This is consistent with the findings of J. Luo (2023), who analysed crisis management strategies in the US fashion retail market. The study highlights the role of the business structure and tenant balance in supporting the sustainability and market position of retail properties during a crisis. The systematisation of multidimensional factors influencing shopping centres (economic, social, technological, urban and behavioural) is consistent with R. Zayadin *et al.* (2023). The authors investigated how entrepreneurs make decisions under conditions of perceived environmental uncertainty, highlighting the multifactorial nature of influences and their interaction with business systems. Differences in the logic of shopping centre management strategies depending on the level of environmental stability were illustrated by F.S. Akerele *et al.* (2022). A study of spatial adaptation strategies in Nigerian entertainment centres showed that the operational efficiency of such facilities directly depends on their ability to adapt to changing conditions and fluctuations in demand. A synthesis of the comparative analysis results indicates the presence of consistent conceptual overlaps between the findings and scientific approaches to the study of retail and entertainment systems. The systemic nature of the functioning of retail and entertainment centres, their dependence on a multidimensional environment, and the interconnection of spatial, commercial and behavioural components have been confirmed. At the same time, it has been established that the key factor in effectiveness is not the isolated optimisation of individual elements, but the coordination of their interaction, which determines the adaptability and stability of the system in a changing environment.

CONCLUSIONS

The research resulted in the development of a theoretical framework for shopping and entertainment centres as a system, the functioning of which is based upon the interaction of its commercial, spatial and behavioural elements. Shopping and entertainment centres should be viewed as more than a commercial property, but as an environment in which economic, behavioural and social interactions take place. As part of the study, the management system of a retail and entertainment centre was broken down, resulting in the identification of three key subsystems: asset management, tenant management and visitor flow management. It was established that each of these subsystems fulfils a distinct functional role, yet their effectiveness is only realised through their interaction. A key

outcome of this approach was the identification of the non-linear nature of the interrelationships between the subsystems, where changes in one trigger cascading transformations in the others. A comparative analysis revealed fundamental differences between these approaches, particularly in terms of parameters such as management logic, letting policy, tenant structure, spatial organisation, and the nature of interaction with visitors. The analysis revealed differences between the strategies in terms of the degree of management flexibility and the level of response to changes in the external environment, which determined the nature of the tenancy policy, tenant structure and spatial organisation. The study also found that the level of adaptability of management decisions varied from a consistently fixed approach in the traditional model to a rapidly transformative one in adaptive and anti-crisis strategies. The study also developed conceptual models for managing the main subsystems of shopping centres, which provided a detailed analysis of their internal structure and functional interrelationships. The study established that the effectiveness of asset management is determined not only by the occupancy rate of the premises, but also by their profitability and their ability to shape visitors' behavioural patterns. In the area of tenant management, the key role of a balanced tenant mix was identified, which ensures synergy between different business categories and contributes to the stability of financial flows. Regarding visitor flow management, it was established that consumer behaviour patterns are a determining factor in the effective use of space and the generation of economic results. Prospects for further research include the development of quantitative models for assessing the effectiveness of shopping centre management and their practical testing, considering the specific characteristics of different markets and property types.

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Методичні підходи до управління торговельно-розважальними центрами в умовах невизначеності: антикризові та адаптивні стратегії

Анотація. Метою дослідження було визначення ефективних моделей управління торговельно-розважальними центрами на основі аналізу взаємодії підсистем активів, орендарів і потоків відвідувачів. Методологія включала порівняльну характеристику управлінських стратегій торговельно-розважальними центрами, системний підхід, а також концептуальне моделювання. Основні результати дослідження полягають у формуванні комплексного уявлення про торговельно-розважальний центр як відкриту адаптивну соціально-економічну систему, функціонування якої визначається взаємодією трьох ключових підсистем, управління активами, управління орендарями та управління потоками відвідувачів. У процесі дослідження вперше структуровано систему факторів впливу на торговельно-розважальні центри за п'ятьма взаємопов'язаними групами – макроекономічними, поведінковими, урбаністичними, технологічними та соціальними, що дозволило обґрунтувати багатовимірність середовища їх функціонування. Виявлено, що визначальним трендом розвитку є трансформація їх функції від переважно торговельної до комплексної – із домінуванням досвіду, дозвілля та сервісів. У результаті порівняльного аналізу управлінських стратегій ідентифіковано три базові типи – традиційні, адаптивні та антикризові – та встановлено їх принципові відмінності за логікою управління, рівнем гнучкості, орендною політикою та здатністю реагувати на зміни середовища. Обґрунтовано, що ефективність функціонування торговельно-розважальних центрів залежить не від використання окремої стратегії, а від здатності до їх комбінування залежно від рівня невизначеності. У межах дослідження розроблено концептуальні моделі управління підсистемами торговельно-розважальних центрів, зокрема модель управління активами, що базується на поєднанні показників заповненості, дохідності та просторової ефективності; модель управління орендарями, яка передбачає формування збалансованої структури орендарів із урахуванням їх ролі у формуванні трафіку; модель управління потоками відвідувачів, що враховує поведінкові патерни споживачів і просторову організацію об'єкта. Практичне значення дослідження полягає у можливості використання розроблених підходів і моделей для оптимізації управління торговельно-розважальними центрами, зокрема у сфері формування орендної політики, управління структурою орендарів, планування простору та аналізу поведінки відвідувачів

Ключові слова: орендна політика; поведінка відвідувачів; структура орендарів; просторова організація; економічна ефективність

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The management of energy and investment processes under the conditions of Ukraine's innovative and sustainable development

Abstract. The aim of this study was to identify and systematise effective managerial decisions aimed at aligning energy and investment processes in Ukraine with the requirements of innovative and sustainable development. The methodological basis of the research comprised comparative-structural, institutional, and regulatory-legal analyses, a problem-oriented approach, case analysis, and descriptive-analytical generalisation of the practice of implementing investment projects in the renewable energy sector. The main findings of the study demonstrated that in 2022, the volume of capital investment in Ukraine's energy sector declined by 49% compared with 2021; however, investment activity began to recover as early as 2023, with total capital investments reaching UAH 109.3 billion. During 2022-2025, annual investments in renewable and low-carbon energy amounted to USD 1.09 billion, whereas in the pre-war period their cumulative volume exceeded USD 12 billion. The share of renewable energy sources within the investment structure of the energy sector remained within the range of 1-5%, while the structure of investments was characterised by the predominance of solar generation (60-70%) and wind generation (20-30%). In 2023, investments in solar power plants for businesses amounted to approximately USD 150 million, providing profitability of 15-20% and a payback period of 5-7 years. During 2022-2025, more than 2 gigawatts of new capacity were commissioned, contributing to a reduction in CO_2 emissions by 5-7 million tonnes annually. The study developed practical recommendations for improving the management of energy and investment processes, based on a portfolio approach, long-term contractual models, and the reduction of military and regulatory risks. The practical significance of the research lies in the

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possibility of using its findings by public authorities, energy companies, and investors to substantiate managerial decisions in the field of renewable energy in Ukraine

Keywords: renewable energy sources; investments; energy efficiency; management; bioenergy; sustainable development; financing

INTRODUCTION

Ukraine's energy transition, under the conditions of wartime risks, European integration, and climate commitments, necessitates the combination of innovative development, investment activity, and energy security. The destruction of energy infrastructure, rising energy costs, limited access to capital, and dependence on imports reinforce the importance of effective management of energy and investment processes as a key prerequisite for sustainable economic recovery. Under these circumstances, the development of renewable energy sources, energy-efficient technologies, green investments, and institutional mechanisms for their promotion constitutes an essential component of the transformation of the energy sector. The limited alignment of investment decisions with the objectives of environmental transformation and the elevated risks within the energy sector complicate the selection of effective financing directions and long-term development planning. L.M. Ivashko (2024), in her study, focused on the management of green investment portfolios in energy enterprises, substantiating the expediency of applying a portfolio approach, integrating Environmental, Social and Governance (ESG) criteria, and employing multicriteria methods for evaluating investment decisions. The findings demonstrated an improvement in the validity of investment choices and a reduction in financial risks. At the same time, O.V. Kalinin *et al.* (2024) examined approaches to managing investments for the sustainable development of green energy by analysing regional and fuel-related shifts in investment flows, opportunities for replacing nuclear generation, and instruments for assessing the investment attractiveness of energy projects based on indicators such as Levelised Unit Energy Cost, Net Present Value (NPV), Internal Rate of Return (IRR), and Return on Investment (ROI). Their findings confirmed the appropriateness of combining renewable energy sources with innovative technologies, particularly small modular reactors, and highlighted the importance of infrastructure modernisation and adaptation of the regulatory environment.

The increasing instability of the economic environment, the scarcity of investment resources, and the technological deterioration of energy infrastructure complicate the achievement of long-term effectiveness in innovation and investment processes. D.V. Babych *et al.* (2024), in their studies, substantiated the key role of innovation and investment development in enhancing the efficiency of the energy complex. The authors demonstrated a close relationship between expenditure on research and development and the growth of energy supply volumes, while also emphasising the importance of state regulation, institutional mechanisms, and strategic planning for the modernisation of energy processes and the strengthening of energy security. The insufficient integration of sustainable development principles into the strategic management of the energy sector, combined with limited investment activity, regulatory fragmentation, and low energy efficiency, constrains the long-term transformation of Ukraine's energy system, as noted in the works of M. Shkvarylyuk & I. Petrunchak (2025). These researchers focused on strategic management in the context of sustainable development, substantiating the need to modernise managerial approaches, strengthen the role of state policy, promote renewable energy sources, and enhance corporate responsibility in order to achieve energy efficiency and environmental sustainability. Similar conclusions can be observed in the studies of K. Kraus *et al.* (2023), in which the strategic development of the energy sector is examined through the lens of innovation, digitalisation of managerial processes, the implementation of advanced technological solutions, the decentralisation of energy systems, and the expanding role of renewable

energy sources. The authors also emphasised that the systematic integration of innovation into production, investment, and managerial decisions creates conditions for improving energy efficiency, strengthening energy security, and enhancing the adaptability of companies to wartime and post-crisis challenges.

Insufficient alignment between economic, social, and environmental objectives in the operation of energy enterprises leads to imbalances in their long-term development and complicates the integration of sustainability principles into managerial decision-making. In the study by Y.S. Papizh *et al*. (2023), the issue of sustainable management of energy enterprises was examined through the lens of contradictions between market imperatives and the requirements of environmental and social responsibility. The authors emphasised the need to revise traditional management models and substantiated the expediency of applying a cluster approach as an instrument for enhancing managerial efficiency. Their proposed model of an autonomous specialised polystructural cluster was considered a mechanism for rationalising resource provision and reducing production costs. In a related field of research, N. Chaplynska & P. Makeienko (2023) focused on innovative approaches to ensuring energy security, paying particular attention to global trends in energy consumption, the development of renewable energy sources, and the role of innovation policy in the transformation of energy systems. Their study analysed the dynamics of global energy consumption, indicators of innovation activity within the energy sector, structural shifts in electricity generation, and reductions in carbon emissions, while also substantiating the importance of renewable energy as one of the key directions for strengthening the resilience of energy systems.

The low level of energy efficiency within economic systems, the high energy intensity of production, and the insufficient alignment of investment and managerial decisions with the principles of sustainable development constrain the possibilities for long-term modernisation and the reduction of Ukraine's energy dependence. These issues were examined in detail in the works of M.M. Klymchuk *et al.* (2021), in which the need for interdisciplinary approaches to energy-saving management was substantiated and the concept of energy-efficient development was proposed as an instrument for combining investment, managerial, and technological decisions. The authors systematised concepts of energy-efficient development, including environmental economics, green leases, passive houses, and urban economics, and demonstrated their suitability for establishing strategic mechanisms aimed at improving energy efficiency. The study also highlighted the potential economic and environmental effects of implementing energy-efficient projects and outlined the role of institutional and managerial factors in reducing energy consumption.

At the same time, issues concerning the integration of innovative managerial decisions with investment and financial mechanisms, the assessment of the long-term economic and financial sustainability of energy projects, and the adaptation of managerial models and strategic decisions to the conditions of wartime and post-war macroeconomic instability in Ukraine remain insufficiently explored. The aim of this study was to substantiate managerial approaches to the coordination of energy and investment decisions, taking into account innovative factors, the risks of a wartime economy, and the requirements of Ukraine's long-term sustainable development. To achieve this aim, the study set the following objectives: to analyse the condition, dynamics, and structure of investments in Ukraine's renewable and low-carbon energy sector under conditions of wartime instability; and to generalise the practice of managing energy and investment processes, together with the institutional, financial, and regulatory mechanisms supporting them.

MATERIALS AND METHODS

The study had a practical orientation and covered the period from 2022 to 2025, as this was the timeframe during which significant changes occurred in the management of energy and investment processes as a result of the full-scale invasion, extensive destruction of energy infrastructure, restricted access to financial resources, and the simultaneous intensification of

Ukraine's adaptation of its energy policy to European requirements in the fields of decarbonisation and sustainable development. Within the framework of the study, the volumes of investment in renewable and low-carbon energy during the specified period were analysed on the basis of materials from Capital Investments in the Energy... (2024) and the work of O. Chaika & I. Orel (2024). A comparative-structural analysis of statistical indicators was employed, involving the comparison of annual volumes of capital investment in the energy sector, their share within the overall structure of capital expenditure, and the proportion of renewable energy sources in 2022-2023 relative to the pre-war level of 2021.

The analysis of bioenergy enterprises in Ukraine during 2022-2025 was conducted using descriptive-analytical and structural-comparative methods. The descriptive-analytical approach was used to generalise open data from Bioenergy in Ukraine: Analytical... (2025) concerning the types of bioenergy enterprises, feedstock resources, generation formats, and the role of bioenergy in heat supply and the substitution of imported natural gas. Structural-comparative analysis was applied to compare bioenergy projects with solar and wind generation in terms of installed capacity scale, investment horizon, and management system organisation. The structure of investment in renewable energy sources (RES) was examined using a structural-comparative analysis by comparing the proportion of investments in solar, wind, bioenergy, and other renewable technologies during the wartime period with their pre-war proportions. This approach made it possible to identify inter-technological shifts and determine the factors underlying the dominance of particular technologies.

A separate section examined the sources of funding for investments in RES, in particular the involvement of the European Bank for Reconstruction and Development (EBRD, n.d.), the European Union (EU), the World Bank and the International Finance Corporation (n.d.). To this end, applied institutional analysis was employed to assess the financial, guarantee and regulatory mechanisms through which international financial organisations participate in the implementation of investment projects in the renewable energy sector within the context of a wartime economy. The effectiveness of investments in renewable energy in 2022-2025 was assessed through a descriptive and analytical synthesis of actual performance indicators for completed projects, including ROI, payback periods, and social and environmental impacts, based on data from Alternative Energy (n.d.). Barriers to the implementation of energy projects, in particular procedural and infrastructural constraints on connection to electricity grids, were examined using a problem-oriented analysis to identify key constraints in the investment process, based on official clarifications from the National Energy and Utilities Regulatory Commission (n.d.a), published in a "question-and-answer" format regarding connection to electricity grids.

The functioning of "green" auctions was analysed using a case study based on data from the first "green" auction of 2025, selected as an example of the initial practical implementation of the auction mechanism within the context of a wartime economy. Within the framework of the case analysis, the announced quota parameters, feed-in premium conditions, the level of investor interest, and the actual results of the auction were assessed, including the absence of participants in the solar energy segment, which made it possible to identify the factors limiting the investment attractiveness of this instrument (The First "Green" Auction..., 2025). Wartime risk insurance mechanisms were examined within the framework of an applied institutional analysis using the instruments of the Multilateral Investment Guarantee Agency (MIGA) (n.d.) as an example. This involved the generalisation of information regarding insurance coverage parameters, premium levels, and certain limitations associated with the application of these instruments in financing renewable energy investment projects under conditions of wartime instability. Following the same methodological approach, government programmes supporting investment and energy efficiency were analysed using applied institutional-descriptive analysis, taking as examples the "Energy Conscious" programme (n.d.), Energodim (n.d.) and the "5-7-9%" programme, in which Privatbank is a participant... (n.d.), selected as the most representative instruments of state support that were directly

utilised between 2022 and 2025 to stimulate investment in energy efficiency and renewable energy. The analysis examined the programmes' objectives, financial support mechanisms, the range of beneficiaries, as well as their role in reducing financial barriers and shaping management decisions regarding energy consumption, modernisation and the decentralisation of generation, which made it possible to link these instruments to the practice of managing energy processes at corporate and regional levels. European regulatory instruments, in particular Directive (EU) 2018/2001 (2018) and Regulation (EU) 2022/869 (2022), were analysed through a legal and regulatory review, which involved examining their objectives, regulatory requirements and the instruments provided to support the development of renewable energy. Ukraine's strategic documents, in particular Resolution of the Cabinet of Ministers of Ukraine No. 868-p (2021), the National Strategy for Low-Carbon Development until 2050... (n.d.) and the National Energy and Climate Plan... (2024), were examined using institutional-descriptive analysis to identify priorities, targets and mechanisms for state governance of energy and investment processes. In the final stage of the research, using methods of synthesis, generalisation and systematisation, practical recommendations were developed to improve the efficiency of managing energy and investment processes, in particular based on an analysis of the case study of the implementation of the LLC "Wind power GSI Volyn 3" project (n.d.), selected as a representative example of an investment project in the renewable energy sector under a wartime economy, and an assessment of legislative changes in the energy and heat supply sectors adopted in 2024-2025, in particular Law of Ukraine No. 4213-IX (2025), which enabled the formulation of practical approaches to improving management decisions in the context of wartime and post-war transformation.

RESULTS AND DISCUSSION

The current state and practice of managing energy and investment processes in Ukraine

Between 2022 and 2025, investment in Ukraine's renewable and low-carbon energy sectordeveloped against a backdrop of profound structural shifts caused by the war, damage to energy infrastructure and the concentration of funding on supporting baseload generation. The lack of a single aggregate indicator for investment in renewable energy means that fragmentary data must be used; however, this data does allow for an assessment of general trends and the proportions of investment. Annual investment in renewable and low-carbon energy during the period 2022-2025 amounted to USD 1.09 billion, whilst in 2011-2021 the total volume exceeded USD 12 billion. Following a sharp decline in capital investment in 2022 (-49% compared with 2021), investment activity in the energy sector began to recover as early as 2023, when total capital investment rose to UAH 109.3 billion, exceeding pre-war levels (Capital investments in the energy... 2024). At the same time, the share of renewable energy sources in the overall investment structure remained limited, fluctuating between 1 and 5%, as the bulk of financial resources was channelled into the refurbishment of thermal power stations, electricity grids and gas sector facilities. In 2023, investment in solar energy alone amounted to around USD 150 million, equivalent to approximately UAH 6 billion, and accounted for around 5.5% of total capital investment in the energy sector (Chaika & Orel, 2024).

The structure of investment in renewable energy sources (RES) in 2022-2025 was characterised by the clear dominance of solar energy, which accounted for 60-70% of all investment. This was due to the speed of project implementation, relatively low capital intensity and the widespread adoption of self-consumption models for businesses. Wind energy accounted for 20-30% of investment, mainly through large-scale infrastructure projects, in particular the construction of wind farms with a capacity exceeding 800 MW, planned for completion by 2030. Bioenergy and small-scale hydropower together accounted for no more than 10-15% of investment, whilst bioenergy projects differed in their management logic from solar and wind generation, as their implementation depended on the stability of raw material supply, biomass contracting and supply logistics, as well as the possibility of combining electricity and heat generation; hydrogen projects remained at the

pilot stage and accounted for less than 1% due to high technological and financial barriers, as noted by O. Dluhopolskyi *et al.* (2023) and I. Bondarchuk (2025). Between 2022 and 2025, bioenergy enterprises in Ukraine formed a distinct segment of the renewable energy sector with a distinct production, management and investment logic, driven by the specific nature of the raw material base, the generation format and integration with the agricultural and municipal sectors. The dominant enterprises were those utilising solid biomass, in particular wood waste, straw, maize stalks and sunflower husks, the resource potential of which is estimated at approximately 94 million tonnes per year, of which less than 15% is actually utilised. It was these enterprises that accounted for around 3.5% of thermal energy production and contributed to replacing up to 17% of imported natural gas, which underscored their importance for regional energy security (Bioenergy in Ukraine: Analytical..., 2025).

The typical feedstock base for bioenergy enterprises in Ukraine is agro-industrial in nature and includes agricultural residues, wood biomass and organic by-products, which amounts to over 90 million tonnes of potential annually and determines how the efficiency of projects depends on the logistics of collection, processing, storage and transport of biofuel. Under these conditions, the management system for bioenergy enterprises was based on long-term contractual relationships with biomass suppliers, the planning of logistics flows and the consideration of the seasonality of agricultural waste, which distinguishes it from management models for solar and wind power generation. The predominant form of energy production was thermal generation and cogeneration, which accounted for over 90% of total bioenergy production, whilst electricity generation played a secondary role due to regulatory constraints and the specific nature of tariff incentives. Bioenergy projects generally have a lower installed capacity (1-10 MW) and a longer investment horizon compared with solar and wind power stations, due to the high capital intensity of the raw material and logistics infrastructure, but at the same time provided stable cash flows through the production of thermal energy (Zhelezna *et al.* 2021). This model reduces enterprises' dependence on fluctuations in the electricity market and enhances the role of bioenergy as a tool for decentralised energy supply, integrated with local communities, agricultural production and district heating systems, which determined its role in enhancing the resilience of Ukraine's energy system amid the instability caused by the war.

Solar projects for self-consumption (solar power stations (SPS) on business rooftops) grew by 20-40% due to reduced costs, whilst wind energy grew due to large wind farms (the 400 MW Tyligulska wind farm). Investment activity in bioenergy and hydropower during 2022-2025 was limited due to logistical factors. Hydrogen projects during this period did not progress to the mass implementation stage and were primarily considered in the medium term, after 2025, with the involvement of international partners. In particular, the strategic project portfolios of certain foreign investors envisaged a combination of wind and solar generation as a basis for the further development of hydrogen infrastructure: ONUR Group (n.d.) announced projects with an installed capacity of approximately 320 MW of wind and 50 MW of solar generation. General approaches to the development of hydrogen energy and its integration with renewable energy sources are consistent with the provisions of strategic documents on the post-war transformation of the energy sector. Overall, the share of renewable energy sources in the energy sector stands at 2-5%, with plans to increase this to 10% (Savchenko, 2025).

In terms of funding sources, investment in renewable energy was predominantly private. Own funds from Ukrainian enterprises and private investors accounted for 50-60% of investment, whilst international financial organisations contributed a further 30-40%. The state budget and grant programmes together did not exceed 10-15%, which is explained by the limited fiscal space in wartime conditions. The EBRD (n.d.), the EU, the World Bank and the International Finance Corporation (n.d.) (IFC) played a key role, not only by financing individual projects but also by reducing risks for private capital through guarantee mechanisms. In particular, the EBRD has earmarked up to EUR

1 billion for investment in renewable energy and energy networks in 2024-2025, whilst also providing a loan of EUR 160 million to Ukrnafta to finance the construction of approximately 250 MW of gas-fired power stations across Ukraine, and has also signed a letter of mandate with Concern Galnaftogaz (n.d.) to raise EUR 60 million for the development of wind energy (The EBRD invests in Ukraine from..., 2025). In addition, the EBRD, together with international partners, is establishing a new financial mechanism with the potential to mobilise up to EUR 2 billion in investment for renewable energy projects, which, together with EU guarantees totalling EUR 9.3 billion, has created the conditions for intensifying auctions and scaling up "green" generation amid the risks posed by the war (Perun, 2025). The IFC invested EUR 60 million in the OKKO wind farm (n.d.) (147 MW) in partnership with the EBRD and the Black Sea Trade and Development Bank (BSTDB, n.d.) in 2025, which will reduce CO_2 emissions by 245,000 tonnes annually. The Corporation is preparing four energy projects for financing, including solar and wind generation, and is developing distributed generation with energy storage systems (Mykhaylova, 2025). The World Bank allocated USD 116 million in grants in 2025 for gas-fired cogeneration plants and district heating equipment in seven cities (Kharkiv, Sumy, Chernihiv, etc.), which enhances the resilience of the systems and promotes low-carbon solutions. A further USD 88 million was allocated to business support programmes, including green technologies and industrial parks with a renewable energy component (The World Bank will provide an..., 2025). The EU, for its part, has allocated EUR 9.3 billion in guarantees under the Embassy of Ukraine to the United Kingdom... (n.d.) to attract private investment in renewable energy, including solar and wind projects, with EUR 2.3 billion in agreements in 2025 (EUR 1.8 billion in loan guarantees + EUR 580 million in grants). The European Investment Bank (EIB, n.d.) has provided EUR 600 million for decentralised generation and EUR 20 million in grants for renewable energy for municipalities in 2024-2025 (New financing from the EIB..., 2024).

The performance of investments in renewable energy in 2022-2025 confirms their economic and social viability. Investments totalling USD 150 million in 2023 yielded an average ROI of 15-20% due to the "green tariff" (EUR 0.117/kWh) and corporate Power Purchase Agreements (PPAs), with an average payback period of 5-7 years for solar power stations. The social impact was evident in the commissioning of over 1,400 new renewable energy facilities, the creation of 10-15 thousand jobs, and the improved resilience of the power system during blackouts (Alternative Energy, n.d.). In total, over 2 GW of new renewable energy capacity was commissioned between 2022 and 2025, enabling a reduction in gas consumption of 1-5 billion cubic metres and a cut in CO_2 emissions of 5-7 million tonnes annually (Nedylko, 2025). The implementation of energy projects in Ukraine between 2022 and 2025 took place against a backdrop of regulatory, financial, institutional and military constraints, which reduced the investment attractiveness of renewable and low-carbon energy. The most critical barrier remained grid connection, the duration of which, depending on capacity, was up to 280 days for 400-1,000 kW facilities and up to 350 days for 1-5 MW projects, including the design, approval and land allocation stages, which in some cases was extended by a further 180 days. Even for distributed generation with a capacity of up to 400 kW, connection times exceeded six months, which hindered the development of rooftop solar power stations and small-scale projects by small and medium-sized enterprises (SMEs). Formally, the least problematic stage was licensing, which is carried out by the National Energy and Utilities Regulatory Commission (NEURC, n.d.) and was nominally set at 10-30 working days; but in practice it dragged on for up to three months due to inspections and deliberations at meetings, whilst a rejection blocked the resubmission of documents for a further three months, which negatively affected the start dates of renewable energy projects (National Energy and Utilities Regulatory Commission, n.d.b).

An additional regulatory factor contributing to low predictability was "green" auctions, the effectiveness of which remained limited due to small quotas, uncertainty regarding feed-in-premium parameters, land-use barriers and war risks. In 2025, the total renewable

energy support quota stood at 330 MW; however, the auction for solar power plants in March (33 MW) did not take place due to a lack of participants, which demonstrated the low investment attractiveness of the proposed terms (The first "green" auction..., 2025). Restrictions limiting participation to 25% of the quota per investor, debts under the "green" tariff scheme and a lack of alignment with the corporate PPA market further undermined business confidence. Although corporate PPAs were gradually gaining ground as a tool for stabilising revenues, their development was hampered by a capacity shortfall following the loss of over 9 GW of generation capacity, the risk of blackouts and the absence of a long-term energy strategy (White paper "Corporate PPAs..., 2024). War-related risks reduced the investment attractiveness of energy projects, as 63,000 energy infrastructure facilities were destroyed between 2022 and 2025, and capacity losses exceeded 9 GW (In Ukraine, during the three years..., 2025). This increased the weighted average cost of capital (WACC) by a further 3-5% and led investors to avoid the eastern and southern regions, concentrating their investments in the west of the country, although even there the risk of repeated attacks made ROI figures less predictable. Insurance against war risks through MIGA (n.d.) and other institutions provided cover for 70-90% of potential losses; however, the high cost of insurance premiums (5-10% of asset value) and the exclusion of force majeure outages limited its effectiveness, particularly for SMEs (MIGA insured the first investment..., 2023).

State guarantees and programmes in 2022-2025 partially offset these barriers through preferential lending, compensation mechanisms provided by the Energy Efficiency Fund, and guarantees of the origin of "green" energy. The "Energy Conscious" programme (n.d.) in 2022-2024 took on a comprehensive nature and covered various groups of beneficiaries, creating the institutional conditions for scaling up energy-efficient and renewable energy solutions. For households, the programme provided preferential loans at 0% per annum of up to UAH 480,000 for the installation of solar panels, small wind turbines and energy storage systems, which contributed to the development of distributed generation and increased energy self-sufficiency in the face of widespread power cuts. For associations of co-owners of multi-apartment buildings (associations of co-owners of multi-apartment buildings and housing and construction cooperatives), the GreenDIM grant scheme (n.d.) was utilised, which provided compensation of up to 70% of the cost of energy efficiency projects, with a maximum funding limit of UAH 2 million, thereby encouraging the modernisation of buildings and a reduction in energy consumption (Energy-Aware: The government..., 2024). The Energodim programme (n.d.), implemented through the Energy Efficiency Fund (n.d.), provided partial reimbursement of costs for the thermal modernisation of buildings, the modernisation of building services systems and the introduction of energy-saving technologies, primarily for associations of co-owners of multi-family residential buildings. Indirectly, this helped to reduce peak loads on the power system and generate additional demand for energy-efficient technologies, thereby creating a favourable environment for investment decisions in related energy sectors. The expansion of the "5-7-9 %" state loan programme (Privatbank is a participant in the programme..., n.d.) between 2022 and 2025 provided small and medium-sized enterprises with access to preferential long-term financing for investment projects in the fields of energy efficiency and renewable energy. The use of interest rate subsidies and the option of partial state loan guarantees helped to reduce the financial burden on businesses, lower the weighted average cost of capital, and enhance enterprises' investment capacity for the deployment of solar power stations, energy-saving equipment and decentralised generation technologies.

A comparison with the study by C. Bistuer-Talavera *et al.* (2024) helped to identify the structural limitations of investment analysis within the context of the energy transition. Similar to this study, the authors interpreted the energy transition as a capital-intensive process, the effectiveness of which is determined by access to finance, institutional stability and the coherence of government policy. At the same time, the focus of C. Bistuer-Talavera *et al.* was

on the micro-financial level – the capital structure of Spanish energy companies, in particular the dominance of debt instruments and project finance. Against this backdrop, the present study broadened the analytical framework, shifting the emphasis to macro- and institutional governance of energy and investment processes in Ukraine, where war risks, infrastructure destruction and limited capital mobilisation remained key determinants. A further comparison with the work of K. Si Mohammed *et al.* (2025) highlighted methodological differences in the study of the impacts of green investments. In both approaches, investments in the energy and green sectors were viewed as a key instrument for decarbonisation and environmental sustainability. However, K. Si Mohammed *et al.* applied a quantitative econometric approach, focusing on the relationship between green technology, investment and CO_2 emission trends in Chinese provinces within the framework of the Kuznets environmental curve model. In contrast, this study prioritised the managerial and institutional dimensions, where environmental outcomes were viewed as derivatives of the system's ability to adapt investment decisions to conditions of high military and macroeconomic uncertainty. A logical extension of this comparison was to draw on the work of C. Han & L. Yang (2024), which presented a corporate-level analysis of the energy transition. Similar to this study, the authors emphasised the role of investment in renewable energy and green finance as drivers of sustainable development. At the same time, their approach focused on the internal management and financial strategies of a single energy corporation in China, utilising machine learning tools. In contrast, this study went beyond the corporate level, analysing the systemic coordination of energy and investment decisions at the national level against a backdrop of military risks and structural instability.

A comparison with the study by A. Thomas *et al.* (2024) enabled to supplement the analysis with a behavioural dimension of investment decisions. As in this paper, the authors interpreted the energy transition as a multi-factorial process dependent on the institutional environment, government policy and managerial decisions. As in the present study, the authors regarded the energy transition as a multifactorial process dependent upon the institutional environment, public policy, and managerial decisions. However, A. Thomas *et al.* focused on the willingness of small and medium-sized enterprises in Italy to invest in the energy transition, demonstrating the predominance of country-specific and socio-psychological factors, while financial constraints played a relatively minor role. In the present study, by contrast, investment behaviour was shaped primarily by wartime risks, infrastructure losses, and limited access to capital, which fundamentally altered the logic of decision-making. A comparison with the work of I. D'Adamo & E.N. Rossi (2025), which emphasised the regional and institutional aspects of investment in sustainable development, enabled to broaden the analytical framework of the study and clarify the role of territorial disparities in shaping investment flows. In both studies, investment was viewed as a key instrument for achieving sustainable development goals and reconciling economic, social and environmental priorities. However, I. D'Adamo & E.N. Rossi focused on analysing the regional distribution of investment in Italy and the impact of Next Generation EU funding on reducing territorial disparities. In contrast, this study focused on the management of energy and investment processes in Ukraine, where the risks of war and a shortage of financial resources have shaped a fundamentally different trajectory for the implementation of sustainable transformations. In both studies – by I. Alvarez & J. Uxó (2025) and the present one – the energy transition was viewed as a driver of long-term economic transformation, whilst investment in renewable energy sources was seen as a tool for enhancing the economy's resilience and competitiveness. Another common feature was the recognition of the key role played by government policy and institutional mechanisms in stimulating investment processes. At the same time, I. Alvarez & J. Uxó focused on a macroeconomic analysis of Spain's energy transition against a backdrop of institutional stability and large-scale support from the EU, particularly through the Next Generation EU funds. In contrast, this study focused on the management of

energy and investment processes in Ukraine amidst the risks of war, infrastructure destruction and limited access to capital, which dictated a different logic for investment decisions and the mechanisms for their implementation. Thus, investment trends in Ukraine's renewable and low-carbon energy sector in 2022-2025 were characterised by a gradual recovery following a sharp decline in 2022, yet remained structurally constrained by military risks, regulatory uncertainty and a shortage of financial resources. Despite the dominance of solar and wind energy and the growing role of private capital and international financial organisations, the share of renewable energy sources in total investment in the energy sector remained low due to the priority given to restoring basic infrastructure. At the same time, the results of completed projects demonstrated the economic viability and significant social impact of investments in renewable energy, laying the groundwork for their scaling up, provided that regulatory and military risks are reduced and support mechanisms are strengthened.

Practical mechanisms for managing investments in the context of the green transition

The transformation of Ukraine's energy sector between 2022 and 2025 took place against a backdrop of a war economy, limited access to financial resources, infrastructure risks and regulatory alignment with European requirements. In such circumstances, the management of investments in renewable energy projects takes on a systemic nature and requires a combination of financial, institutional and risk-oriented mechanisms. A key factor is aligning investment decisions with long-term energy policy objectives, in particular increasing the share of renewable energy sources to 27% by 2030, in accordance with "Green" transformation in the world... (2022). One of the fundamental instruments for institutional support of investment in "green" energy is the introduction of a system of guarantees of origin for electricity from renewable sources. In accordance with the requirements of European legislation, in particular Directive (EU) 2018/2001 (2018) and Regulation (EU) 2022/869 (2022), electricity from renewable sources, biomethane, and, in the future, renewable hydrogen must be verified by means of guarantees of origin; this is a prerequisite for their circulation within the EU internal market and participation in cross-border trade. Between 2022 and 2025, work in Ukraine is intensifying on establishing a mechanism for the circulation of such guarantees, which involves the creation of registers, rules for transfer and control over their use. The existence of guarantees of origin adds financial value to electricity from renewable energy sources and enhances the predictability of cash flows within corporate power purchase agreements. The development of the system of guarantees of origin is directly linked to the implementation of Ukraine's strategic climate documents. In particular, Resolution of the Cabinet of Ministers of Ukraine No. 868-p (2021), the National Energy and Climate Plan... (2024) and the Strategy for Low-Carbon Development... (n.d.) provide for a phased increase in the share of renewable sources in final energy consumption and a reduction in greenhouse gas emissions. In these documents, the system of guarantees of origin is regarded as a tool for market-based verification of "clean" energy and a prerequisite for Ukraine's integration into the European energy area.

The financing of investment projects in the renewable energy sector for 2022-2025 was based on a combination of private capital, state support instruments and resources from international financial organisations. The models actually implemented included limited recourse project finance, corporate PPAs, blended finance incorporating grant components, and mechanisms for insuring against war risks. Some of the large-scale wind and solar projects during this period were implemented with the participation of international financial organisations, notably the EBRD (n.d.), the IFC (International Finance Corporation, n.d.) and the Credit Institution for Reconstruction (KFW) (n.d.), within the framework of EU financial programmes. The involvement of such institutions provided not only direct lending or quasi-equity financing, but also mitigated risks for private investors through co-financing mechanisms, the provision of guarantees, technical assistance and the standardisation of environmental and

social responsibility requirements for projects. The use of blended finance models, in which grant funds were combined with concessional loans, made it possible to reduce the weighted average cost of capital, increase the internal rate of return on investment projects and offset heightened war and regulatory risks. In the practical implementation of investment projects, the Ukraine Facility (n.d.) was utilised, under which funding of approximately EUR 2.3 billion was earmarked for decarbonisation measures and the restoration of energy infrastructure. Resources from this programme were used to support investment in renewable generation, the modernisation of electricity grids, the development of energy storage systems and the implementation of decentralised energy solutions. The combination of grant components, concessional debt financing and EU guarantees created the conditions for launching investment projects even in the face of limited access to commercial capital and heightened uncertainty linked to military risks, which significantly expanded the scope for implementing renewable energy projects in Ukraine (Ukraine received 2.3 billion euros..., 2025).

The development of wind energy during 2022 and 2025 illustrates the practical application of such financial models. Prior to the full-scale invasion, the installed capacity of wind farms in Ukraine exceeded 2 GW, accounting for over 20% of the renewable generation mix. Despite the loss of some assets in the temporarily occupied territories, around 230 MW of new capacity was commissioned during the full-scale war, and the project portfolio exceeds 7 GW. Achieving the targets of 6.1 GW of onshore and 0.1 GW of offshore wind generation by 2030 will require investment of around USD 20 billion. In this context, annual feed-in-premium auctions and corporate PPAs are used as mechanisms to mitigate price risks and secure long-term contractual revenues. Regulatory changes in 2024-2025 play a distinct role in the practical management of investments, in particular the introduction of a cable pooling mechanism and new grid connection rules for facilities with a capacity exceeding 20 MW. Transparent grid capacity allocation and municipal incentives for the deployment of renewable energy facilities reduce administrative delays and enhance the predictability of investment schedules (Ukraine's 2025 wind market..., 2025). This is significant both for large centralised projects and for distributed generation, which is actively developing in the form of rooftop solar power stations for small and medium-sized businesses. Managing investments in a wartime and post-war economy requires the systematisation of risks and the selection of appropriate tools to mitigate them. The main types of risks and response mechanisms are set out in Table 1.

Table 1. Key risks of investment projects in Ukraine's renewable energy sector and management instruments (2022-2025)

Risk group	Characteristics	Practical management instruments
Military	Physical damage to facilities, suspension of power generation, restrictions on access to sites	Insurance by MIGA, distributed generation, and project modularity
Currency	Exchange rate volatility of the hryvnia under foreign currency debt financing	PPAs with currency indexation, hedging, and currency diversification
Regulatory	Changes in tariff policies, payment delays, and adaptation to EU regulations	Long-term contracts, Ministry of Finance guarantees, and the involvement of multilateral financial organisations (MFOs)
Infrastructure	Limited grid transmission capacity and damage to substations	Cable pooling, local energy storage systems, and backup grid connections
Financial	Restricted access to capital and an increase in the weighted average cost of capital (WACC)	Blended finance, preferential loans from the EBRD and IFC, and EU grants

Source: compiled by the authors based on Ukraine's 2025 wind market... (2025), Y.I. Shcherbak & T.V. Nagachevska (2025), EBRD (n.d.), International Finance Corporation (n.d.)

The risks associated with investment projects in Ukraine's renewable energy sector for 2022-2025, as summarised in the table, are multi-layered in nature and form an interlinked system of constraints on investment activity. The predominance of security and macro-financial factors is leading to a shift in management decisions towards risk-oriented and contractual models, within which mechanisms for guaranteeing, diversifying and distributing risks among project participants play a key role. The combination of financial and non-financial management tools signals a shift from isolated responses to individual threats towards a comprehensive approach aimed at maintaining the investment viability of projects amid military and regulatory uncertainty. The use of appropriate tools ensures that investment decisions are aligned with ESG principles, which are gradually being incorporated into the financial and management models of energy projects. The environmental dimension is realised through the reduction of emissions and the decarbonisation of production processes, whilst the social dimension is achieved through the expansion of distributed generation and an increase in the energy self-sufficiency of businesses and households, whilst the governance component is based on the use of transparent contractual mechanisms, standardised financial reporting and compliance with the requirements of international investors. In practical terms, this creates the conditions for attracting financial resources on more favourable terms and reducing the weighted average cost of capital for renewable energy projects. Consequently, investment management in the context of Ukraine's green transition in 2022-2025 emerges as a multi-level system that integrates financial models, regulatory mechanisms and risk management tools. The development of guarantees of origin, the proliferation of PPAs, the involvement of international financial organisations and the adaptation of infrastructure solutions form the institutional framework for scaling up renewable energy in the context of post-war recovery and further integration into the European energy area.

A comparative analysis with the study by X. Shi & D. Shi (2025) made it possible to outline the financial dimension of managing the green transformation. Similar to the present study, the authors considered investment to be a key instrument for enhancing the efficiency of energy systems and reducing barriers to the deployment of renewable technologies. At the same time, their analysis focused primarily on the functioning of green financial instruments – green lending, green bonds and government incentives – within China's relatively stable institutional environment. Against this backdrop, this study expanded the financial logic by combining it with regulatory and risk-oriented mechanisms adapted to conditions of high uncertainty, thereby transforming investment from a development tool into a means of simultaneously stabilising and restoring the energy system. A shift in focus from financial instruments to technological outcomes was evident when compared with the work of H.P. Zhou & Y.H. Liu (2025). In both studies, investment, energy efficiency and government policy were considered as interrelated elements of sustainable development. However, H.P. Zhou & Y.H. Liu concentrated on the technological and innovative dimensions of the energy transition, analysing the role of digitalisation and improved energy efficiency within a context of institutional stability. In contrast, this study examined technological solutions through the prism of investment management, where access to capital, military risks and the state of infrastructure significantly limited the potential for implementing even economically viable technologies. A similar distinction between quantitative and managerial approaches was evident when comparing this study with that of S.D. Nabella *et al.* (2025). The authors empirically demonstrated the positive impact of green investments on the structure of the renewable energy mix under conditions of relative macroeconomic stability, emphasising the role of economic factors and government policy. At the same time, this study went beyond quantitative relationships, focusing on practical mechanisms for managing investments in a situation where macroeconomic stability had been disrupted by military action, and investment decisions were determined not only by economic feasibility but also by security and institutional constraints. The institutional

dimension of the energy transition was interpreted differently compared with the work of H. Wibisono *et al.* (2024). Both studies viewed the energy transition as a complex socio-technical process dependent on the quality of governance and policy coherence. However, H. Wibisono *et al.* focused on the consequences of failures in renewable energy projects, analysing how technical and managerial failures undermine public trust in the transition process itself. In contrast, this study aimed to prevent such failures by developing adaptive investment mechanisms, in which financial, regulatory and risk-oriented instruments were viewed as a means of enhancing the resilience of the energy system.

A comparison with the work of A. Idris & A. Rahman Razak (2025) added a macroeconomic perspective to the analysis. In both studies, the energy transition and green growth were treated as prerequisites for long-term development. At the same time, A. Idris & A. Rahman Razak used spline modelling to identify the non-linear impact of these processes on economic growth in the Asia-Pacific region, whilst disregarding the practical aspects of investment implementation. In contrast, this study focused specifically on investment management mechanisms, where war risks, infrastructure destruction and capital shortages determined not only the scale but also the form of the green transition. A comparison with the work of I. Farida & D. Setiawan (2024) made it possible to clearly distinguish between the corporate and systemic levels of analysis. Like this study, the authors recognised the importance of green investments for sustainable development, but focused on the financial performance of such investments at the level of individual companies. In contrast, the present study considered investments as an element of the national energy sector governance system, within which corporate decisions were strictly constrained by institutional conditions, the state of infrastructure and military uncertainty. Between 2022 and 2025, the management of investments in Ukraine's renewable energy sector took place against a backdrop of military risks, a transforming regulatory environment and gradual integration into the European energy market. The implementation of investment projects during this period was based on the use of long-term pricing contract models, energy origin guarantee instruments, the involvement of international financial organisations, and multi-level risk management mechanisms. The establishment of a system of guarantees of origin, the development of corporate PPAs, and the introduction of auction mechanisms and blended finance have created the institutional conditions for stabilising cash flows and reducing investment uncertainty. Taken together, these instruments ensure that investment decisions are aligned with Ukraine's climate commitments, the requirements of European legislation and the objectives of post-war energy infrastructure reconstruction.

Recommended approaches to improving the management of energy and investment processes

The management of energy and investment processes in Ukraine during the period of the war economy was characterised by a combination of infrastructure losses, financial constraints and regulatory transformation. The combination of these factors has created a need not only to adapt current management practices but also to systematise applied management decisions aimed at preserving the energy sector's investment capacity in conditions of heightened uncertainty. In this context, it is appropriate to identify key directions for improving the efficiency of managing energy and investment processes. The first direction is the development of management decisions for enterprises in the energy sector, which was implemented in 2022-2025 through the gradual introduction of long-term strategic planning and the formalisation of investment procedures. Following the loss of around half (35 GW) of generating capacity as a result of missile attacks in 2022-2024, companies were forced to shift from a focus on large-scale centralised facilities to portfolio management of projects, particularly in the solar and wind generation segments. In practice, this has manifested itself in the creation of internal investment committees, the phased commissioning of capacity, and a shift towards corporate PPA models, which allow future cash flows to be locked in

without direct dependence on state tariff mechanisms. Such management approaches are already being applied in the implementation of large-scale wind projects financed through limited recourse project finance arrangements involving international financial organisations (Kryzhny, 2024). In particular, in 2024-2025, an investment project was carried out to construct a wind farm with an installed capacity of 147 MW, implemented by a specially established project company, LLC "Wind power GSI Volyn 3" (n.d.). The project was implemented under a limited recourse project finance model, under which funding was provided in the form of a long-term senior secured loan of up to EUR 60 million, with future cash flows from the generation and sale of electricity identified as the primary source of debt service. The financing was structured as secured debt involving the EBRD, IFC and BSTDB, which entailed the application of project analysis standards, environmental and social requirements, as well as risk management procedures typical of participation by international financial organisations. The loan was secured by the project company's assets and contractual rights relating to the sale of electricity. An additional element of the project's financial architecture was the use of a first-loss coverage mechanism under the European Union launches... (2024), which was applied to redistribute war and country risks between private investors and public institutions. The use of this instrument helped to reduce the risk burden on lenders and created conditions for attracting long-term debt financing amid military instability (Galnaftogaz Wind, n.d.).

The second direction involves stimulating investment in renewable energy at the regional level, where institutional changes linked to the decentralisation of energy decision-making took place between 2022 and 2025. Local authorities became increasingly involved in creating the conditions for the deployment of renewable energy facilities by streamlining land-use procedures, co-financing grid infrastructure and supporting distributed generation projects. In 2024-2025, government policy was supplemented by the launch of tenders for the construction of new generation capacity ranging from 5 to 80 MW, as well as major tenders for 700 MW, to be commissioned by the end of 2027. This approach combines regional interests with the national objective of increasing the share of renewable energy sources to 27% of the energy mix by 2030, in line with the government-approved plan involving total investment of around USD 20 billion (Ukraine approves $20 billion plan..., 2024). The third direction relates to instruments designed to enhance the investment attractiveness of projects for private investors, which, during the period under review, were implemented primarily through a combination of financial and insurance mechanisms. Practical experience shows that, in wartime conditions, private capital is mainly attracted through the involvement of international financial organisations in the form of blended finance. The use of such models helps to reduce investment risks for private investors whilst maintaining the market-based nature of financing without complete dependence on budgetary resources.

The fourth direction concerns the adaptation of management models to the conditions of green and military-economic transformation, which entails a review of approaches to risk management, financial planning and institutional interaction. Between 2022 and 2025, legislative changes were adopted in Ukraine in the energy and heat supply sectors, notably Law of Ukraine No. 4213-IX (2025). This law was aimed at removing regulatory barriers to the operation of energy enterprises by simplifying grid connection procedures, extending the validity of technical specifications and adapting requirements for the implementation of energy projects under martial law. These changes created a regulatory framework for the accelerated connection of renewable energy facilities to electricity grids, the introduction of a cable pooling mechanism, and the extension of the validity periods of technical specifications for projects whose implementation had been suspended due to hostilities. As a result, management models are gradually evolving towards greater flexibility, modularity and scalability following the conclusion of the active phase of hostilities. The systematisation of practical management solutions applied within the energy sector is presented in Table 2.

Table 2. Main directions for improving the efficiency of energy and investment process management

Management direction	Content of managerial decisions	Practical instruments
Corporate governance	Alignment of investment decisions with long-term energy objectives	Strategic development plans and internal investment committees
Financial planning	Enhancement of cash flow predictability	NPV, IRR, ROI, and long-term PPAs
Risk management	Formalisation and monitoring of key risks	Insurance, currency indexation, and diversification
Regional policy	Promotion of investment at the local level	Municipal programmes and infrastructure co-financing
Institutional support	Attraction of external sourcesof financing	Blended finance and the participation of multilateral financial organisations (MFOs)
Adaptation to wartime conditions	Flexibility in project implementation	Modularity and the phased commissioning of capacities

Source: compiled by the authors based on Ukraine approves $20 billion plan... (2024), Galnaftogaz Wind (n.d.)

Table 2 summarises the key directions for improving the efficiency of energy and investment management in Ukraine for the period 2022-2025 and demonstrates how they complement one another. The combination of corporate strategic planning, financial tools for cash flow forecasting and formalised risk management provided the basis for sustaining investment activity in an environment of limited access to capital. At the same time, the intensification of regional policy and institutional support in the form of blended finance, with the participation of international financial organisations, helped to reduce investment risks and enhance the projects' attractiveness to banks. Adapting management models to wartime conditions through modularity and the phased commissioning of capacity increased the flexibility of project implementation and laid the groundwork for the further scaling up of renewable energy in the post-war period.

A comparison with the study by M. Kowalska *et al.* (2025) made it possible to clearly delineate the difference between strategic-normative and operational-managerial approaches to energy transition. As in this study, the authors emphasised the need to integrate economic, social and environmental objectives into the development of the energy sector and highlighted the role of institutional mechanisms and public policy. At the same time, their analysis focused on the macro level – the interrelationship between socio-economic cohesion and sustainable energy development in EU countries, which led to recommendations being formulated primarily in terms of policy alignment and cross-sectoral coordination. Against this backdrop, the present study shifted the focus to applied mechanisms for managing energy and investment processes, detailing financial, regulatory and risk-oriented instruments adapted to capital shortages and heightened military risks. E. Cutore *et al.* (2023) proposed a formulation of the problem that was similar in content but different in logic. In both studies, the energy transition was viewed as a process requiring targeted management of investment flows and institutional support, as well as the creation of predictable conditions for attracting private capital. However, E. Cutore *et al.* operated within the context of a stable institutional environment, focusing on the optimisation of regulatory and policy instruments. In contrast, the present study was based on conditions of high uncertainty, where practical investment management mechanisms had to fulfil not only the function of improving efficiency, but also that of ensuring the continuity of energy projects given limited access to capital. The institutional dimension of the energy transition was explored in greater theoretical depth in the work by M.R. Di Nucci & A. Prontera (2023). Similar to the present study, the authors emphasised that the effectiveness of investments in renewable energy depends not only on financial resources, but also on the stability of regulatory frameworks, policy consistency and trust between the state, business and society. At the same time, M.R. Di Nucci & A. Prontera focused primarily on a political and institutional analysis of the energy transition within the framework

of stable European multilevel governance. In contrast, this study examined institutional decisions in conjunction with financial, guarantee and risk-oriented instruments, driven by the need to sustain investment activity amid the risks of war and infrastructure destruction.

A comparison with the study by A. Raihan *et al.* (2024) added an environmental and economic perspective to the analysis. In both studies, investment in renewable energy and energy efficiency was treated as a key instrument for decarbonisation and reducing the environmental impact, whilst government policy was seen as a factor in stimulating "green" transitions. However, A. Raihan *et al.* focused on macroeconomic and environmental analysis, assessing the impact of energy consumption and economic growth on greenhouse gas emissions in relatively stable economies. In contrast, this study examined environmental objectives through the prism of investment management in the energy sector, where the risks of war, infrastructure losses and limited access to financial resources significantly altered the practical logic of implementing the green transition. Between 2022 and 2025, the management of energy and investment processes in Ukraine evolved from centralised, tariff-oriented models towards more flexible, portfolio-based and risk-adapted approaches capable of functioning amid the uncertainty of war and limited access to capital. The key outcomes of this period were the institutionalisation of strategic planning, the expansion of project finance and corporate PPAs, the decentralisation of investment decisions, and the active use of blended finance mechanisms involving international financial organisations. Taken together, these changes formed the practical basis for enhancing the resilience of the energy sector, reducing investment risks and creating the conditions for post-war recovery and the scaling up of renewable energy in line with European strategic guidelines.

CONCLUSIONS

The conducted study demonstrated that the management of energy and investment processes in Ukraine during 2022-2025 evolved under conditions of unprecedented wartime risks, extensive destruction of energy infrastructure, and restricted access to financial resources, which substantially altered the logic of implementing an innovative and sustainable energy transition. It was established that, following a sharp decline in investment in 2022 (-49% compared with 2021), capital expenditure recovered in 2023 to UAH 109.3 billion, exceeding the pre-war level. Nevertheless, the structure of investment remained imbalanced due to the priority given to financing the restoration of core infrastructure, while the share of renewable energy sources accounted for only 1-5% of total investment. The analysis showed that annual investment in renewable and low-carbon energy during 2022-2025 amounted to USD 1.09 billion, whereas in the pre-war period the cumulative volume exceeded USD 12 billion. The dominance of solar energy (60-70% of investment) and the significant share of wind projects (20-30%) were driven by the speed of implementation, relatively lower capital intensity, and the growing prevalence of self-consumption models and corporate PPAs. In 2023 alone, investment in solar energy for businesses amounted to approximately USD 150 million, providing an average return on investment of 15-20% and a payback period of 5-7 years, thereby confirming the economic viability of such projects even under conditions of high uncertainty. It was established that international financial institutions played a key role in sustaining investment activity, providing 30-40% of financing for renewable energy projects and complementing private capital (50-60%) through guarantee and insurance mechanisms. In particular, the mobilisation of up to EUR 1 billion in investments for renewable energy and energy networks in 2024-2025, together with the establishment of new financial instruments with the potential to mobilise up to EUR 2 billion, created conditions for the partial mitigation of wartime risks and the reduction of investment uncertainty. Practical recommendations for improving the management of energy and investment processes involve a transition towards flexible and risk-adaptive management models capable of operating under wartime and post-war uncertainty. The application of a portfolio approach to the implementation of energy projects, with the phased commissioning of capacities, is considered appropriate, as it reduces

investment risks and enhances the financial resilience of enterprises. One of the key directions is the broader use of long-term contractual instruments (corporate PPAs and auction mechanisms with market premiums), which ensure the predictability of cash flows and income stability. At the institutional level, the efficiency of investment management may be enhanced through greater utilisation of blended finance mechanisms, guarantees, and wartime risk insurance involving international financial institutions, as well as through the further simplification of grid connection procedures and the development of cable pooling mechanisms. Prospects for further research lie in the more in-depth quantitative assessment of the effectiveness of investment instruments and energy project management models, taking into account post-war reconstruction and Ukraine's integration into the European energy market.

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Управління енергетичними та інвестиційними процесами в умовах інноваційного та сталого розвитку України

Анотація. Метою дослідження було визначення та систематизація ефективних управлінських рішень щодо узгодження енергетичних і інвестиційних процесів в Україні з вимогами інноваційного та сталого розвитку. Методологічною основою дослідження були порівняльно-структурний, інституційний, і нормативно-правовий аналізи, проблемно-орієнтований підхід, кейс-аналіз та описово-аналітичне узагальнення практики реалізації інвестиційних проєктів у сфері відновлюваної енергетики. Основні результати засвідчили, що у 2022 році обсяг капітальних інвестицій в енергетичний сектор України скоротився на 49 % порівняно з 2021 роком, однак уже у 2023 році інвестиційна активність почала відновлюватися, а загальні капітальні вкладення досягли 109,3 млрд грн. У 2022-2025 роках щорічні інвестиції у відновлювану та низьковуглецеву енергетику становили 1,09 млрд дол., тоді як у довоєнний період їх сукупний обсяг перевищував 12 млрд дол. Частка відновлюваних джерел енергії у структурі інвестицій енергетичного сектору залишалася в межах 1-5 %, а структура вкладень характеризувалася домінуванням сонячної (60-70 %) та вітрової генерації (20-30 %). У 2023 році інвестиції у сонячні електростанції для бізнесу становили близько 150 млн дол., забезпечуючи рентабельність 15-20 % і строк окупності 5-7 років. Упродовж 2022-2025 було введено понад 2 гігавати нових потужностей, що сприяло скороченню викидів CO_2 на 5-7 млн тонн щорічно. У ході дослідження було сформовано прикладні рекомендації з підвищення ефективності управління енергетичними та інвестиційними процесами, засновані на портфельному підході, довгострокових контрактних моделях і зниженні воєнних та регуляторних ризиків. Практичне значення дослідження полягає у використанні його результатів органами державної влади, енергетичними компаніями та інвесторами для обґрунтування управлінських рішень у сфері відновлюваної енергетики в Україні

Ключові слова: відновлювані джерела енергії; інвестиції; енергоефективність; менеджмент; біоенергетика; сталий розвиток; фінансування

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Financing the development of water infrastructure in Ukraine under conditions of full-scale military actions

Abstract. The purpose of the article was to investigate the sources, structure and mechanisms of financing the development of Ukraine's water infrastructure under conditions of full-scale military actions, as well as to substantiate directions for improving the financial provision of the sector in the context of post-war economic recovery. Particular attention was paid to assessing the role of state financing, international financial assistance and public-private partnership mechanisms in ensuring the functioning of river and port infrastructure. In the course of the research, a set of general scientific and specific methods was employed, including methods of analysis and synthesis, statistical analysis, comparison, generalisation, and systemic and institutional approaches. The informational basis of the research comprised Ukraine's regulatory and legal acts, statistical materials of state authorities, reports of international financial organisations, as well as the results of scientific research in the field of transport and water infrastructure development. The results of the research established that in 2020-2024 there was a substantial increase in the volume of financing for Ukraine's water infrastructure, which was driven by the need to ensure alternative logistics routes under conditions of the blockade of part of the seaports. In particular, the total volume of state financing of the sector grew from UAH 470 million in 2020 to UAH 2.77 billion in 2024, while international assistance attracted in 2022-2024 exceeded USD 500million. The main sources of financial provision of the sector were identified, including the state budget, international financial assistance and investments attracted through public-private partnership mechanisms. The growing strategic importance of Danube ports and inland waterways in ensuring export activity and maintaining the state's economic resilience was substantiated. The scientific novelty of the research lies in a comprehensive assessment of the current structure of financing Ukraine's water infrastructure under martial law and the identification of the features of the interaction

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between state, international and private financial resources in the processes of its development and recovery. The practical significance of the results obtained lies in the possibility of their use by public authorities, economic entities and potential investors in developing programmes for modernising water infrastructure and forming an effective financial policy in the field of transport logistics

Keywords: transport and logistics system; public-private partnership; international financial assistance; recovery; river corridors

INTRODUCTION

Water infrastructure is an important element of Ukraine's transport system, ensuring the functioning of logistics chains, the development of international trade and the stability of the economy. Water transport acquired particular significance during the period of full-scale military actions, when traditional maritime logistics routes were partially or completely blocked. The destruction of transport infrastructure, decline in investment activity, disruption of logistics links and restricted access to ports necessitated a revision of approaches to financing water infrastructure. Under these conditions, effective financial provision for the development of water transport became a critically important factor in ensuring the state's economic resilience. Financial provision for the development of water infrastructure and transport and logistics systems under conditions of war-induced crisis transformations is a relevant area of scientific research, given its significance for maintaining Ukraine's export capacity and economic recovery.

V.V. Prokhorova *et al.* (2025) investigated Ukraine's economic potential in the context of post-war recovery. The authors substantiated that the modernisation of the infrastructure complex is one of the basic prerequisites for accelerating economic growth and enhancing the state's competitiveness. At the same time, the issue of financing water infrastructure specifically remains insufficiently detailed. M. Hamdouna & M. Khmelyarchuk (2025) examined the impact of technological change on the economic development of enterprises. The researchers demonstrated that the introduction of innovations directly affects the efficiency of resource use and the formation of new competitive advantages. These conclusions are important for water infrastructure, the modernisation of which requires significantinvestment in digitalisation and technological renewal. F. Musiello-Neto *et al.* (2025) investigated a synergetic-emergent approach to developing enterprise competitiveness potential. The authors emphasised the need for a comprehensive combination of financial, organisational and innovative development mechanisms. This approach is also relevant for the field of water infrastructure, where the effectiveness of investments depends on the coordination of actions between the state, business and international partners. Research on the circular economy presented in the works of Yu. Danko & T. Shevchenko (2021) and T. Shevchenko & Yu. Danko (2022) is of significant interest. The authors substantiated the need to transition to resource-efficient development models and to introduce innovative mechanisms for managing infrastructure systems. The proposed approaches create a theoretical basis for forming long-term strategies for modernising transport and water infrastructure in accordance with the principles of sustainable development.

An important contribution to the study of mechanisms for developing transport infrastructure was made by a work that revealed the potential for using public-private partnership to modernise facilities of Ukraine's maritime economic complex. O.M. Aliabieva (2020) demonstrated that attracting private capital contributes to increasing the efficiency of infrastructure asset management and accelerating the implementation of investment projects. S.A. Mashkantseva (2020) investigated the innovative development of the transport industry within the system of multimodal transportation. The work substantiated the need to integrate different modes of transport and improve logistics chains, which is particularly relevant for the functioning of river and sea transport corridors. The project of the Ministry of Infrastructure of

Ukraine (2017) identified priorities for modernising the transport system and developing inland waterways. The document focused on the need to increase the investment attractiveness of the sector and form a modern infrastructure network in accordance with European standards. Practical aspects of port infrastructure development are covered in the "Kherson" specialized seaport concession (n.d.) and "Olvia" specialized seaport concession (n.d.). These documents present mechanisms for attracting private investment to modernise port facilities, demonstrating the promise of using concession models in the development of water infrastructure.

At the same time, an analysis of scientific works showed that the majority of studies are devoted to individual aspects of transport or water management infrastructure development, issues of innovative development, public-private partnership, or economic recovery. Insufficiently researched remain the issues of a comprehensive assessment of the sources of financing Ukraine's water infrastructure under conditions of full-scale military actions, their structure, effectiveness and the role of international financial support, which determines the relevance of this study. The purpose of the article was to substantiate the priorities of financial provision for the modernisation of Ukraine's water infrastructure under conditions of military challenges, taking into account available sources of financing, investment needs and prospects for improving the efficiency of resource management.

MATERIALS AND METHODS

The research was carried out on the basis of a comprehensive analysis of the processes of financing the development of Ukraine's water infrastructure under conditions of full-scale military actions. The type of research is an applied economic study using elements of comparative, statistical and institutional analysis. The research design involved a combination of quantitative and qualitative approaches for assessing the sources, structure and effectiveness of financing water infrastructure. The object of the research was the processes of financing the development of Ukraine's water infrastructure. The subject of the research comprised the economic relations, mechanisms, instruments and sources of financial provision for the development of river, port and logistics infrastructure under conditions of martial law. The informational basis of the research consisted of Ukraine's regulatory and legal acts, in particular Law of Ukraine No. 1054-IX (2020) and Law of Ukraine No. 2404-VI (2010), and materials of EU-Ukraine Solidarity Lanes (n.d.). The analysis also included the concessions of "Kherson" specialized seaport concession (n.d.) and "Olvia" specialized seaport concession (n.d.). The source and regulatory base was selected according to the following criteria: the official status of the source, the reliability of statistical data, the availability of quantitative indicators regarding the financing of infrastructure facilities, the relevance of information to the conditions of wartime and post-war recovery, and compliance with the subject of the research.

The time frame of the research covered 2020-2024. The choice of this period is due to several factors. First, it was during this period that significant institutional changes occurred in the field of inland water transport, associated with the adoption of specialised legislation and the reform of the sector's management system. Second, the period under study includes both the pre-war stage of water infrastructure functioning and the period of full-scale military aggression, which makes it possible to assess the transformation of financial mechanisms under conditions of crisis challenges. Third, it was during the selected period that the role of river logistics and international financial assistance in ensuring the resilience of Ukraine's export chains grew significantly. In the course of the research, a set of general scientific and specific methods was used. At the first stage, the method of analysis and synthesis was applied to generalise scientific approaches to financing infrastructure projects and to identify the features of water infrastructure development in Ukraine. At the second stage, an analysis was conducted of the dynamics of state financing, international assistance and investment inflows in 2020-2024. At the third stage, a comparative method was applied to assess the structure of financing and identify changes in investment priorities under the influence of military factors. At

the fourth stage, an institutional approach was used to investigate the role of state authorities, international organisations and public-private partnership mechanisms in financing the sector. At the final stage, the method of generalisation and logical modelling was applied to form conclusions and develop recommendations for improving the financial provision of the development of Ukraine's water infrastructure.

RESULTS AND DISCUSSION

The financing of water infrastructure in Ukraine during 2020-2024 became not only a subject of state policy but also an important element of the strategic provision of economic resilience under conditions of profound socio-political transformations caused by the war, the disruption of international supply chains and environmental threats. Water infrastructure, which includes river and sea ports, navigable waterways, locks, dams, canals, water transport facilities, and logistics hubs, plays a critically important role in ensuring the export potential of the agro-industrial complex, supporting international trade, and forming conditions for attracting investment in the transport and logistics sectors (Vasiliev & Simakhova, 2025). In the period after 2020, there was increased attention to the modernisation of water infrastructure both from the state and international partners. The adoption of Law of Ukraine No. 1054-IX (2020), the establishment of relevant state funds, and the active use of public-private partnership mechanisms made it possible to implement a number of projects aimed at improving the efficiency and environmental safety of water transport. At the same time, military actions, which significantly restricted maritime traffic in the southern regions of Ukraine, necessitated the prompt reorientation of export flows to alternative river routes, primarily through the Danube transport corridor. As a result, the need for additional financing of repair works, fairway dredging, modernisation of port infrastructure, and development of border crossings and logistics hubs increased.

International support programmes, in particular the EU-Ukraine Solidarity Lanes (n.d.) of the European Union (EU), gained particular importance during this period. Support was directed both towards restoring physical infrastructure and towards creating favourable institutional conditions for its further development. The engagement of private investors in the joint financing of water logistics projects within the framework of public-private partnership (PPP) became a new instrument for restoring economic activity in regions close to the front line, where infrastructure degradation had reached a critical level. During the period 2020-2024, the financing of Ukraine's water infrastructure from state budget funds was carried out in several key areas: modernisation of locks on the Dnipro, maintenance of inland waterways, investments in port infrastructure, and support for the sector through legislative and institutional changes. Following the adoption of Law of Ukraine No. 1054-IX (2020), budget expenditures for the maintenance of inland waterways were systematised for the first time, which made it possible to introduce a more predictable financing model. A special source was also created – funds from the river toll, which were directed to the State Specialised Fund for the Development of Inland Waterways. Table 1 shows the dynamics of budget financing of key areas of water infrastructure development in 2020-2024.

Table 1. State financing of Ukraine's water infrastructure, 2020-2024 (million UAH)

Year	Maintenance of IWW	Reconstruction of locks	Port infrastructure	Total volume
2020	0	150	320	470
2021	150	200	450	800
2022	380	290	500	1,170
2023	610	350	1,240	2,200
2024*	740	420	1,610	2,770

Note: IWW – inland waterways; * – forecast for the end of the year

Source: developed by the author based on Law of Ukraine No. 1054-IX (2020), Yurii Lytvyn: In 2023, cargo turnover... (2024), Y. Hryhorenko (2025)

As shown in Table 1, in 2020 no targeted financing of inland waterways was envisaged; however, the situation changed from 2021 onwards due to new legislation. The volume of financing grew steadily, reaching almost UAH 2.8 billion in 2024. The greatest dynamics was shown by the expenditure item related to the development of port infrastructure, in particular under conditions of the blockade of Black Sea ports and the rapid development of the Danube cluster. It is worth noting that in the structure of state financing, the main emphasis was placed on ensuring the navigational capacity of the main river arteries, primarily the Dnipro, through the maintenance of hydraulic structures, dredging works, and the modernisation of locks. In 2023, the state completed major repairs of the Kremenchuk lock, which made it possible to increase throughput capacity by more than 25%. In parallel with direct budget financing, the institutional structure of the sector was reformed: the Inland Waterways Administration was established, an electronic register of the river fleet was launched, and new mechanisms for public-private cooperation were introduced. Thus, state support was not only fiscal but also systemic in nature, contributing to the formation of prerequisites for private business participation.

Following the start of the full-scale invasion of Ukraine by the Russian Federation, international assistance became one of the key factors in the support, restoration and modernisation of critical water infrastructure, as confirmed by the initiatives of Updated Ukraine recovery... (2025), FAO launches a $150 million Emergency... (2025), and The European Bank for Reconstruction and Development... (2025). Against the backdrop of a decline in domestic investment resources, it was these sources that became the drivers of restoring the transport and logistics potential of Ukraine's river and port facilities. During 2022-2024, significant emphasis was placed on supporting logistics projects on the Danube, reconstructing facilities in the ports of Izmail, Reni and Ust-Dunaisk, and ensuring safe navigation. In 2023, the World Bank approved the allocation of $200 million for the development of critical infrastructure, part of which was directed towards dredging works at the mouth of the Bystre, which made it possible to restore navigation via an alternative sea corridor (Kolisnichenko, 2023a). Separate support was provided through the EU-Ukraine Solidarity Lanes (n.d.), within the framework of which measures were financed to increase the throughput capacity of Danube ports and improve integration with the European transport network. The volume and sources of support for Ukraine's water infrastructure are presented in Table 2.

Table 2. State financing of Ukraine's water infrastructure, 2020-2024 (million UAH)

Source of financing	Volume of support (million USD)	Main objectives
World Bank	200	Dredging, repairs, port modernisation
EBRD	120	Port infrastructure, export support
EU	100	EU-Ukraine Solidarity Lanes programme, technical assistance
FAO	35	Projects for adapting infrastructure to climate change
United States Agency for International Development, other donors	50	Logistics, navigation safety

Source: V. Kolisnichenko (2023a), The European Bank for Reconstruction and Development... (2025), EU-Ukraine Solidarity Lanes (n.d.)

An analysis of the data presented shows that the total volume of international financial support for Ukraine's water infrastructure exceeded USD 500 million, with almost half of the funds directed towards rapid-response projects in 2022-2023. International partners provided not only finance but also technical expertise, including assessment of the condition of critical facilities, modelling of export flows, logistics solutions and environmental impact. An in-depth analysis of the structure of financing Ukraine's water infrastructure shows that

during the period under study, significant changes occurred not only in the absolute volumes of financial resources but also in the ratio between individual sources of their formation. While before 2022 a development model prevailed that was based predominantly on state financing and limited attraction of private capital, since the beginning of the full-scale war a new financial architecture of the sector has been forming, in which international financial institutions, donor organisations and public-private partnership mechanisms are playing an increasingly important role. The growing importance of international financial support is explained not only by the need to restore damaged infrastructure facilities but also by the necessity of rapidly adapting the transport and logistics system to new operating conditions. The blockade of a significant part of maritime routes and the change in export routes caused substantial pressure on inland waterways and Danube ports. As a result, there arose a need for large-scale dredging works, modernisation of transshipment complexes, expansion of warehouse infrastructure, and renewal of navigation equipment. The role of the Danube transport cluster in ensuring Ukraine's export potential deserves particular attention. It was the ports of Izmail, Reni and Ust-Dunaisk that became important hubs for the transportation of agricultural products, metallurgical raw materials and other types of cargo during the period of military actions (Kolisnichenko, 2023b). As a result, cargo turnover at these ports increased several times compared to the pre-war period. At the same time, the rapid increase in transportation volumes revealed a number of infrastructure limitations related to insufficient berth capacity, a limited quantity of transshipment equipment, and the need to modernise logistics processes.

An analysis of international experience shows that the development of water infrastructure in EU countries is based on the principles of long-term strategic planning, integration of transport networks, and diversification of financial resources. As noted by Z. Xiao & J.S.L. Lam (2022), in most EU countries the financing of infrastructure projects is carried out through a combination of budgetary funds, credit resources of international financial institutions, grant programmes and private investment. It is precisely this model that ensures the resilience of infrastructure project implementation even under conditions of economic instability. For Ukraine, the use of a similar approach is becoming particularly relevant. Given the limited state financial resources and the significant scale of destruction caused by military actions, the further development of water infrastructure is impossible without the active attraction of external financing. At the same time, an important task is not only to increase the volume of investment but also to improve the efficiency of its use by enhancing the mechanisms of planning, monitoring and control over the implementation of infrastructure projects. An important area of water infrastructure modernisation is the introduction of digital technologies for managing transport flows. Under modern conditions, the competitiveness of transport systems is largely determined by the level of digitalisation of management processes. The use of automated vessel traffic monitoring systems, electronic document management, digital platforms for coordinating logistics operations, and technologies for forecasting cargo flows makes it possible to significantly reduce time and financial costs, increase the transparency of infrastructure facility operations, and minimise the risks of logistics delays (Raza *et al.*, 2023). In addition to the economic effect, investments in water infrastructure have a significant multiplier effect on the development of related sectors of the economy. The implementation of infrastructure projects stimulates the development of the construction industry, mechanical engineering, logistics, energy and the services sector. The creation of new logistics hubs and transport corridors contributes to the formation of additional jobs, increased business activity in regions, and expanded opportunities for attracting domestic and foreign investors.

At the same time, the analysis conducted makes it possible to identify a number of risks that may hinder the further development of the sector. These include a high level of war-related uncertainty, insufficient predictability of budget financing, lengthy approval procedures for infrastructure projects, and limited opportunities for insuring investment risks. The presence of these factors negatively affects the

investment attractiveness of the sector and may reduce the interest of potential investors in implementing long-term projects. In this regard, one of the priority areas of state policy should be the formation of a favourable institutional environment for attracting investment in the development of water infrastructure. This concerns improving the legislative framework, increasing the transparency of infrastructure project implementation, creating effective mechanisms of state guarantees, and ensuring the stability of the regulatory environment. The implementation of these measures will make it possible to create the prerequisites for the sustainable functioning of water infrastructure and its transformation into one of the key factors of Ukraine's economic recovery in the post-war period. FAO's technical assistance was particularly important in restoring irrigation systems and water intakes, as well as in equipping river harbours with communication facilities, GPS navigation, and hydrographic instruments (FAO launches a $150 million Emergency..., 2025). For its part, the EU supported the development of digital platforms for managing river transport and the throughput capacity of border logistics hubs (Ukraine: EU supports eQueue..., 2025). Thus, international assistance proved to be systemic, multi-level, and such that it not only compensated for losses but also created a new quality of logistics and water infrastructure. These initiatives enabled Ukraine, under critical conditions, not merely to preserve the functionality of river transport but also to adapt it to new geopolitical realities, making it a cornerstone element of agricultural export.

In the context of limited budgetary resources, the critical need for infrastructure restoration, and the strategic importance of waterways, Ukraine is actively implementing public-private partnership mechanisms as an instrument for attracting long-term investment in river and port infrastructure. During the period 2020-2024, PPP became one of the key forms of financing the modernisation of water transport, making it possible to attract private sector resources, reduce pressure on the state budget, and ensure flexibility in the implementation of infrastructure projects. PPP was most actively implemented in the field of port management. Thus, successful cases include the concession agreements at the ports of "Olvia" and "Kherson", signed before the full-scale invasion by the Russian Federation in 2022, the implementation of which nevertheless continued under extremely difficult conditions. Investors not only fulfilled their obligations regarding berth repairs but also launched new logistics services, including alternative channels for grain transportation by river (A memorandum was signed on the restoration..., 2025; "Kherson" specialized seaport concession, n.d.). Despite the military actions, these examples proved the effectiveness of PPP as an instrument for the development of the sector. Since 2022, an active dialogue has begun regarding the expansion of public-private cooperation mechanisms in the Danube delta (Kolisnichenko, 2023a). The Government of Ukraine has created conditions for private companies to invest in the creation of new transshipment terminals, the restoration of floating docks, and ship-repair capacities. In particular, in the territory of the port of Reni, a private operator launched a new transshipment line for agricultural products with a throughput capacity of over 1 million tonnes per year in 2023. The project was financed through the company's own funds and bank loans, but with state support through the simplification of permitting procedures. Table 3 demonstrates the key initiatives for the development of Ukraine's water infrastructure.

Table 3. Main PPP projects in the field of Ukraine's water infrastructure (2020-2024)

Facility	Type of project	Volume of investment (million USD)	Form of partnership	Results
Port of "Olvia"	Concession	125	PPP (concession agreement with QTerminals, Qatar)	Modernisation of berths, new warehouses
Port of "Kherson"	Concession	12	PPP with the company Risoil-Kherson	Restoration of terminals, attraction of cargo
Reni (terminal)	Private investment with state support	20	Investment project with simplified access to land	Creation of new capacities of 1 million tonnes

Table 3, Continued

Facility	Type of project	Volume of investment (million USD)	Form of partnership	Results
Ust-Dunaisk	Reconstruction of harbour	10	Support of private operators through the United States Agency for International Development programme	Renewal of navigation

Source: developed by the author based on V. Kolisnichenko (2023a; 2023b), A memorandum was signed on the restoration... (2025), "Kherson" specialized seaport concession (n.d.), "Olvia" specialized seaport concession (n.d.)

Considering the results of PPP implementation, it can be argued that one of the most significant achievements was the reduction of infrastructure's dependence on exclusively budgetary financing. The terms of partnership made it possible to attract innovations, technologies, and experience in managing port facilities. For example, the Qatari company that manages the port of "Olvia" introduced new logistics models that take into account the risks of the armed conflict and changes in export routes. The success of using PPP mechanisms is also confirmed by the active participation of international financial institutions – in particular, EBRD supports concession... (2020) and International Finance Corporation (IFC) and EBRD to help modernize Chornomorsk Port... (2021), which have repeatedly declared their readiness to participate in co-financing such initiatives. In addition to financial participation, these organisations provided advisory support and conducted assessments of the economic feasibility of projects. At the same time, the full-scale deployment of large-scale PPP in the water infrastructure sector requires the improvement of the regulatory framework. Law of Ukraine No. 2404-VI (2010) has undergone updates but still requires adaptation to wartime and post-war realities, in particular regarding investment security guarantees. The analysis conducted made it possible to generalise the features of financing the development of Ukraine's water infrastructure during the specified period and to assess the contribution of state, international and private sources to the restoration of port and river infrastructure. It was established that state financing predominantly ensured priority needs, while international support and private investment played the leading role in implementing modernisation and development projects. An analysis of public-private partnership mechanisms demonstrated the growing role of business in infrastructure modernisation. Enterprises, despite the risks, are initiating investments in river terminals, barge fleets, elevator capacities and transshipment hubs, particularly in the Danube basin. At the same time, legal and regulatory barriers significantly reduce PPP potential, which requires targeted reforms at the legislative level. As A. Pedko & O. Yemelianov (2025) emphasised, the experience of EU countries, in particular Poland, the Netherlands and Romania, could be integrated into the creation of a favourable institutional environment for implementing long-term infrastructure projects with the participation of private capital.

The results of the research conducted are generally consistent with the conclusions of contemporary scientific works devoted to the financial provision of water infrastructure development, water use, and institutional mechanisms of water resource management. Thus, O.I. Bondar *et al.* (2021) substantiated the need to diversify sources of financing the water sector and strengthen the role of investment mechanisms in ensuring its sustainable development. The results obtained in the present study confirmed this position, as it was established that exclusively budgetary financing does not provide the necessary volumes of water infrastructure modernisation, especially under conditions of martial law. The conclusions of D.O. Butskykh (2023) regarding the importance of state regulation in the field of water supply and sanitation also correspond to the results of this study. The author emphasised the need to improve institutional mechanisms for managing the sector. In turn, the analysis showed that the effectiveness of financial resource use largely depends on the quality of regulatory provision and coordination between state institutions. O. Labenko & M. Klymenko (2025) examined

the financial provision of water resource reproduction as a component of environmental economics. In contrast to their approach, this article focuses not only on the natural resource aspect but also on the logistics and transport function of water infrastructure. At the same time, both studies confirmed the need for long-term investment programmes and the combination of state and private sources of financing.

A. Pedko & O. Yemelianov (2025), in their comparative study of budget financing models for water supply in Ukraine and Group of Seven countries, proved the feasibility of using mixed financial models. The results actually confirmed this conclusion, as the greatest effectiveness in water infrastructure development was demonstrated by projects implemented with the participation of the state, international organisations, and private capital. N. Andryeyeva *et al.* (2021) substantiated the influence of state economic policy on the development of infrastructure and natural resource systems. The results obtained supplemented these conclusions, demonstrating that under conditions of military challenges, it is state policy that determines the priorities for allocating financial resources among various segments of transport and water infrastructure. M.V. Slobodianyk (2025) emphasised the need to ensure the financial and economic sustainability of water sector enterprises by modernising sources of financing and improving the efficiency of resource management. Similar trends were identified in this study regarding port and river infrastructure, where the level of sustainability directly depends on the diversification of financial sources. J. Berbel *et al.* (2017) and V. Vyhovska *et al.* (2022) examined economic instruments for stimulating rational water use. Despite the difference in the subject area of research, their conclusions confirm the importance of economic incentives as a factor in improving the efficiency of managing water resources and infrastructure facilities. Z. Derii *et al.* (2021) investigated problems of water use in the context of the sustainable development paradigm. In contrast to that work, the present study focuses primarily on the financial mechanisms of water infrastructure development. At the same time, both approaches demonstrated the need to combine economic, environmental and institutional instruments to ensure the long-term effectiveness of the water sector. Thus, the results of the research conducted do not contradict contemporary scientific approaches but extend them through a comprehensive analysis of state financing, international assistance, and public-private partnership mechanisms in the development of Ukraine's water infrastructure under conditions of full-scale war.

CONCLUSIONS

In the course of the research, it was established that it was river ports and shipping canals that ensured the stability of exports under conditions of the maritime blockade. The growth in transshipment volumes through the ports of Izmail, Reni and Ust-Dunaisk became a critical compensator for losses caused by the blockade of the Black Sea gateway. The materials analysed showed a 3.5-fold increase in cargo turnover at these ports over the period 2021-2023, which confirmed the effectiveness of resource mobilisation and management decisions under crisis conditions. At the same time, this dynamic could not have been sustainable without significant capital investment in the restoration of locks, dredging, the procurement of new vessels, and the repair of hydraulic structures. The implemented initiatives for the digitalisation of logistics processes, including systems for tracking the movement of cargo and vessels, indicated a gradual transition to a modern model of water infrastructure management. However, the pace of innovation implementation remained slower than in comparable sectors in European countries. This necessitated the stimulation of investment in technology startups capable of ensuring the accuracy, safety and predictability of logistics flows.

The overall results demonstrated that the main prerequisite for the long-term restoration of water infrastructure was the coordination of efforts between the state, international partners and private business. To this end, it is necessary to strengthen strategic planning, adopt a medium-term financing programme with transparent monitoring mechanisms, update legislation on inland water transport, and ensure scientific and analytical support for each project. It is emphasised that, in the future,

Ukraine could transform river infrastructure into one of the centres of post-war economic recovery, where waterways would serve not only for transportation but also as a mechanism for deeper integration into the European space of sustainable development. An important result of the study was the establishment of a direct relationship between the level of water infrastructure development and ensuring the resilience of Ukraine's agricultural exports. During the period of full-scale war, it was river transport corridors that made it possible to partially compensate for the loss of maritime port throughput capacity and to ensure the continuity of foreign economic activity. This provides grounds for considering the financing of water infrastructure not only as a sectoral instrument of transport policy but also as a component of the state's food security system and support for the competitiveness of the agro-industrial complex. The analysis conducted also demonstrated that further improvement in the efficiency of financial resource use requires the introduction of a comprehensive infrastructure project monitoring system that would ensure the assessment not only of the volumes of funds disbursed but also of the socio-economic results of the implementation of relevant measures. The prospects for further research should be linked to modelling the effectiveness of investment in water infrastructure, optimising sources of financing for post-war recovery, and assessing the impact of river logistics modernisation on the export potential and competitiveness of Ukraine's economy.

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Фінансування розвитку водної інфраструктури в Україні в умовах повномасштабних військових дій

Анотація. Метою статті було дослідження джерел, структури та механізмів фінансування розвитку водної інфраструктури України в умовах повномасштабних військових дій, а також обґрунтування напрямів удосконалення фінансового забезпечення галузі в контексті післявоєнного відновлення економіки. Особливу увагу приділено оцінці ролі державного фінансування, міжнародної фінансової допомоги та механізмів державно-приватного партнерства у забезпеченні функціонування річкової та портової інфраструктури. У процесі дослідження використано комплекс загальнонаукових і спеціальних методів, зокрема методи аналізу та синтезу, статистичного аналізу, порівняння, узагальнення, системного та інституційного підходів. Інформаційну базу дослідження становлять нормативно-правові акти України, статистичні матеріали державних органів влади, звіти міжнародних фінансових організацій, а також результати наукових досліджень у сфері розвитку транспортної та водної інфраструктури. За результатами дослідження встановлено, що у 2020-2024 роках відбулося суттєве зростання обсягів фінансування водної інфраструктури України, що було зумовлено необхідністю забезпечення альтернативних логістичних маршрутів в умовах блокування

частини морських портів. Зокрема, загальний обсяг державного фінансування галузі зріс з 470 млн грн у 2020 році до 2,77 млрд грн у 2024 році, а залучена міжнародна допомога у 2022-2024 роках перевищила 500 млн дол. Визначено основні джерела фінансового забезпечення галузі, серед яких державний бюджет, міжнародна фінансова допомога та інвестиції, залучені через механізми державно-приватного партнерства. Обґрунтовано зростання стратегічного значення дунайських портів та внутрішніх водних шляхів у забезпеченні експортної діяльності та підтриманні економічної стійкості держави. Наукова новизна дослідження полягає у комплексній оцінці сучасної структури фінансування водної інфраструктури України в умовах воєнного стану та визначенні особливостей взаємодії державних, міжнародних і приватних фінансових ресурсів у процесах її розвитку та відновлення. Практична значущість отриманих результатів полягає у можливості використання сформульованих висновків і рекомендацій органами державної влади, суб'єктами господарювання та потенційними інвесторами під час розроблення програм модернізації водної інфраструктури та формування ефективної фінансової політики у сфері транспортної логістики

Ключові слова: транспортно-логістична система; публічно-приватне партнерство; міжнародна фінансова допомога; відновлення; річкові коридори

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