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ORIGINAL PAPER
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# CURRENT STATE ASSESSMENT OF THE INVESTMENT IN LAND RESOURCES IN THE AGRICULTURAL SECTOR OF UKRAINE

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## ABSTRACT

**Motives:** The agricultural sector of Ukraine faces severe challenges caused by the war and economic instability, which have significantly reduced its investment attractiveness. Infrastructure destruction, uncertainty, and land degradation have weakened the sector's capacity for recovery and sustainable development.
**Aim:** The article aims to assess the current state of investment in agricultural land resources, identify key risk factors, and develop an adaptive risk assessment model to support post-war recovery.
**Results:** A comprehensive investment risk assessment model integrating war-related impacts, land condition indicators, contamination levels, and recovery potential is proposed. A scenario-based analysis was conducted, and adaptive strategies for mitigating risks were suggested. The findings emphasize the crucial role of effective public policy in strengthening investor confidence, ensuring food security, and supporting sustainable economic recovery.

**Keywords**: sustainable development, land management, agriculture, investment activity, risk assessment

## INTRODUCTION

Investments in land resources in the agricultural sector are a key factor determining the efficiency of agricultural production, the stability of the national economy and the level of food security in the country. Land resources, as a basic element of agricultural production, require a systematic approach to their assessment and investment flows management, since a significant part of agricultural enterprises face problems of soil degradation, reduced fertility and insufficient use of territories' potential due to limited access to modern technologies (Koshkalda et al., 2023).

Before the outbreak of full-scale war, the agricultural sector was one of the leading drivers of Ukraine's economy, providing a significant share of foreign exchange earnings and jobs. In the current

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context of military action and global climate change, investment in land resources is strategically important. They should be aimed not only at restoring production capacity, but also at achieving long-term socio-economic results related to increasing the profitability of enterprises, preserving natural capital and introducing innovative technologies in land use (Yarmolenko, 2024).

The destruction of infrastructure and production capacities in the agricultural sector because of military operations highlights the need for comprehensive restoration of the industry, which, in turn, leads to an increased need to attract investment resources to ensure its sustainable functioning. At the same time, a key obstacle remains the high level of uncertainty caused by military risks, which negatively affects the investment attractiveness of Ukraine's agricultural sector.

According to an assessment conducted by the World Bank (Ecoaction, 2023), during the first year after the full-scale invasion (February 2022 – February 2023), direct losses to the agricultural sector amounted to US$8.7 billion, indirect losses due to reduced production capacity amounted to US$31.5 billion and total losses amounted to US$40.2 billion. The cost of demining is estimated at $37.6 billion and the cost of reconstructing irrigation systems at over $8.9 billion. The total cost of restoring Ukraine's agriculture in 2024–2033 is estimated at $29.7 billion. These data indicate the need to develop an effective state policy to attract investment in land resources as the basis for the restoration and development of the agricultural sector. Such a policy should be aimed at increasing the efficiency of land use, improving its quality, ensuring rational land use and creating a safe investment environment.

Modern scientific research increasingly focuses on issues related to investment in land resources in the context of food security and sustainable land use. Foreign and Ukrainian scientists study the economic efficiency of investments, legal regulation of land relations, the impact of foreign capital and the possibilities of digitalisation to improve the efficiency of land resource management. At the same time, there is a certain fragmentation in approaches: most studies focus either on financial or environmental aspects and less often on an integrated assessment of investment risks.

International studies show that the development of global value chains, digital innovations and sustainable development policies is significantly transforming agricultural markets. According to a FAO report (FAO, 2020), more than a third of global agricultural trade takes place within global value chains, creating new opportunities for investment in land infrastructure. At the same time, small farmers' limited access to financial resources and technology remains a key obstacle (FAO, 2020). Pickson et al. (2024) emphasise that public policy should stimulate private investment in the agricultural sector, while Belhadi et al. (2021) and Donckt et al. (2022) highlight the importance of a stable institutional environment for increasing investment activity.

Research by Zhao and Chen (2023) demonstrates the uneven distribution of global investment in agriculture: countries with the highest levels of food insecurity receive only about 20% of total agricultural investment. In wartime conditions, this imbalance is exacerbated, particularly in Ukraine, which negatively affects the stability of global food markets (Behnassi & El Haiba, 2022; Ben Hassen & El Bilali, 2022; Lin et al., 2023). Researchers note that the war has led to increased logistics costs, resource shortages and reduced access to external markets (Amicarelli et al., 2023), which directly reduces the investment attractiveness of agricultural production.

Ukrainian scientists also emphasise the complexity of the investment environment and the need for a systematic approach to its restoration. Tkachenko (2021) points to imperfect tax policy and a shortage of credit instruments as the main constraints on the investment process. Koshkalda and Dombrovska (2025) classify the restraining factors such as instability of the regulatory environment, manufacturers' low level of awareness regarding innovations, limited access to finance and identify areas for intensifying investment activity. Other studies emphasise the importance of environmentally oriented land use

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(Yarmolenko, 2024) and the need to build a modern investment management system based on digital technologies and sustainable development principles (Finagina et al., 2021; Sadovyy et al., 2022).

Despite the difficult situation, some researchers (Kurman, 2023; Makaliuk et al., 2023) note that even in wartime, there has been a gradual revival of investment activity, indicating the potential for recovery in the industry. To make this happen, we need deep institutional reforms, like improving the legal framework, making sure things are transparent, and protecting property rights. Segeda (2023) emphasises the advisability of investing in the modernisation of production facilities and the development of the processing industry, while Saik et al. (2024) offer an environmentally balanced model for the use of degraded land based on the LDN (Land Degradation Neutrality) concept.

Summarising the results of previous studies, it can be argued that the current state of investment in land resources in Ukraine is determined by a combination of military, environmental and institutional risks. Despite considerable scientific interest in this issue, there is still no single methodology for the quantitative assessment of risks associated with investing in land resources that would integrate economic, environmental and security factors. Filling this scientific gap is the main objective of further research.

The research hypothesis is that an integrated assessment of investment risks in land resources, based on a multifactorial model, will make it possible to quantitatively determine the investment attractiveness level of agricultural areas and identify regional priorities for post-war agricultural recovery.

## MATERIALS AND METHODS

The main materials used in the study are statistical data for 2018–2024 obtained from open sources: the State Statistics Service of Ukraine (indicators of agricultural land structure, investment volumes in agriculture, financial results of enterprises), the Ministry of Agrarian Policy and Food of Ukraine (data on the state of the land fund, land restoration and reclamation) and analytical reports of the World Bank, FAO and OECD for international comparison of investment risks in the agricultural sector. To estimate the current state of investment in land resources in the agricultural sector, a set of methods was applied, including literature analysis to study current scientific approaches to investment and investment risk assessment, quantitative economic analysis to assess key economic indicators of the investment climate and the state of land resources, modelling of the integrated Investment Risk Index (IRI) to quantitatively assess the investment attractiveness level of regions and scenario analysis to forecast possible changes in the investment climate in the agricultural sector under various conditions of recovery and modernisation of the industry. The application of these methods allows to perform a comprehensive assessment of the investment current state in land resources, considering economic, environmental and military factors, as well as determining priorities for the post-war recovery of the agricultural sector.

We have proposed a risk assessment model for investors in the agricultural sector that considers the consequences of the war, the state of the land fund, the level of pollution and the prospects for recovery. Formula for the Integral Risk Index (IRI):

$$IRI = WRI \times w_1 + AERI \times w_2 + EFRI \times w_3 - RPI \times w_4 \quad (1)$$

where:

WRI – War-Related Risks Index;
AERI – Agro-Ecological Risks Index;
EFRI – Economic & Financial Risks Index;
RPI – Recovery Potential Index;
$w_1$, $w_2$, $w_3$, $w_4$ – weighted coefficients.

Weighted coefficients ($w_1$–$w_4$) were determined based on literature analysis and multi-criteria risk assessment methodology (AHP) (FAO, 2022a; Ishizaka & Labib, 2011; Pylypenko et al., 2025; Saaty, 2008), which allows considering the relative importance of each component of the index and ensuring the scientific comparability of the assessment results with international practices. The proposed weighted

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coefficients indicate the priority of the military factor in the structure of the integrated risk assessment: $w_1 = 0.35$ for the War-Related Risks Index (WRI), as it has a decisive influence on the condition and use of agricultural land; $w_2 = 0.25$ for Agro-Ecological Risks Index (AERI), as environmental conditions are important but less critical than military ones; $w_3 = 0.25$ for Economic & Financial Risks Index (EFRI), which shape the investment attractiveness of the territory; and $w_4 = 0.15$ for the Recovery Potential Index (RPI), which reduces the overall level of risk but has relatively less weight compared to other components.

Each criterion is assessed on a standardised scale from 0 to 1, where: 0 – no risk/negative impact, 1 – maximum risk/critical condition. Standardisation ensures the comparability of different data types and enables an integrated assessment.

The model is based on a multifactor risk analysis and uses an integral risk index (IRI) that takes into account four key groups of factors (Table 1).

In the model, formula (2) reflects an integral assessment of military risks for investing in land resources, combining key parameters that directly affect the possibility of effective land resources use in agriculture. The weighted coefficients of the integral War-Related Risks Index (WRI) are determined based on data from previous scientific studies, which used the analytical hierarchy process (AHP) to assess risks in agriculture and agricultural investments (FAO, 2022b; Klymenko et al., 2023; Ma et al., 2022; Tian & Tunio, 2023). The use of these weighted coefficients makes it possible to consider the relative significance of key risk factors such as the level of land damage, mine danger, physical security and institutional stability. The weights obtained ensure the comparability of results and consistency with international practices for assessing agricultural risks. Explanation of weighted coefficients:

- 0.4 (Level of land damage) is the main factor in the loss of land functionality, which directly affects its suitability for agricultural use;
- 0.3 (Mine danger) is one of the critical risks that limits investment activity and increases the cost of demining;
- 0.2 (Physical security) determines the stability of production and preservation of tangible assets in the medium term;
- 0.1 (Institutional stability) indirectly affects the level of risk but shapes the long-term territory attractiveness for investment.

Formula (3) reflects the integral assessment of Agro-Ecological Risks Index (AERI), which considers the main threats to the sustainability of land resources: soil contamination with heavy metals, erosion processes, hydrological disturbances and reduced bioproductivity. Weighted coefficients (0.3; 0.3; 0.2; 0.2) were determined based on international approaches to land degradation assessment developed by FAO (2020, 2022c), EEA (2021), Lal (2020), Bai et al. (2008), Micallef et al. (2023) and adapted to the conditions of Ukraine according to research Gulich et al. (2024); Kucher (2025). This index structure allows for a systematic assessment of environmental factors impact on the risks of investing in land resources and their integration into the overall risk model for Ukraine's agricultural sector.

The Economic & Financial Risks Index (EFRI) is determined by formula (4) and reflects the impact of key financial and economic factors on the investment attractiveness of the agricultural sector. The index includes the availability of credit for agricultural enterprises, fluctuations in agricultural product prices, access to markets and the level of state support for the agricultural sector. Each factor is normalized on a scale of 0–1 or as a percentage and then integrated into a weighted formula: 0.4 for credit availability, 0.3 for price volatility, 0.2 for market access and 0.1 for government support. The weighted coefficients are determined based on an analysis of previously published studies on financial risk assessment in the agricultural sector and multifactor models of investment attractiveness (FAO, 2022a; Lehenchuk et al., 2023; OECD, 2021; Semenenko et al., 2024; Vasylchuk & Izmaylova, 2025; World Bank, 2023b). This approach allows for the relative importance of financial and economic factors to be considered and ensures that the assessment results are scientifically comparable with international practices.

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**Table 1**. A risk assessment model for investors in the agricultural sector that takes into account the effects of the war, the state of the land fund, the level of pollution and the prospects for recovery

| Features | Calculation formula |
|---|---|
| 1. War-Related Risks Index (WRI)<br>Evaluation criteria:<br>1.1. Level of damage to agricultural land<br>1.2. Presence of minefields and military contamination<br>1.3. Level of physical security of the region<br>1.4. Institutional stability (legislative initiatives to protect investors, legal guarantees, anti-corruption mechanisms) | WRI = 0.4 × (Damage level) + 0.3 × (Mine danger) + 0.2 × (Physical security) + 0.1 × (Institutional stability), (2) |
| 2. Agro-Ecological Risks Index (AERI)<br>Evaluation criteria:<br>2.1. Soil pollution with heavy metals and chemicals<br>2.2. Level of land erosion and degradation<br>2.3. Changes in the hydrological regime (presence of drainage system disruptions, flooding, drought)<br>2.4. Decrease in biological productivity of soils (coefficient of yield reduction) | AERI = 0.3 × (Soil pollution) + 0.3 × (Land erosion) + 0.2 × (Hydrological changes) + 0.2 × (Biological productivity), (3) |
| 3. Economic & Financial Risks Index (EFRI)<br>Evaluation criteria:<br>3.1. Availability of credit for the agricultural sector<br>3.2. Fluctuations in agricultural prices<br>3.3. Access to markets<br>3.4. Level of state support for the agricultural sector | EFRI = 0.4 × (Availability of credit) + 0.3 × (Prices fluctuations) + 0.2 × (Access to markets) + 0.1 × (State support), (4) |
| 4. Recovery Potential Index (RPI)<br>Evaluation criteria:<br>4.1. The level of investment in the restoration of the agricultural sector (amount of investment as a percentage of the region's GDP)<br>4.2. Rate of demining of territories<br>4.3. The level of support from international organizations (financial grants, preferential lending, strategic programs)<br>4.4. Innovation potential (implementation of smart farming, use of environmental technologies in agriculture) | RPI = 0.4 × (Investment in recovery) + 0.3 × (Demining rate) + 0.2 × (International support) + 0.1 × (Innovative potential), (5) |
| Model application:<br>If IRI > 0,70, high risk → state support and additional guarantees are needed<br>If IRI = 0,40–0,70, medium risk → investment insurance and analysis of recovery prospects are recommended<br>If IRI < 0,40, low risk → investment is appropriate, with a focus on expanding agricultural production | |

*Source*: own elaboration.

The integrated Recovery Potential Index (RPI) assesses the ability of the agricultural sector to recover quickly after military and economic shocks (formula 5). The index includes: the level of investment in the recovery of the agricultural sector, the pace of demining, the level of support from international organisations and innovation potential (the introduction of smart farming and environmental technologies). The weighted coefficients of the RPI index are based on the results of previous studies covering the topics of post-conflict recovery of the agricultural sector, international support, innovation and investment in modernisation. This way, investment in restoration is the main factor (weight 0.4) as this is confirmed by the conclusions of FAO and OECD and other scientific studies that the Ukrainian agricultural sector needs tens of billions of dollars in investment (Broyaka et al., 2025; FAO, 2022a;

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OECD, 2024), the pace of demining/reconstruction (weight 0.3) is consistent with the analysis of the Centre for Strategic and International Studies on the need for rapid decontamination of territories and reconstruction of logistics and production chains (CSIS, 2025), level of international support – weight 0.2 is based on data on grants, credit lines and other forms of external assistance allocated to Ukraine (Ministry of Economy, Environment and Agriculture, 2024; Ukrainian Agrarian Confederation, 2023), innovative potential – weight 0.1 is considered to be a strategic factor for the long-term sustainability and modernisation of the agricultural sector.

This approach allows to systematically assess the complex risks of investing in Ukraine's agricultural sector, considering military, environmental, economic and renewable factors and integrating them into a single model to support investor decision-making.

## RESULTS

The agricultural sector was the main driving force of Ukraine's economy before the outbreak of the full--scale war and will continue to play an important role in the recovery process. Attracting investments is primarily aimed at ensuring the growth of profitability of enterprises, preserving their capital, and achieving socially significant results (Yarmolenko, 2024). In the context of the agricultural sector, these goals are complemented by the objectives of increasing soil fertility, using modern agricultural technologies, improving business conditions, and introducing innovations in livestock production, which ultimately contributes to improving the quality of life of the rural population. An important area of investment in today's environment is the elimination of the consequences of military operations: demining of agricultural land, reconstruction of damaged or destroyed infrastructure, purchase of new equipment to replace the lost equipment, provision of seeds, fuel, oils, lubricants, plant protection products, and restoration of livestock potential.

In recent years, the structure of capital investment in Ukraine has shown variable trends driven by both external and internal factors. The main industries that consistently remain leaders in terms of capital investments are industry, agriculture, transportation and real estate (Table 2).

In particular, industry accounts for the largest share of investment, on average 35–36% of total investment in 2018–2024. This indicates a high interest in developing production capacity and modernizing enterprises.

Among other industries, there has been a decline in investment in construction, financial and insurance activities, and information and telecommunications technologies. This is due to high risks, uncertainty in legislation, and a general decline in the investment climate in the context of the armed conflict.

In general, the analysis of investment flows dynamics by type of economic activity shows a reorientation of resources to strategically important sectors, in particular those that ensure food security, technological self-sufficiency and infrastructure sustainability of the state.

Agriculture consistently holds the second place, which indicates the strategic importance of the agricultural sector for the Ukrainian economy. In recent years, there has been an unstable dynamics of investments in agriculture due to changes in land legislation (opening of the land market, updating of lease mechanisms), macroeconomic situation (inflation, availability of loans for agribusiness), geopolitical risks (military actions, loss of some agricultural land), changes in demand for agricultural products (global trends in environmental standards, increased competition) (Fig. 1).

Several key trends can be noted from Fig. 1:

1. Decrease in investment in agriculture: during the period from 2018 to 2022, there is a significant decline in investment in agriculture (from UAH 66.1 billion in 2018 to UAH 51.4 billion in 2022). This reduction is about 22.3%, which indicates the negative impact of the crisis, particularly the war, on the agricultural sector. However, in 2023, an increase in investment was recorded to UAH 65.4 billion, which may indicate the beginning of a recovery from difficult periods.

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**Table 2.** Dynamics of investment resources by types of economic activity in 2018–2024

| Economic activity | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |
|---|---|---|---|---|---|---|---|
| Agriculture, forestry and fisheries | 66,104,075 | 59,129,469 | 50,679,695 | 69,950,276 | 51,439,446 | 65,432,115 | 42,885,079 |
| Industry | 199,895,976 | 254,196,157 | 180,537,373 | 242,922,915 | 126,112,607 | 220,652,238 | 209,139,029 |
| Construction | 55,993,934 | 62,346,613 | 39,614,886 | 55,724,649 | 32,627,592 | 42,239,728 | 41,723,503 |
| Wholesale and retail | 51,817,634 | 44,173,676 | 41,684,741 | 58,785,092 | 36,719,392 | 55,665,700 | 44,158,742 |
| Transportation and warehousing | 50,078,332 | 43,792,846 | 34,884,633 | 43,944,578 | 49,532,867 | 53,516,555 | 46,824,821 |
| Temporary accommodation and catering services | 2,675,101 | 2,832,178 | 1,951,234 | 2,690,167 | 2,183,565 | 2,147,303 | 1,841,796 |
| Information and telecommunications | 29,884,869 | 21,063,402 | 22,381,603 | 23,858,581 | 16,869,947 | 24,100,283 | 25,849,426 |
| Financial and insurance activities | 10,652,260 | 11,246,265 | 11,979,335 | 10,100,515 | 8,906,802 | 17,339,298 | 16,450,320 |
| Real estate transactions | 27,556,805 | 28,147,232 | 19,940,118 | 30,668,730 | 14,280,236 | 21,269,525 | 9,296,633 |
| Professional, scientific and technical activities | 10,798,221 | 11,912,398 | 11,823,599 | 17,125,898 | 6,012,609 | 13,347,761 | 11,369,670 |
| Activities in the field of administrative and support services | 11,837,847 | 11,741,145 | 8,623,796 | 13,162,620 | 6,587,010 | 13,327,526 | 5,422,232 |
| Public administration and defence; compulsory social insurance | 44,597,812 | 54,305,541 | 62,303,585 | 73,982,860 | 36,530,833 | 66,237,066 | 60,980,940 |
| Education | 4,459,984 | 4,788,707 | 3,740,151 | 3,866,557 | 2,008,563 | 2,721,508 | 2,425,306 |
| Healthcare and social assistance | 8,138,788 | 9,484,642 | 14,835,634 | 21,779,237 | 1,7412,896 | 24,967,326 | 13,482,562 |
| Arts, sports, entertainment and recreation | 3,663,168 | 4,146,160 | 2,772,823 | 4,423,066 | 2,152,565 | 3,829,717 | 2,122,842 |
| Others | 571,579 | 672,504 | 463,836 | 913,598 | 283,043 | 487,117 | 444,166 |
| Total | 578,726,385 | 623,978,935 | 508,217,042 | 673,899,339 | 409,659,973 | 627,280,766 | 534,417,067 |

*Source:* own elaboration based on Official website of the State Statistics Service of Ukraine (2025).

2. Total investment in Ukraine: total investment in Ukraine has also experienced significant fluctuations. For example, in 2022, investments decreased to UAH 409.7 billion, which is a sharp decline compared to the previous year (UAH 673.9 billion in 2021). However, in 2023, there was a gradual recovery, and total investment increased to UAH 627.3 billion.
3. Ratio of agricultural investment to total investment: the share of investment in agriculture relative to total investment is fluctuating, dropping to 12.1% in 2022 after peaking in 2019 (9.4%). This reflects both general trends in the economy and the specifics of the situation in the agricultural sector during the war.
4. Prospects and recovery: increased investment in agriculture in 2023 may indicate renewed interest in the sector after difficult years, due to possible changes in the political situation, infrastructure rebuilding and economic initiatives.

Overall, although the agricultural sector suffered a significant decline in investment in 2022 due to the crisis, the recovery in investment in 2023 indicates possible positive trends and prospects for agriculture in Ukraine in the nearest future.

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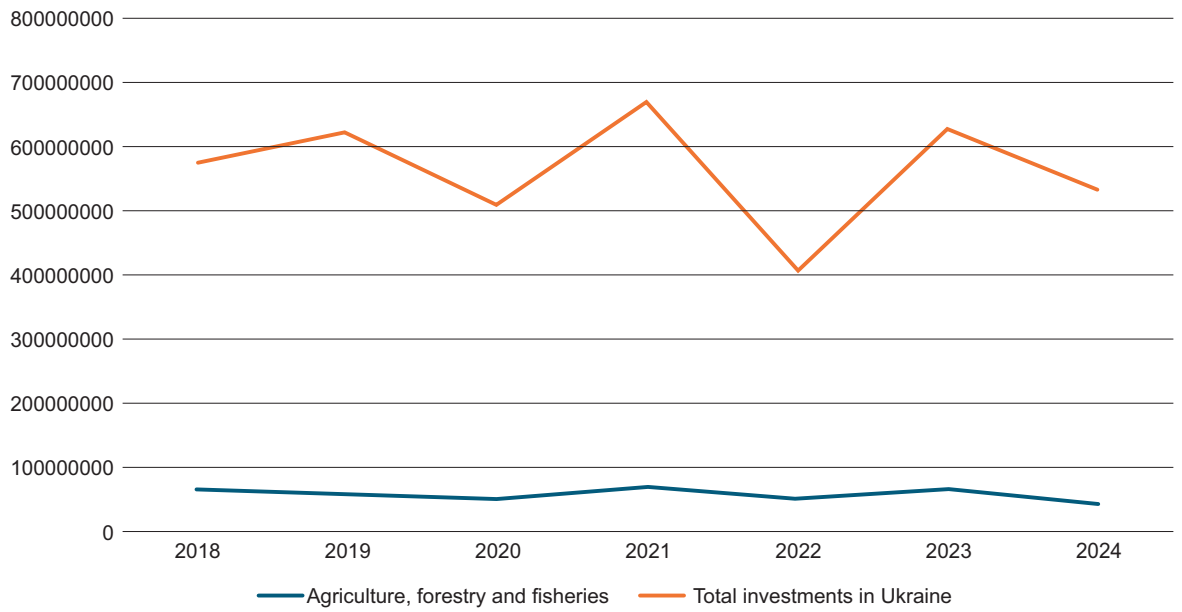



**Fig. 1.** Investment in agriculture and total investment in Ukraine from 2018–2024
*Source*: own elaboration based on data from the State Statistics Service of Ukraine.

In 2020–2024, capital investments in Ukraine were mainly made at the expense of enterprises and organizations' own funds (over 66% annually), which indicates their key role in financing in the context of limited access to external resources. The share of state budget funds gradually increased (from 8.7% to 10.9%), reflecting the growing role of the state in supporting investment during the war. At the same time, investments from local budgets declined significantly, as did bank lending, due to the limited capacity of local governments and increased financial risks. The share of households' funds for housing construction remained stable (around 5–6%), indicating that interest in the housing sector remained high even in the crisis. Investments by non-residents dropped sharply to a minimum level due to high military risks, and other sources of financing played a minor role in the overall structure (Fig. 2).

The main objectives of investing in land resources of agricultural enterprises are presented in Table 3. Each of the areas reflects the key components of strategic investment aimed at increasing the productivity, efficiency and long-term sustainability of the agricultural sector.

Given the above challenges, there is an urgent need to develop tools that allow for a comprehensive assessment of the risks of investing in the agricultural sector.

To demonstrate the practical relevance of the model and assess its effectiveness, an empirical test was conducted using the example of the Kharkiv region. This region was chosen due to its significant proportion of damaged agricultural landscapes and high level of risk as a frontline region.

Based on data collected for the Kharkiv region from open sources, the key components of the War-Related Risks Index (WRI) were calculated. The results of these calculations are presented in Table 4.

The key components and calculation of the Agro-Ecological Risks Index (AERI) are presented in Table 5.

The key components and calculation of the Economic & Financial Risks Index (EFRI) are presented in Table 6.

The key components and calculation of the Recovery Potential Index (RPI) are shown in Table 7.

The Integral Risk Index (IRI) for the Kharkiv region is calculated using formula 1 and is IRI=0.49.

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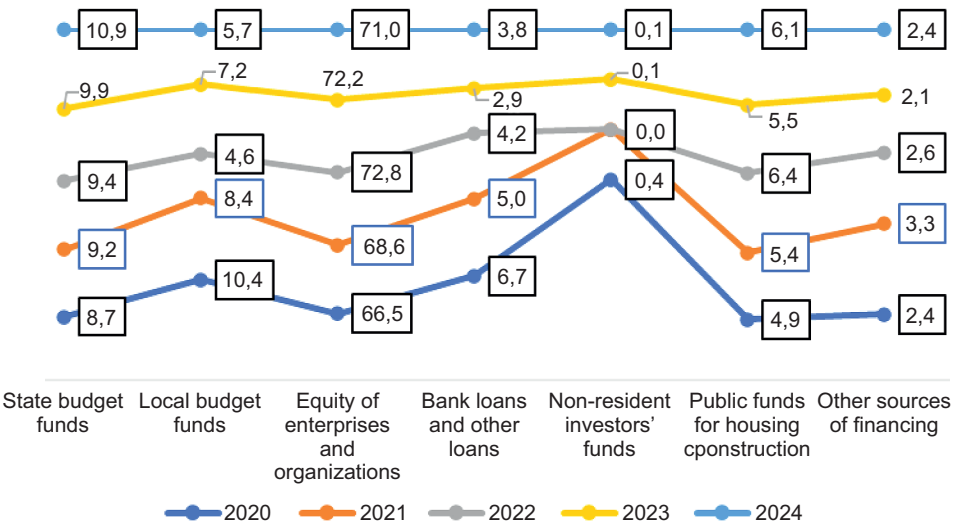



**Fig. 2.** Capital investments by sources of financing
*Source*: own preparation based on data from the State Statistics Service of Ukraine (2025); data cover the period 2020–2024.

The overall rating of 0.49 indicates that investment activity in the agricultural sector of the Kharkiv region is accompanied by significant uncertainty and requires the use of risk minimisation tools such as insurance, state guarantees, support from international programmes and individual investor protection mechanisms. The result also confirms the analytical relevance of the offered model and demonstrates its ability to adequately reflect the real state of the risk environment in the region.

To comprehensively assess possible trajectories for the development of Ukraine's agricultural sector, the study uses scenario analysis, which allows for the variability of external conditions, the level of infrastructure restoration, the extent of environmental damage and the intensity of state support to be considered. Three scenarios were analysed: optimistic, baseline and pessimistic, each detailing potential risks and investment opportunities.

**Table 3.** Main sources of financing investments in the land fund of the agricultural sector

| Source of funding | Features | Shortcomings |
|---|---|---|
| Own funds of agricultural enterprises | The most reliable source, ensuring financial independence and autonomy in decision-making | Limited scope, especially for small and medium-sized enterprises; insufficient for large projects |
| Bank loans and leasing | They make it possible to quickly attract investments for the purchase of machinery, equipment, and infrastructure modernization | High interest rates, difficulty accessing credit, the need for collateral and good financial statements |
| State support programs | Concessional loans, subsidies, interest compensation to support farmers and develop efficient land use | Limited funding, complex bureaucratic procedures, unequal access to programs in different regions and enterprises |
| Foreign investments and international grants | Promote the introduction of the latest technologies, development of sustainable agriculture, and improvement of land management | Dependence on external factors (politics, security), lengthy approval process, and high requirements for projects |

*Source:* own elaboration.

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**Table 4**. War-Related Risks Index (WRI) for the Kharkiv region

| Indicator | Description of the situation / data | Rate (0–1) | Source |
|---|---|---|---|
| Level of damage to agricultural land | Explosions damaged 4.2 thousand hectares, potentially contaminated another 28.2 thousand hectares, asoil compaction 3.4 thousand hectares | 0.7 | Ministry of Economy, Environment and Agriculture, 2024; Neiter et al., 2024 |
| Mine danger | The region is among the 11 most heavily mined areas in Ukraine. Over 40% of the region's territory, including 574 hectares of agricultural land, is contaminated with explosive remnants of war | 0.8 | Decentralization, 2024; State Emergency Service of Ukraine, 2024 |
| Physical security of the region | Regular drone and missile attacks | 0.8 | State Emergency Service of Ukraine, 2025 |
| Institutional stability | According to the rating agency IBI Rating, the region received a credit rating of 'uaBBB-' with a 'developing' outlook, indicating risks to the stability of the institutional environment | 0.5 | IBI-Rating, 2025 |
| **WRI** = 0.4× (Damage level) +0.3 × (Mine danger) +0.2 × (Physical security) +0.1 × (Institutional stability) = **0.75** | | | |

*Source:* own elaboration.

**Table 5.** Agro-Ecological Risks Index (AERI) for the Kharkiv region

| Indicator | Current situation / data | Rate (0–1) | Source |
|---|---|---|---|
| Soil pollution with heavy metals | In the combat zone of the Kharkiv region, elevated concentrations of Pb, Cu, Zn, and Cd have been recorded, ranging from 1.5 to 3.8 times the maximum permissible concentration (varies by location). Much of the contamination is associated with shelling and the destruction of military equipment | 0.7 | Bilyi et al., 2025; Solokha et al., 2024 |
| Land erosion and degradation | 28–32% of arable land has been degraded: explosions, craters, soil compaction, destruction of the topsoil. Over 3,400 hectares have been directly compacted by human activity | 0.6 | Krainiuk et al., 2024; Plisko et al., 2023 |
| Hydrological changes | Damaged parts of land reclamation systems, local flooding, changes in drainage structure; in 2022–2024, pockets of hydrological degradation are recorded | 0.5 | Ecoaction, 2023b; Krainiuk et al., 2024 |
| Decrease in soil biological productivity | The average drop in yields for key crops in the Kharkiv region was 18–25% in 2022–2023. In frontline areas, it was up to 40% | 0.6 | Ecoaction, 2023a; Solokha et al., 2024 |
| **AERI** = 0.3 × (Soil pollution) + 0.3 × (Land erosion) + 0.2 × (Hydrological changes) + 0.2 × (Biological productivity) = **0.61** | | | |

*Source:* own elaboration.

**Table 6.** Economic & Financial Risks Index (EFRI) for the Kharkiv region

| Indicator | Current situation / data | Rate (0–1) | Source |
|---|---|---|---|
| Accessibility of credit for the agricultural sector | The World Bank and government programmes support farmers but access to financing is limited due to the war | 0.5 | Maliy et al., 2025 |
| Fluctuations in prices for agricultural products | Strong fluctuations in prices for grain crops and oilseeds due to logistics disruptions and export restrictions | 0.7 | Bondarenko, 2025 |
| Access to markets | Logistical constraints due to hostilities, domestic and export channels partially operational | 0.6 | Ahapova, 2025 |
| Level of state support for the agricultural sector | Support programmes are available, but the amounts are small compared to the needs of farmers in the combat zone | 0.5 | Kharkiv Regional State Administration, 2025 |
| **EFRI** = 0.4 × (Availability of credit) + 0.3 × (Prices fluctuations) + 0.2 × (Access to markets) + 0.1 × (State support) = **0.58** | | | |

*Source:* own elaboration.

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**Table 7.** Recovery Potential Index (RPI) for the Kharkiv region

| Indicator | Current situation / data | Rate (0–1) | Source |
|---|---|---|---|
| Level of investment in the recovery of the agricultural sector | Investment volumes in the recovery of the agricultural sector in the Kharkiv region are moderate due to military risks and destroyed infrastructure (2024 – UAH 1,542,321 thousand; 2021 – UAH 3,802,148 thousand) | 0.5 | FAO, 2022a; Main Department of Statistics in Kharkiv Region, 2025 |
| Territory demining rates | Over 40% of the region's territory is contaminated with explosive objects; recovery is ongoing | 0.5 | Handicap International, 2025 |
| Level of support from international organisations | The World Bank, FAO and EU provide grants and preferential loans to agricultural enterprises | 0.6 | Congress of local and regional authorities, 2024; World Bank Group, 2024a,b |
| Innovative potential | Partial implementation of smart farming and environmental technologies; limited distribution so far | 0.5 | Mamchur & Studinska, 2023; Slobodskyi region, 2024 |
| **RPI=** 0.4× (Investment in recovery) +0.3× (Demining rate) +0.2× (International support) +0.1× (Innovative potential) = **0,52** | | | |

*Source:* own elaboration.

The optimistic scenario envisages a rapid recovery of the agricultural sector, a high level of international and state support and production growth of 20–25%. Under such conditions, investments could potentially yield returns of 15–20% per annum. This scenario corresponds to conditions where the risks recorded by the integral index are rapidly declining. Research (Addison, 2005; Dashko & Mykhailichenko, 2024; David et al., 2011; Kosarevic, 2022) has found that most countries affected by war experience rapid economic growth after the war ends.

The baseline scenario is considered the most likely given current trends and is characterised by a slow recovery of the land fund (50–60% in 1–2 years) and moderate production growth (10–15%). The expected return on investment is 10–12%, which corresponds to the average profitability of agribusiness in the pre-crisis period (OECD, 2021) and estimates of the profitability of agriculture in Central and Eastern European countries in the context of structural reforms. For this scenario, the IRI value of 0.49 remains a relevant indicator of the average level of risk and the need for gradual adaptation.

The pessimistic scenario reflects the long-term consequences of the war, high levels of land contamination, a lack of investment and slow infrastructure rehabilitation. Production volumes may decline by 5–10%, and investment returns will not exceed 3–5%. Such profitability levels are typical for agricultural sectors in post-conflict countries, where investment risks remain high and recovery processes are fragmented (UNDP, 2015). In this case, the Integrated Risk Index could rise to high values, significantly limiting investment activity.

Thus, integrated risk assessment combined with scenario analysis provides a comprehensive picture of possible trajectories for the recovery of the agricultural sector in the Kharkiv region. The results can be used by investors, authorities and agricultural enterprises to develop adaptation strategies aimed at reducing risks, optimising resource use and ensuring sustainable development of the region in the post-war period.

## DISCUSSION

The current state of investment in land resources in Ukraine's agricultural sector is characterised by significant turbulence caused by military action, infrastructure destruction and a high level of uncertainty. Our results, in particular the Integrated Risk Index (IRI = 0.49), confirm that the overall level of risk in regions affected by hostilities remains moderate but manageable, provided that adaptive investment strategies are implemented. This is consistent with international research on post-conflict recovery, which

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emphasises that an average level of risk is typical for regions with partial infrastructure degradation and potential for recovery (FAO, 2025; World Bank, 2023a).

Similar conclusions are drawn by researchers in the context of Syria, Iraq and Rwanda, where the restoration of agricultural land was identified as a key factor in economic stabilisation after conflicts (Collier & Duponchel, 2013; UNDP, 2015). They emphasise that a return to productive land use and the attraction of investment form the basis for economic growth. Our findings confirm this pattern: investment in land resources is indeed critical for the recovery of Ukraine's agricultural sector and for ensuring food security.

At the same time, the values obtained for individual risk indices – War-Related Risks Index (WRI = 0.75), Agro-Ecological Risks Index (AERI = 0.61) and moderate Economic & Financial Risks Index (EFRI = 0.58) demonstrate the structural complexity of the risk environment. A similar approach to multi-component risk assessment is used in international models, in particular Risk Matrix Approach (OECD, 2009) and FAO Agricultural Risk Assessment Framework (Conforti et al., 2020). The consistency of the results with these models confirms the scientific validity of the proposed methodology.

Our calculations also show that the Recovery Potential Index (RPI = 0.49) partially offsets the negative impact of other risk groups, indicating the existence of preconditions for gradual recovery. This is consistent with the findings of studies by the World Bank, the European Bank for Reconstruction and Development (EBRD) and the International Institute for Sustainable Development, which indicate that investments in demining, environmental rehabilitation and infrastructure reconstruction can accelerate post-conflict recovery even in conditions of limited resources (Ecoaction, 2022; IISD, 2022; World Bank, 2023b; 2025).

A significant contribution of our research lies in combining an integrated risk model with scenario analysis of the agricultural sector. The EU study (Fellmann et al., 2025) also emphasises the importance of scenario analysis of investments impact on the agricultural sector, but it does not include a comprehensive risk index as in our study. That is why the scenarios we present (optimistic, baseline, pessimistic) allow for a broader interpretation of the meaning of the obtained IRI index and outline possible development trajectories.

A comparison with international studies shows that our approach is both practical and scientifically innovative. First, it systematically integrates military, environmental, economic and financial risks that arise simultaneously in wartime. Secondly, the results confirm that the process of restoring Ukraine's agricultural sector is in line with global trends in post-conflict recovery but has its own characteristics such as a significantly larger scale of mining, a high level of environmental damage and a structural decline in investment.

Thus, extensive discussion leads to the conclusion that the results obtained not only describe the current state of risks but also reveal the mechanisms that will determine the trajectory of Ukraine's agricultural sector recovery. Our conclusions are consistent with global research and complement the existing scientific literature, demonstrating the importance of integrated risk assessments and scenario modelling for management decision-making in the post-war period.

## CONCLUSIONS

The investments in land resources in Ukraine's agricultural sector are currently characterised by high risks and instability caused by the consequences of full-scale war, such as destruction of infrastructure, decline in economic activity and deterioration in the quality of agricultural land. This has led to a significant decline in the investment attractiveness of the industry, hindering its recovery and modernisation. At the same time, investment remains a key factor in renewing the land fund, improving land use efficiency and ensuring the country's food security.

The investment risk assessment model proposed in the study provides comprehensive consideration of military consequences, land condition, pollution levels and restoration potential, which creates a basis for informed management decisions. The scenario analysis demonstrated significant differentiation

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in risk levels in the short and long term, which necessitates adaptive investment strategies that consider regional specifics.

Under these conditions, it is important to develop an active and consistent state policy aimed at improving the investment climate by supporting infrastructure projects, stimulating innovation, introducing tax incentives and providing state guarantees.

Thus, attracting domestic and foreign investment in land resources in the agricultural sector is a key prerequisite for its sustainable development, increased productivity, environmental safety and further integration of Ukraine into the European economic space.

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