ISSN: 2221-1055
E-ISSN: 2413-2322

Національний науковий центр «Інститут аграрної економіки»

ЕКОНОМІКА АПК

Міжнародний науково-виробничий журнал

Заснований у 1994 році
Випускається 6 разів на рік

Том 33, № 1

Київ – 2026

Рік заснування: 1994

Рекомендовано до друку та поширення
через мережу Інтернет Вченою радою
Національного наукового центру «Інститут аграрної економіки»
(протокол № 3 від 12 лютого 2026 р.)

Рішення Національної ради України
з питань телебачення і радіомовлення № 1498,
протокол № 15 від 09.05.2024.
Ідентифікатор медіа – R30-04656.

Журнал входить до Переліку наукових фахових видань України
Категорія «Б». Спеціальності: С1 (051) – Економіка, D1 (071) – Облік і оподаткування,
D2 (072) – Фінанси, банківська справа, страхування та фондовий ринок, D3 (073) – Менеджмент,
D7 (076) – Підприємництво та торгівля
(наказ МОН України від 23 грудня 2025 року № 1693)

Журнал представлено у міжнародних наукометричних базах даних, репозитаріях та пошукових системах: Google Scholar, Фахові видання України, Національна бібліотека України імені В. І. Вернадського, Crossref, AGRIS, German Union Catalogue of Serials, Econlit, ECONBIZ, UCSB Library, WorldCat, EZB, Litmaps, Ulrichsweb Global Serials Directory, PBN, UBL, COPE, TIB, I2OR, BASE, ERIH PLUS, EBSCO, Open Ukrainian Citation Index, Dimensions, University of Oslo Library, University of Hull Library, Search Oxford Libraries Online, European University Institute, Cambridge University Library

Адреса редакції:
Національний науковий центр «Інститут аграрної економіки»
03127, вул. Героїв Оборони, 10, м. Київ, Україна
E-mail: info@eapk.com.ua
https://eapk.com.ua/uk

ISSN: 2221-1055
E-ISSN: 2413-2322

National Scientific Centre “Institute of Agrarian Economics”

EKONOMIKA APK

Founded in 1994
Published six times per year

Volume 33, No. 1

Kyiv – 2026

Year of foundation: 1994

Recommended for printing and distribution
via the Internet by the Academic Council
of the National Scientific Centre "Institute of Agrarian Economics"
(Minutes No. 3 of February 12, 2026)

Decision of the National Council
of Television and Radio Broadcasting of Ukraine No. 1498,
Minutes No. 15, dated 09.05.2024.
Media identifier – R30-04656.

Journal is included in the List of Scientific professional publications of Ukraine
Category "B". Specialties: 0311 – Economics, 0411 – Accounting and Taxation, 0412 – Finance, Banking and Insurance, 0413 – Management and Administration, 0416 – Wholesale and Retail Sales
(order of the Ministry of Education and Science of Ukraine No. 1693 dated December 23, 2025)

Journal is presented international scientometric databases, repositories and scientific systems: Google Scholar, Professional publications of Ukraine, Vernadsky National Library of Ukraine, Crossref, AGRIS, German Union Catalogue of Serials, Econlit, ECONBIZ, UCSB Library, WorldCat, EZB, Litmaps, Ulrichsweb Global Serials Directory, PBN, UBL, COPE, TIB, I2OR, BASE, ERIH PLUS, EBSCO, Open Ukrainian Citation Index, Dimensions, University of Oslo Library, University of Hull Library, Search Oxford Libraries Online, European University Institute, Cambridge University Library

Editors office address:
National Scientific Centre "Institute of Agrarian Economics"
03127, 10 Heroiv Oborony Str., Kyiv, Ukraine
E-mail: info@eapk.com.ua
https://eapk.com.ua/en

Редакційна колегія

EKONOMIKA APK Volume 33, No. 1

Editorial Board

ЗМІСТ /CONTENTS

Received: 28.09.2025. Revised: 30.12.2025. Accepted: 12.02.2026. Published: 05.03.2026.

EKONOMIKA APK

https://doi.org/10.32317/ekon.apk/1.2026.10

Ekonomika APK, 33(1), 10-19

UDC 631.1:330.322:519.237(65)

ISSN: 2221-1055; E-ISSN: 2413-2322

Predicting farm investment success in semi-arid regions of Algeria: An asset-based policy tool

Amar Rouabhi*
PhD in Agronomy, Associate Professor
Ferhat Abbas Sétif University 1
19137, El Bez Campus, Sétif, Algeria
https://orcid.org/0000-0001-6226-662X

▸ **Abstract.** The aim of this research was to develop a predictive model for agricultural investment success in Algeria's semi-arid cereal farming systems, with the view to guiding governmental policies on loan and subsidy allocation. The research focused on semi-arid regions, where cereal farming was fundamental for food security and strategic agricultural investment was crucial for enhancing outcomes and farm resilience. Utilising survey data from 198 farms in Setif-Algeria, it was built seven composite asset dimensions and established farm typologies via multiple variate analysis. A binary logistic regression model was developed to predict agricultural investment success. The logistic regression model demonstrated a practical overall classification accuracy of 79.8%, with a R^2 of 0.358 and R^2 of 0.486. Results indicated that "Technical Asset" was the strongest positive predictor of success (B = 0.728, OR = 2.072, p = 0.002). Some composite assets such as "Diversity of Farming", "Connectivity", and "Performance" were found to negatively predict investment success, suggesting complex dynamics such as over-diversification or higher-risk schemes by well-resourced farms. The results confirmed substantial structural differences between farm types, with large-scale farms demonstrating significantly higher levels of biophysical, human, and diversification assets, reflecting stronger resource capacity and adaptive potential. The developed predictive model showed strong explanatory and classification performance, confirming the key role of technical capacity as a decisive factor in achieving successful investment outcomes. The research gave a practical predictive framework for policymakers, enabling data-driven decisions to optimise resource distribution, reduce the risks associated with public financing and ultimately foster more successful agricultural investments, thereby strengthening sustainable cereal cropping and food security. These findings provided policymakers with a data-driven screening tool to optimise the allocation of agricultural subsidies and loans, directly strengthening food security in semi-arid regions

▸ **Keywords:** food security; farm typology; agricultural policy; predictive modelling; sub-arid

▸ Introduction

In Algeria, cereal production formed the base of national food security and was a core element of its sovereignty. This staple crop was deeply rooted in the Algerian diet and agricultural heritage, serving not only as a vital caloric source for the population but also as a key economic and social engine for rural communities. C. Baghdad (2022) documented how the Algerian agricultural sector remained structurally constrained by its limited contribution to economic diversification, with cereal farming simultaneously representing both a development priority and a vulnerability, given its heavy dependence on rainfall and public subsidies. Achieving self-sufficiency in cereal productivity was therefore a paramount national objective, aiming to reduce reliance on unpredictable international markets and to protect the country from global price fluctuations and supply chain disruptions. Algeria's food security remained approximately 70% dependent on cereal imports, with food imports providing for nearly 75% of the population's needs (Tanchum, 2021). This structural import dependency exposed the country to significant geopolitical and economic risks, making food autonomy crucial for ensuring socio-economic stability and preserving decision-making independence amidst climatic and political uncertainties.

▸ **Suggested Citation**: Rouabhi, A. (2026). Predicting farm investment success in semi-arid regions of Algeria: An asset-based policy tool. *Ekonomika APK*, 33(1), 10-19. doi: 10.32317/ekon.apk/1.2026.10.

*Corresponding author

However, the vast semi-arid regions of Algeria faced significant challenges to sustainable cereal production. C. Ingrao *et al.* (2023) identified irregular rainfall patterns and substantial water scarcity as the primary biophysical constraints on agricultural productivity in dryland systems, noting that competition over freshwater resources between agricultural and non-agricultural users was intensifying across the Mediterranean and North African regions. S. Sharma *et al.* (2025) noted that this was compounded by the fact that agricultural water consumption already accounted for a disproportionately large share of total freshwater use, placing mounting pressure on already depleted water systems. B. Golla (2021) emphasised that frequent droughts further exacerbated the incidence of crop failure and rural poverty, particularly among smallholder farmers with limited adaptive capacity. A.R. Dzvene *et al.* (2025) conducted a comprehensive scoping review of climate change challenges in arid and semi-arid agri-food systems, concluding that the convergence of erratic weather patterns, urban encroachment onto agricultural land, and degraded soil conditions was progressively undermining the productive potential of dryland farming across Africa and the Mediterranean basin.

Agricultural investment in such environments was therefore both urgent and inherently complex. R.B. Pickson *et al.* (2024) demonstrated that in developing agricultural economies, private and public investment in farming activities can serve as a powerful mechanism for enhancing productivity and building long-term rural resilience, but only when investment decisions were aligned with the specific resource endowments and constraints of target farming systems. In semi-arid smallholder contexts across North Africa, the success of agricultural investments was strongly conditioned by pre-existing farm asset structures, institutional support, and access to technical knowledge; factors that vary considerably across farm types and agroecological zones. Despite these inherent constraints, semi-arid lands also offered genuine prospects. Their vast area provided a foundation for large-scale cereal cultivation, and with strategic investments in climate-resilient farming practices, these zones possessed the capacity to boost national food reserves and reduced Algeria's chronic dependency on cereal imports. P.K. Thornton *et al.* (2018) demonstrated that in water-scarce environments, the interaction between human capital (knowledge and skills), social capital (networks and institutions), and natural capital (land and water resources) created synergistic effects that significantly influenced investment outcomes. R.B. Pickson *et al.* (2024) demonstrated that agricultural investment was a crucial catalyst for sustainable development, not only generating employment and improving rural infrastructure but also driving technology adoption and increasing agricultural productivity. Their cross-regional analysis showed that targeted private-sector investment, when complemented by strong institutional support, yields the most sustained improvements in food security outcomes.

However, agricultural investments in such environments carry risks and should be supported. For governmental bodies and financial institutions, making informed agricultural investment decisions was crucial but complex (Blandford, 2007). The ability to predict investment success ex-ante was a critical missing link for efficient resource allocation and effective policy design, as evidence-based agricultural policies require careful scientific knowledge transfer in governmental processes (El Benni *et al.*, 2023). Academic work frequently examined isolated factors influencing agricultural performance, such as credit access or farmer education. Based on this theoretical framework, the study hypothesises that farms with higher composite asset scores across multiple dimensions will demonstrate significantly greater agricultural investment success compared to farms with concentrated asset portfolios, and that the interaction between human and technical asset dimensions will have a stronger predictive effect on investment outcomes. This study aimed to develop a predictive model of agricultural investment success in semi-arid Algerian cereal farming using a multi-dimensional asset-based approach. Specifically, the objectives were: 1) to construct seven composite asset dimensions capturing the key resource and capability profiles of cereal farms in Setif province; 2) to establish farm typologies based on these asset dimensions using multivariate analysis; 3) to develop a binary logistic regression model predicting investment success and identifying the most influential asset predictors

▸ Materials and methods

Study area, sample, and data collection

The study was conducted in the Setif province of Algeria, located on the high plateaus of the Northeastern part of Algeria, a region strategically vital for national cereal production in spite of its thought semi-arid climate. Setif province was characterised by an average annual rainfall of 458 mm (Rouabhi *et al.*, 2019) with significant inter-annual variability. Its agricultural landscape was dominated by rainfed cereal cultivation, primarily durum wheat, combined with some livestock breeding. Figure 1 illustrated the geographical distribution of the seven municipalities: Ain Sebt, Maouia, Dehamcha, Beni Aziz, Guelta Zerga, El Eulma, and Bazer Sakra; from which the 198 farms were sampled. The sampled municipalities were clustered in two distinct geographical zones, reflecting potential variations in agro-ecological conditions and agricultural practices. The Northern cluster included Ain Sebt, Maouia, Dehamcha, and Beni Aziz. This cluster might exhibit different climatic and topographic characteristics with mountainous reliefs indicating a small scall farming. The Southern cluster comprised Guelta Zerga, El Eulma, and Bazer Sakran municipalities. The proximity of these municipalities suggested a shared agro-ecological zone, characterised by vast plains conducive to large-scale cereal production. The distinct grouping of these municipalities allowed the study to capture potential regional variations in farm asset endowments and investment behaviours, which might be influenced by localised environmental conditions. This geographical distribution ensured that the sample reflected the heterogeneity of farming systems within the broader semi-arid cereal-producing landscape in Setif. A structured survey was run to a randomly selected sample of 198 farms primarily engaged in cereal production. The sampling frame was derived from the Sétif Provincial Agricultural Directorate registry of active farms (Setif province, n.d.), ensuring a diverse representation of

farm sizes and operational characteristics. The data collection was conducted in April-May 2021. A limitation of this study lain in the fact that this period corresponded to a key stage in the agricultural cycle, when farmers were actively engaged in production activities and were able to provide accurate and up-to-date information on farm operations and investment decisions. The data collection instrument was a comprehensive questionnaire comprising 56 questions across seven main sections, including socio-demographic characteristics, farm structure and land tenure, technical practices and equipment, access to information and connectivity networks, performance indicators, and details on agricultural investment activities (including type, and perceived success or failure).

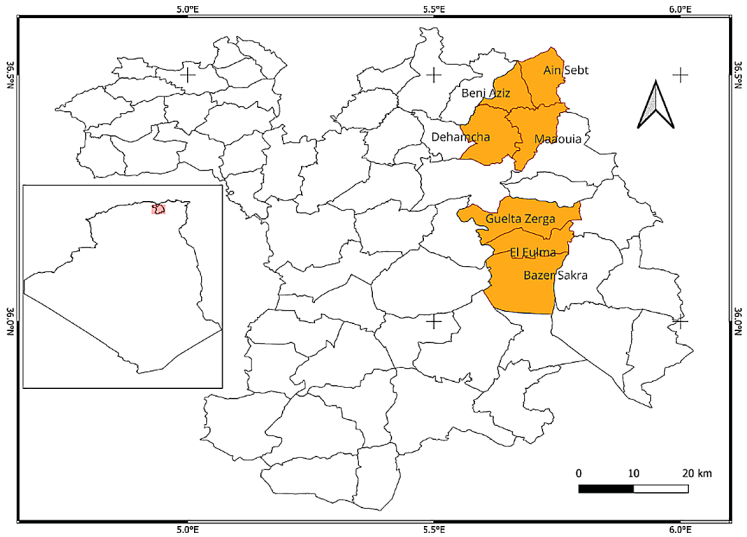

Figure 1. Map of sampled municipalities in Sétif province, Algeria
Source: developed by the author

Variables of operationalisation and composite dimension descriptions

The primary dependent variable, "Agricultural Investment Outcome", was operationalised as a binary variable. It was coded as "Success" (1) if the farmer reported having undertaken an agricultural investment and perceived it as having met or exceeded expectations, and "Failure" (0) if the investment was undertaken but perceived as having failed to meet expectations or resulted in a loss. Only farms that reported agricultural investment activity (n = 84) were included in the predictive modelling phase, focusing the analysis solely on the determinants of success among investing farms. Seven independent composite metrics (assets) were systematically constructed to capture distinct dimensions of farm resources and capabilities. Each composite was formed by aggregating relevant standardised individual variables from the survey, ensuring conceptual coherence and equal weighting of underlying components. The "Biophysical Asset" aggregated land area and livestock holdings to reflect the farm's natural productive base. The "Human Asset" combined education, training, and labour variables to represent the household's knowledge and management capacity. The "Diversity Asset" aggregated indicators of engagement in multiple productive activities, reflecting the degree of income diversification. The "Connectivity Asset" captured institutional integration through variables measuring access to advisory services, administrative relationships, and associative membership. The "Technical Asset" reflected agronomic sophistication, drawing on variables related to soil preparation, fertilisation, crop rotation, and equipment mastery. The "Performance Asset" aggregated yield, economic outcomes, and resource potential indicators to represent baseline farm viability. Finally, the "Constraint Asset" combined variables related to water deficit, soil degradation, land fragmentation, and tenure issues to quantify the structural risk burden faced by each farm. Together, these seven composites form the independent variable set used in the multivariate analyses and the binary logistic regression model.

Given the mixed nature of the dataset, a general overview of descriptive statistics and t-test comparisons were done to highlight the most important bodies of variation. A standard Principal Component Analysis (PCA) was performed on 198 farms. Then a Mixed Factorial Analysis (MFA) was conducted on 84 farms having invested in a new agricultural activity. MFA was suited for analysing datasets containing both quantitative and qualitative variables organised into distinct groups. Finally, a binary logistic regression model was developed with the binary Agricultural Investment Outcome (Success/Failure) as the dependent variable with the 7 composite metrics as independent variables. This model was selected for its suitability in modeling dichotomous outcomes and its capacity to produce interpretable Odds Ratios (OR) quantifying each asset's contribution to success probability. Model fit was assessed using the Hosmer Lemeshow (HL) test, where a non-significant result ($p > 0.05$) indicated adequate fit, while predictive performance was evaluated through overall classification accuracy, and pseudo-R^2 coefficients (Cox & Snell, 1989; Nagelkerke, 1991). The study was conducted in accordance with the norms of The Declaration of Helsinki (2013), statistical analyses were done by the free RStudio software V.2024.12.1.

▸ Results and Discussion

Composite means by region and investment level. Multivariate analysis and farm typology

The comparative analysis of composite asset means revealed distinct profiles among farms, influenced by their regional location and tendency to invest. Farms in El Eulma, Guelta Zerga and Bazer Sakra municipalities with large scale farming showed significantly superior "Biophysical Assets" (average 81.07 vs. 18.80, $p < 0.001$) compared to those in small scale farming, in Ain Sebt, Beni Aziz, Dehamcha and Maaouia municipalities, generally characterised by a mountainous landscape (Table 1). This substantial difference underscored the intrinsic advantages of peri-urban zones, likely benefiting from more fertile lands and better water access, crucial for cereal production in semi-arid. Simultaneously, "Diversity Asset" score was higher in large-scale farming (average 3.17 vs. 1.72, $p < 0.001$), suggesting greater engagement in diverse agricultural activities, which can enhance resilience (Nicol *et al.*, 2015). "Human Asset" also showed a significant advantage for large-scale farming (average 12.71 vs. 10.01, $p < 0.01$), indicating potentially higher education or more skilled labour. However, "Connectivity Asset", "Technical Asset", "Performance Asset", and "Constraint Asset" do not significantly differentiate these two regional farm types, implying these attributes might be shaped by factors beyond geographical scale.

Table 1. Scores of composite assets by region and t-test equality of means

		Biophycal	Human	Diversity	Connectivity	Technical	Performance	Constraint
Small scale farming	Ain sebt	16.29	10.29	2.07	4.14	7.93	41.29	4.78
	Beni aziz	21.75	9.67	2.30	3.87	6.77	37.80	5.99
	Dehamcha	20.15	8.33	1.52	3.50	7.35	39.22	4.70
	Maouia	17.00	11.78	1.00	4.56	7.56	30.33	3.92
	Average	**18.80**	**10.01**	**1.72**	**4.02**	**7.40**	**37.16**	**4.85**
Large scale farming	El-Eulma	63.51	14.74	2.53	3.74	8.21	31.32	6.91
	Guelta-Zerga	90.25	10.65	2.96	3.70	7.93	32.63	9.62
	Bazer-Sakra	89.45	12.74	4.03	3.82	7.38	47.21	5.37
	Average	**81.07**	**12.71**	**3.17**	**3.75**	**7.84**	**37.05**	**7.30**
	Sig. (2-tailed)	***	**	***	**ns**	**ns**	**ns**	*
Investment undertaking	No	51.46	10.34	2.02	3.82	7.67	35.04	5.47
	Yes	53.45	11.26	3.16	3.71	7.36	41.47	7.46
	Sig. (2-tailed)	**ns**	**ns**	***	**ns**	**ns**	***	**ns**

Note: levels of significance – *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$, ns – not significant
Source: developed by the author

When examining farms according to whether or not they have undertaken (Yes/No), the "Diversity Asset" emerged as a highly significant discriminator, with investing farms demonstrating higher diversification (average 3.16 vs. 2.02 for non-investors, $p < 0.001$). Diversification acts as a safety shield, particularly for small farms, by ensuring self-sufficiency and reducing reliance on single crops or livestock (Kurdyś-Kujawska, 2016). This reinforced the notion that diversified income streams provided the financial stability necessary to undertake new investments. Similarly, "Performance Asset" was significantly higher among investing farms (average 41.47 vs. 35.04 for non-investors, $p < 0.001$), indicating that current economic success and productivity were strong enablers of future investment. Z. Ahmadirad (2024) noted that the integration of technology and financial innovations was reshaping investment landscapes and became a critical factor in future investment decisions. The other composites, including "Biophysical Asset", "Human Asset", "Connectivity Asset", "Technical Asset", and "Constraint Asset", do not show significant differences between investing and non-investing farms, suggesting that, although important, they were not the main distinguishing factors in the decision to invest or not. PCA was conducted on the seven composite asset dimensions to identify underlying patterns and reduce data dimensionality. The eigenvalues indicated that the first three dimensions were the most significant, with eigenvalues of 2.397, 1.517, and 1.035, respectively (Table 2).

Table 2. PCA eigenvalues, variance explained, and the quality representativenee of the most important dimensions

Eigenvalues	Dimension 1			Dimension 2			Dimension 3		
	2.397			1.517			1.035		
% of variance	34.24			21.67			14.79		
Cumulative % of var	34.24			55.91			70.70		
Asset	**loading**	**ctr**	**cos_2**	**loading**	**ctr**	**cos_2**	**loading**	**ctr**	**cos_2**
Biophysical	0.53	11.57	0.28	0.613	24.73	0.37	0.02	0.03	0.00
Human	0.759	24.04	0.58	-0.14	1.39	0.02	0.23	5.04	0.05
Diversity	0.51	10.96	0.26	0.698	32.07	0.49	-0.01	0.01	0.00
Connectivity	0.834	29.01	0.69	-0.32	7.15	0.11	0.01	0.02	0.00
Technical	0.754	23.74	0.57	-0.32	6.81	0.10	-0.13	1.55	0.02
Performance	-0.01	0.00	0.00	0.53	18.41	0.28	-0.584	32.99	0.34
Constraint	-0.13	0.68	0.02	0.38	9.42	0.14	0.790	60.36	0.62

Note: ctr – % of contribution, cos_2 – representativeness quality
Source: developed by the author

Cumulatively, these three dimensions explained 70.70% of the total variance. This significant cumulative variance indicated that a three-dimensional model effectively captures the primary data structure, allowing for a parsimonious summary of the asset relationships. This reduction was crucial for establishing robust farm typologies, as it focused on the most relevant aspects of farm asset profiles (Jolliffe, 2002). Dimension 1 (34.24% of variance) was primarily defined by high positive loadings from "Connectivity Asset" (0.834), "Human Asset" (0.759), and "Technical Asset" (0.754). This dimension can be interpreted as a "Technical-Connectivity Capacity" factor, highlighting farms with strong social integration and technical adoption. Dimension 2 (21.7% of variance) was strongly associated with "Diversity Asset" (0.698) and "Biophysical Asset" (0.613), suggesting a "Resource and Diversification" factor. This indicated that farms with better resources often pursue a wider range of activities. Dimension 3 (14.79% of variance) was dominated by "Constraint Asset" (0.790) and "Performance Asset" (-0.584). This factor differentiated farms based on their ability to manage limitations and achieve economic results, where higher constraints were inversely related to performance. Other asset categories have minimal influence on this dimension, indicating that it isolated the trade-off between performance and constraint assets. The biplot visually confirmed these relationships, showing clear groupings of variables along these principal axes, where three distinct variable clusters emerge. Constraint and performance assets followed a third dimension, represented on the two-dimensional biplot (Fig. 2).

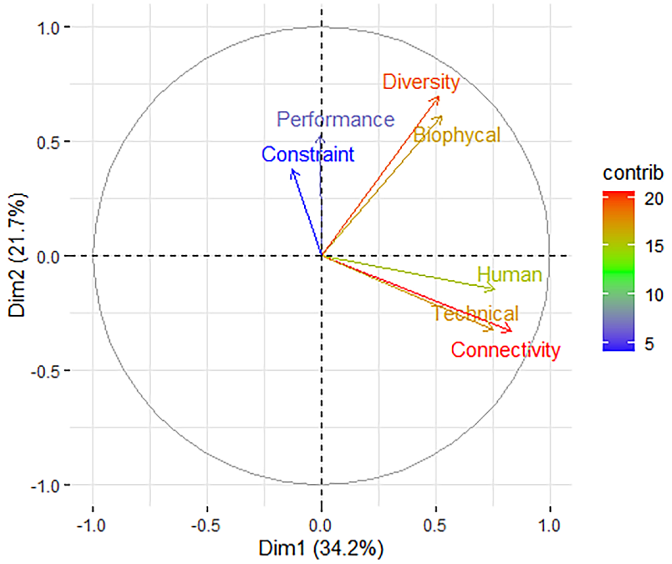

Figure 2. PCA factorial map showing the contribution of composite dimensions
Source: developed by the author

The clear variable separation with distinct contribution patterns validated the PCA approach, though the 55.9% explained variance suggested additional components might enhance comprehensive analysis.

Mixed factorial analysis investment activities and outcomes

The two MFA factor maps provided insightful visualisations of how different agricultural investment activities and investment outcomes (success/failure) were positioned within the multidimensional space of farm characteristics. From the Figure 3, "Activity Investment" illustrated the centroids of various newly invested agricultural activities, while the right plot, displayed the centroids for investment success and failure. The shared dimensional axes (Dim. 1: 18.6% variance; Dim. 2: 14.1% variance) allowed for direct comparison and interpretation of associations. In the "Activity Investment" map, "Poultry" and "Cow Breeding" activities were positioned in the upper-left quadrant, suggesting they were associated with certain basic farm characteristics captured by negative Dim. 1 and positive Dim. 2. Conversely, "Fruit Plantation" and "Sheep Breeding" were located in the right-hand side. "Market Garden", "Beekeeping", and "Services" appeared closer to the centre, implying they were broadly distributed across farms. This spatial arrangement helped identify distinct investment profiles among farms. The "Invest" map clearly separated "Failure" and "Success" outcomes. "Failure" was predominantly located in the upper-left quadrant, aligning spatially with "Poultry" from the activity map. This visual overlap suggested a potential association: "Poultry" investments were predominantly associated with "Failure", accounting for 53% of all reported investment failures. This suggested that poultry farming might present significant challenges or higher risks for farmers in this context. S.U. Khan *et al.* (2023) that the productivity and profitability of poultry farms in Algeria were influenced by several interrelated factors, including disease prevention and optimal breeding practices. However, the bovine breeding faces several challenges, including environmental degradation, and resource constraints. Desertification was a significant issue affecting nearly 80% of Algeria's agricultural land, leading to a scarcity of

forage resources and declining farming activities (Daoudi *et al.*, 2010). Also, financial constraints and lack of technical knowledge were barriers to adopting sustainable practices (Yulianti *et al.*, 2024). On the other side of the plot, "Success" centroid was located in the lower-right quadrant, suggesting a positive association with market-gardening, representing 40% of all successful investments. However, cow breeding contributed to both failure (31%) and success (23%), implying it's a high-risk, high-reward activity, for this purpose farmers tend to employ traditional extensive grazing systems, which helped to improve farm's incomes (Table 3).

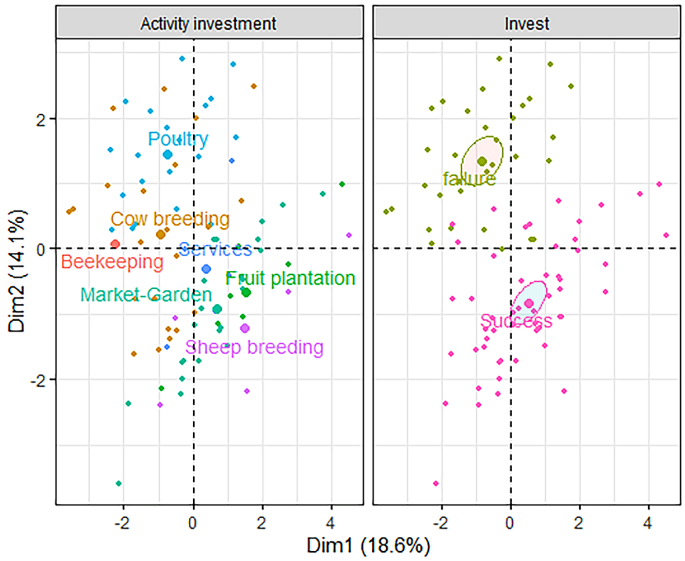

Figure 3. MFA factorial map

Notes: each dot represents an individual farm. In the left panel, dot colours indicate the type of agricultural activity invested in (blue: "Poultry"; orange: "Beekeeping", etc.). In the right panel, colours reflect investment outcome centroids (pink: "Success"; green: "Failure"). Farm positions along Dim. 1 (18.6% of variance) and Dim. 2 (14.1% of variance) reflect their composite asset profiles

Source: developed by the author

Table 3. Distribution of Agricultural Investment output by farming activity, %

Invest output		Activity investment							
		Beekeeping	Cow breeding	Fruit plantation	Market-gardening	Poultry	Services	Sheep breeding	Total
	Failure	3	31	0	6	53	6	0	100
	Success	0	23	15	40	6	6	10	100

Source: based on R. Meziane *et al.* (2024)

To identify the asset dimensions most predictive of investment success, a binary logistic regression model was applied to 84 farms that had undertaken an agricultural investment. The model demonstrated strong explanatory and predictive power. Prediction model showed enhanced explanatory power with R^2 of 0.358 and R^2 of 0.486, indicating that approximately 36-49% of variance in investment success was explained by the predictors (Cox & Snell, 1989; Nagelkerke, 1991). The HL test ($\chi^2 = 6.035$, $p = 0.643$) indicated excellent model fit, confirming that the logistic regression assumptions were adequately met. The predictive capability of binary logistic regression in classification accuracy was model selection, and data quality. The classification accuracy of 79.8% demonstrated strong predictive capability, with impressive sensitivity for successful investments (92.3% correctly classified) compared to moderate specificity for failures (59.4%) (Table 4). This pattern suggested the model was especially effective at identifying successful investments, which was valuable for investment decision-making. Logistic regression was noted for its robustness to linear dependencies and scaling issues, which can enhance accuracy without extensive pre-processing.

Table 4. Classification model of the predicted investment output, %

Observed		Predicted		
		Investment output		Percentage correct
		Failure	Success	
Investment output	Failure	19	13	59.4
	Success	4	48	92.3
Overall percentage				79.8

Source: based on P. Komarek & A. Moore (2005)

From the binary logistic regression-built model, "Technical Asset" emerged as the strongest positive predictor (B = 0.728, p = 0.002, OR = 2.072), indicating that investments with higher farm technical skills were over twice as likely to succeed. This finding strongly aligned with contemporary research on technical innovation driving superior investment returns and competitive advantages (Brynjolfsson & McAfee, 2014). However, "Diversity Asset" showed a significant negative effect on investment success (B = -0.521, p = 0.027, OR = 0.594). This suggested that diversification may reduce success probability by approximately 41%. This counterintuitive finding contested traditional portfolio theory but may reflect over-diversification penalties or focus benefits in specific investment contexts (Goetzmann & Kumar, 2008). While diversification mitigated risk and provided alternative income, excessive engagement in too many activities might dilute management focus, spread resources too sparsely, and prevent the specialisation needed for high returns in any single project (Table 5).

Table 5. Binary logistic regression-built model for predicting investment success

Assets	B	Significance	95% C.I. for OR		
			OR	Lower	Upper
Biophycal	0.011	0.124	1.011	0.997	1.025
Human	0.016	0.775	1.016	0.911	1.134
Diversity	-0.521	0.027	0.594	0.375	0.941
Connectivity	-0.745	0.034	0.475	0.238	0.946
Technical	0.728	0.002	2.072	1.319	3.254
Performance	-0.073	0.005	0.929	0.883	0.978
Constraint	0.056	0.101	1.057	0.989	1.130
Constant	1.608	0.319	4.992	-	-

Note: B – unstandardised logistic regression coefficient; OR – Odds Ratio; 95% C.I. – 95% confidence interval for OR (lower and upper bounds)
Source: developed by the author

"Connectivity Asset" emerged as another significant negative predictor (B = -0.745, p = 0.034, OR = 0.475), this finding contradicted network theory expectations, but may reflect information overload, decision complexity, or systemic risk exposure in highly connected systems (Battiston *et al.*, 2012). The substantial negative coefficient indicated that each unit increase in connectivity reduces success odded by approximately 53%. A negative association with success might imply that high interconnectedness exposed farmers to information overload or even herd mentality, leading them to invest in popular but potentially unsuitable projects without thorough individual farm assessment. Alternatively, a strong reliance on external networks might reduce internal innovation or critical evaluation of investment opportunities.

"Performance Asset" showed a small but significant negative effect (B = -0.073, p = 0.005, OR = 0.929) on the investment success. A negative link to investment success could be due to already high-performing farms undertaking riskier, more ambitious investments. These ventures, while having higher potential returns, also inherently carry a greater chance of absolute failure. Investors often overestimate their knowledge and abilities, leading to risky decisions without adequate information (Xie, 2024). Such farms might be leveraging their strong performance to experiment with novel or large-scale projects, which were not guaranteed successes. This complex interplay highlighted that the factors driving the ability to invest were distinct from those guaranteeing investment success. This finding resonated with data of J. Lakonishok *et al.* (1994), who suggested that performance chasing can lead to suboptimal outcomes. The remaining assets – biophysical, human, and constraint showed non-significant effects, though their inclusion contributed to overall model performance.

Indeed, understanding agricultural investment through the lens of farm assets had become an increasingly prominent area of inquiry, within smallholder farming contexts. The theoretical foundation of this approach traces back to the sustainable livelihood's framework introduced by F. Ellis (2000), which conceptualised agricultural outcomes as products of the dynamic interplay among different capital assets. R. Chambers & G.R. Conway (1992) further advanced this thinking by demonstrating that adaptive capacity in farming systems was shaped not by financial resources alone, but by the full spectrum of livelihood assets available to farm households. Complementing this view, A. Sen (2001) argued through the capability approach that what ultimately determined agricultural outcomes was the farmer's ability to translate available assets into productive action. Subsequent empirical work had reinforced and extended these theoretical foundations. A. Bebbington (1999) showed that households managing diverse asset portfolios tend to display stronger resilience and a greater capacity for investment. Building on this, A. Khatri-Chhetri *et al.* (2017) provided more recent evidence that farms characterised by well-balanced asset endowments were better positioned to embrace new technologies and realise higher returns on their investments. Together, these studies lend robust support to a multi-dimensional understanding of agricultural investment success. Despite this growing body of knowledge, a significant gap remained. As F. Rosa *et al.* (2019) observed, farmers typically construct their production plans under conditions of incomplete information, which introduced systematic biases into decision-making. In summary, investment success was driven by technical competency, while diversification, connectivity, and current performance paradoxically reducd success odds. These findings contest simplistic assumptions about asset endowments

and highlight the complexity of investment dynamics in resource-constrained environments.

▸ Conclusions

Study underscored the critical importance of strategic agricultural investment for enhancing food security in Algeria's semi-arid cereal farming regions, where understanding the drivers of successful investment was paramount for national resilience. This research developed a robust predictive model based on seven composite asset dimensions, offering a practical framework for evidence-based agricultural policy design. The binary logistic regression model demonstrated strong predictive performance, achieving an overall classification accuracy of 79.8%, with a R^2 of 0.486, the model explains nearly half of the variance in investment outcomes. The HL test confirmed excellent goodness of fit ($\chi^2 = 6.035$), validating the reliability of the model's predictions across the full range of estimated probabilities. The model's results revealed that a farm's "Technical Asset" was the strongest and most significant positive predictor of investment success (OR = 2.072, p = 0.002), confirming that farms with higher technical competency were more than twice as likely to achieve successful outcomes. Three asset dimensions exert significant negative effects: "Diversity Asset" (OR = 0.594, p = 0.027), "Connectivity Asset" (OR = 0.475, p = 0.034), and "Performance Asset" (OR = 0.929, p = 0.005). These counterintuitive findings suggested that over-diversification, information overload from extensive networks, and risk-seeking behaviour among already high-performing farms may collectively undermine investment success. These insights offered a powerful tool for governmental policies, enabling a shift from reactive support to proactive, evidence-based allocation of loans and subsidies. By targeting farms with asset profiles associated with higher success probability, policymakers can optimise public spending and directly contribute to sustainable cereal production. The study acknowledged limitations related to its cross-sectional design and regional scope. Future research should prioritise longitudinal studies and broader geographical coverage to refine and generalise the predictive framework.

▸ Acknowledgements

I would like to acknowledge Benlaoukli Mouna and Mentasseur Tounes for their valued help.

▸ Funding

None.

▸ Conflict of interest

None.

▸ References

[1] Ahmadirad, Z. (2024). The banking and investment in the future: Unveiling opportunities and research necessities for long-term growth. *International Journal of Applied Research in Management, Economics and Accounting*, 1(2), 34-41. doi: 10.63053/ijmea.7.

[2] Baghdad, C. (2022). The Algerian agricultural sector between the question of food security and its implication in economic diversification strategy. *World Food Policy*, 8(2), 263-275. doi: 10.1002/wfp2.12049.

[3] Battiston, S., Puliga, M., Kaushik, R., Tasca, P., & Caldarelli, G. (2012). DebtRank: Too central to fail? Financial networks, the FED and systemic risk. *Scientific Reports*, 2, article number 541. doi: 10.1038/srep00541.

[4] Bebbington, A. (1999). Capitals and capabilities: A framework for analyzing peasant viability, rural livelihoods and poverty. *World Development*, 27(12), 2021-2044. doi: 10.1016/S0305-750X(99)00104-7.

[5] Blandford, D. (2007). Information deficiencies in agricultural policy design, implementation and monitoring. *OECD Food, Agriculture and Fisheries Papers*, 6. doi: 10.1787/067228574571.

[6] Brynjolfsson, E., & McAfee, A. (2014). *The Second Machine Age: Work, progress, and prosperity in a time of brilliant technologies*. New York; London: W.W. Norton & Company.

[7] Chambers, R., & Conway, G.R. (1992). Sustainable rural livelihoods: Practical concepts for the 21st century. In *IDS Discussion Paper 296*. Brighton: Institute of Development Studies.

[8] Cox, D.R., & Snell, E.J. (1989). *Analysis of binary data* (2nd ed.). London: Chapman & Hall.

[9] Daoudi, A., Benterki, N., & Terranti, S. (2010). The fight against desertification of steppe grazing areas: The approach of integrated agro-pastoral development. In *ISDA 2010* (pp. 1-11). Montpellier: Open Science.

[10] Dzvene, A.R., Zhou, L., Slayi, M., & Dirwai, T.L. (2025). A scoping review on challenges and measures for climate change in arid and semi-arid agri-food systems. *Discover Sustainability*, 6, article number 151. doi: 10.1007/s43621-025-00945-z.

[11] El Benni, N., Grovermann, C., & Finger, R. (2023). Towards more evidence-based agricultural and food policies. *Q Open*, 3(3), article number qoad003. doi: 10.1093/qopen/qoad003.

[12] Ellis, F. (2000). *Rural livelihoods and diversity in developing countries*. Oxford: Oxford University Press. doi: 10.1093/oso/9780198296959.001.0001.

[13] Goetzmann, W.N., & Kumar, A. (2008). Equity portfolio diversification. *Review of Finance*, 12(3), 433-463. doi: 10.1093/rof/rfn005.

[14] Golla, B. (2021). Agricultural production system in arid and semi-arid regions. *International Journal of Agriculture Sciences and Food Technology*, 7(2), 234-244. doi: 10.17352/2455-815X.000113.

[15] Ingrao, C., Stripolli, R., Lagioia, G., & Huisingh, D. (2023). Water scarcity in agriculture: An overview of causes, impacts and approaches for reducing the risks. *Heliyon*, 9(8), article number e18507. doi: 10.1016/j.heliyon.2023.e18507.

[16] Jolliffe, I.T. (2002). *Principal component analysis* (2nd ed.). New York: Springer. doi: 10.1007/b98835.

[17] Khan, S.U., Fouzder, S.K., & Sarkar, P.K. (2023). Productivity and profitability of commercial broiler chickens under various farming conditions. *Journal of Experimental Biology and Agricultural Sciences*, 11(1), 209-215. doi: 10.18006/2023.11(1).209.215.

[18] Khatri-Chhetri, A., Aggarwal, P.K, Joshi, P.K., & Vyas, S. (2017). Farmers' prioritization of climate-smart agriculture (CSA) technologies. *Agricultural Systems*, 151, 184-191. doi: 10.1016/j.agsy.2016.10.005.
[19] Komarek, P., & Moore, A. (2005). Making logistic regression a core data mining tool. A practical investigation of accuracy, speed, and simplicity. In *ICDM '05: Proceedings of the fifth IEEE international conference on data mining* (pp. 685-688). Washington, D.C.: IEEE Computer Society. doi: 10.1109/ICDM.2005.90.
[20] Kurdyś-Kujawska, A. (2016). Significance of production diversification in ensuring financial security of farms in Poland. *Journal of Agribusiness and Rural Development*, 40(2), 355-366. doi: 10.17306/JARD.2016.39.
[21] Lakonishok, J., Shleifer, A., & Vishny, R.W. (1994). Contrarian investment, extrapolation, and risk. *The Journal of Finance*, 49(5), 1541-1578. doi: 10.1111/j.1540-6261.1994.tb04772.x.
[22] Meziane, R., Mouss, A.K., Hammouche, D., Boughris, M., & Boughris, F. (2024). Practical management of sheep farming in Eastern Algeria: Situation, constraints and perspectives. *World's Veterinary Journal*, 14(3), 389-399. doi: 10.54203/scil.2024.wvj46.
[23] Nagelkerke, N.J.D. (1991). A note on a general definition of the coefficient of determination. *Biometrika*, 78(3), 691-692. doi: 10.1093/biomet/78.3.691.
[24] Nicol, A., Langan, S., Victor, M., & Gonsalves, J. (2015). Building resilience: Farm-scale management practices to improve productivity and resilience. In A. Nicol, S. Langan, M. Victor & J. Gonsalves (Eds.), *Water-smart agriculture in East Africa* (pp. 31-34). Colombo, Kampala: IWMI and CGIAR research program on WLE; GWI EA.
[25] Pickson, R.B., Gui, P., Jian, L., & Boateng, E. (2024). The role of private sector investment in agriculture: A catalyst for sustainable development in Asia. *Sustainable Development*, 33(1), 113-128. doi: 10.1002/sd.3105.
[26] Rosa, F., Taverna, M., Nassivera, F., & Iseppi, L. (2019). Farm/crop portfolio simulations under variable risk: A case study from Italy. *Agricultural and Food Economics*, 7, article number 8. doi: 10.1186/s40100-019-0127-7.
[27] Rouabhi, A., Laouar, A., Mekhlouk, A., & Dhehibi, B. (2019). Socioeconomic assessment of no-till in wheat cropping system: A case study in Algeria. *New Medit*, 18(1), 52-64. doi: 10.30682/nm1901e.
[28] Sen, A. (2001). *Development as freedom*. Oxford: Oxford University Press.
[29] Setif province. (n.d.). Retrieved from https://www.wilayasetif.dz/CTOIC/Fr/index.html.
[30] Sharma, S., Yost, M.A., & Reeve, J.R. (2025). Roles of organic agriculture for water optimization in arid and semi-arid regions. *Sustainability*, 17(12), article number 5452. doi: 10.3390/su17125452.
[31] Tanchum, M. (2021). The fragile state of food security in the Maghreb: Implication of the 2021 cereal grains crisis in Tunisia, Algeria, and Morocco. *Middle East Institute*. Retrieved from https://mei.edu/publication/fragile-state-food-security-maghreb-implication-2021-cereal-grains-crisis-tunisia/.
[32] The Declaration of Helsinki. (2013). Retrieved from https://surl.lu/bdlzxk.
[33] Thornton, P.K., *et al.* (2018). A framework for priority-setting in climate smart agriculture research. *Agricultural Systems*, 167, 161-175. doi: 10.1016/j.agsy.2018.09.009.
[34] Xie, J. (2024). The impact of investor psychology on investment decisions. *Advances in Economics, Management and Political Sciences*, 114, 101-109. doi: 10.54254/2754-1169/114/2024bj0168.
[35] Yulianti, U.A., Muchtar, A., & Amruddin, A. (2024). Sustainable livestock management practices: Balancing production and environmental conservation. *Riwayat*, 7(4), 2923-2930. doi: 10.24815/jr.v7i4.42615.

Прогнозування успішності аграрних інвестицій у напівпосушливих регіонах Алжиру: інструмент політики на основі активів

Амар Руаабі
Доктор агрономії, доцент
Університет Ферхата Аббаса Сетіф 1
19137, кампус Ель Без, м. Сетіф, Алжир
https://orcid.org/0000-0001-6226-662X

► **Анотація.** Метою цього дослідження було розробити прогностичну модель успішності аграрних інвестицій в напівпосушливих зернових господарствах Алжиру з метою сприяння розробці урядових політик щодо розподілу кредитів і субсидій. Дослідження було зосереджено на напівпосушливих регіонах, де зернове господарство було основою продовольчої безпеки, а стратегічні аграрні інвестиції стали важливими для поліпшення результатів і підвищення стійкості господарств. Використовуючи дані опитування 198 фермерських господарств у Сетіфі (Алжир), було створено сім складених вимірів активів і визначено типи господарств за допомогою багатовимірного аналізу. Для прогнозування успішності аграрних інвестицій була розроблена модель бінарної логістичної регресії. Модель логістичної регресії показала практичну загальну точність класифікації 79,8 %, з $R^2 = 0{,}358$ та $R^2 = 0{,}486$. Результати показали, що «Технічний актив» був найсильнішим позитивним предиктором успіху (B = 0,728, OR = 2,072, p = 0,002). Деякі складені активи, такі як «Різноманітність фермерства», «Зв'язок» та «Продуктивність», виявилися негативними предикторами успіху інвестицій, що вказувало на складні динаміки, такі як надмірна диверсифікація або вищі ризики в господарствах з більшими ресурсами. Результати підтвердили значні структурні відмінності між типами господарств, при цьому великі господарства продемонстрували значно вищі рівні біофізичних, людських і диверсифікаційних активів, що відображало більшу ресурсну базу та адаптаційний потенціал. Розроблена прогностична модель показала високу пояснювальну та класифікаційну ефективність, підтверджуючи ключову роль технічної спроможності як вирішального фактору для досягнення успіху інвестиційних результатів. Дослідження надало практичну прогностичну основу для розробників політики, що дозволило приймати рішення на основі даних для оптимізації розподілу ресурсів, зниження ризиків, пов'язаних з державним фінансуванням, та в кінцевому підсумку сприяння успішнішим аграрним інвестиціям, що зміцнювали сталий розвиток зернових культур та продовольчу безпеку. Ці результати надали розробникам політики інструмент для відбору даних, що оптимізував розподіл аграрних субсидій та кредитів, безпосередньо зміцнюючи продовольчу безпеку в напівпосушливих регіонах

► **Ключові слова:** продовольча безпека; типологія господарств; аграрна політика; прогностичне моделювання; напівпосушливі регіони

Received: 21.10.2025. Revised: 10.01.2026. Accepted: 12.02.2026. Published: 05.03.2026.

EKONOMIKA APK

https://doi.org/10.32317/ekon.apk/1.2026.20

Ekonomika APK, 33(1), 20-36

UDC 338.439:330.43:355.01

ISSN: 2221-1055; E-ISSN: 2413-2322

Forecasting the dynamics of food security indicators in Ukraine during the wartime period of 2025-2026

Olena Shebanina*
Doctor of Economics, Professor
Mykolaiv National Agrarian University
54008, 9 Georgiy Gongadze Str., Mykolaiv, Ukraine
https://orcid.org/0000-0001-7663-5991

Oleksandr Zhebko
Postgraduate Student
Mykolaiv National Agrarian University
54008, 9 Georgiy Gongadze Str., Mykolaiv, Ukraine
https://orcid.org/0009-0009-1604-5952

Yelyzaveta Zhdanova
Student
Separate Structural Subdivision "Technological and Economic Applied College of Mykolaiv National Agrarian University"
54008, 9 Georgiy Gongadze Str., Mykolaiv, Ukraine
https://orcid.org/0009-0007-3514-5460

► **Abstract.** This article focuses on forecasting key food security indicators for Ukraine in 2025-2026 under conditions of wartime uncertainty. The aim of the study was to develop adaptive forecasting models that made it possible to assess the impact of wartime shocks and to determine possible trajectories for the recovery of the food system in the medium term. The methodology was based on the combined application of three classical time series models – linear trend, exponential smoothing, and the autoregressive integrated moving average model. For each indicator, three alternative forecasting models were constructed based on annual data up to 2022, and their accuracy was evaluated using the criteria of mean absolute percentage error, root mean square error, and the AIC information criterion. Given the absence of official statistics for 2022-2026, the baseline forecasts were adjusted according to a "partial recovery" scenario, which took into account a short-term decline (2022) and gradual stabilisation of indicators in 2023-2026. The results obtained indicated that in 2025-2026 the food system of Ukraine demonstrated signs of stabilisation; however, a full return to the pre-war trajectory did not occur. In particular, the daily energy value of the diet amounted to 2,596 kcal in 2025 and increased to 2,650 kcal in 2026, approaching the 2021 level. The adequacy index of consumption for most key products in 2025-2026 fluctuated within the range of 1.00-1.04, indicating the restoration of a rational level of consumption. The volume of state grain reserves increased to 1,253 thousand tonnes in 2025 and to 1,282 thousand tonnes in 2026, ensuring the recovery of the reserve adequacy indicator to 27-29%. The share of household expenditure on food gradually decreased to 48% in 2025 and to 46% in 2026. Import dependence in 2025-2026 amounted to 38-39% for fruit and berries, 40-42% for fish, and 45-46% for oil, whereas for bread products, potatoes, and eggs it did not exceed 2-11%, confirming the preservation of a high level of domestic self-sufficiency in basic food products

► **Keywords:** scenario modelling; wartime economic shocks; state food reserves; economic accessibility of food; food import dependence; resilience of the agricultural system

► Introduction

Russia's full-scale armed aggression against Ukraine, which began in 2022, has caused a structural disruption in the trends of Ukraine's key food security indicators. Whilst their development between 2000 and 2021 was

► **Suggested Citation**: Shebanina, O., Zhebko, O., & Zhdanova, Ye. (2026). Forecasting the dynamics of food security indicators in Ukraine during the wartime period of 2025-2026. *Ekonomika APK*, 33(1), 20-36. doi: 10.32317/ekon.apk/1.2026.20.

*Corresponding author

characterised by relative trend stability, the war period led to a sharp change in the production, logistical and price parameters of the food system's functioning. The relevance of this study stems from the need to quantitatively assess the extent of the impact of military operations on food security and to identify possible trajectories for its recovery in the medium term. Scientific research on assessing food security in the context of armed conflicts has covered a wide range of methodological approaches. M. Svanidze *et al.* (2019) investigated the spatial integration of wheat markets under export restrictions and demonstrated that trade barriers significantly disrupted price transmission between Ukraine and the rest of the world. C.P. Martin-Shields & W. Stojetz (2019) confirmed the bidirectional relationship between food security and armed conflicts, emphasising that food instability has been both a cause and a consequence of military action. P. Meyfroidt *et al.* (2022) systematised the lessons of global shocks and proposed a conceptual framework for transforming food systems to enhance their resilience. L. Ye (2023) highlighted the need to enhance the resilience of food systems in the face of external shocks and emphasised that adaptability, diversification of supply sources and the flexibility of institutional mechanisms have become key factors in maintaining food security. The author argued that periods of crisis required a shift from linear planning to scenario-based management of food systems, taking uncertainty into account. These propositions are methodologically aligned with the approach presented in this article to the scenario-based adjustment of forecasts for Ukraine's food security indicators during the war. J. Clapp & W.G. Moseley (2020) revealed the structural vulnerabilities of global food security in the context of the COVID-19 crisis, which is methodologically akin to the analysis of wartime shocks. S. O'Hara & E.C. Toussaint (2021) investigated the crisis mechanisms affecting access to food during the COVID-19 pandemic and demonstrated that food security was largely determined by socio-economic inequalities and institutional capacity. The findings were conceptually relevant to the analysis of war shocks as factors disrupting food availability. Researchers O. Shubravska & K. Prokopenko (2022) conducted a comprehensive analysis of the challenges and opportunities for Ukraine's food security in the post-war period, identifying strategic guidelines and directions for the modernisation of the agricultural sector, taking into account the specifics of sustainable development. The authors also emphasised the importance of developing local agri-food systems and supporting small-scale producers to ensure the availability of quality food for all sections of the population. Researchers L. Artemenko *et al.* (2023) conducted a comprehensive analysis of the state of food security in Ukraine during wartime, substantiated strategic directions for its stabilisation and the modernisation of the agricultural sector, and proposed practical measures taking into account the challenges and potential of digitalisation and innovative transformation. C. Béné (2020) identified the key factors underpinning the resilience of local food systems in times of crisis, emphasising the role of diversifying supply sources and adaptive recovery mechanisms. The researcher noted that a system's resilience is determined not only by the volume of stocks but also by the ability of market actors to adapt to destabilising shocks.

Researchers O. Sobkevych *et al.* (2023) examined the challenges associated with ensuring food security and its impact on national security in a wartime context. The researchers emphasised the need to strengthen the resilience of the agricultural sector and industry in order to counter external threats. Also significant was the study by S. Kvasha *et al.* (2024), who analysed the impact of martial law on the provision of basic foodstuffs to Ukrainian citizens and conducted a regression analysis of the influence of macroeconomic factors on the level of food security. The authors found that the main problem was not so much the physical availability of food as its financial inaccessibility. Researcher V. Zaliznyuk (2019) examined the level of food security in Ukraine through a quantitative analysis of a system of indicators and their threshold values, which reflected accessibility, consumption and self-sufficiency in the food sector. The main focus was on comparing consumption levels with recommended norms and identifying structural problems in access to quality food. The difficulty in assessing the dynamics of food security indicators during wartime was due not only to the scale of the economic shock but also to the limited availability of statistical data, which were only accessible up to 2021. The period from 2022 onwards was characterised by structural changes that made it impossible to directly extrapolate pre-war trends. Under these conditions, it became appropriate to apply combined forecasting approaches that combined historical trends with expert-based scenarios of wartime and post-war development.

The aim of this article was to forecast the trends in Ukraine's key food security indicators during wartime using a combined approach to modelling and scenario analysis. To achieve this aim, the following objectives had to be addressed: 1) to analyse the retrospective dynamics of Ukraine's food security indicators for the period 2000-2021 and establish a forecasting information base; 2) to construct, compare and assess the accuracy of alternative time-series models for each indicator, determining the optimal specification for forecasting for 2025-2026; 3) to perform scenario-based adjustments to forecast values, taking into account military shocks, and to interpret the results from the perspective of formulating state policy in the field of food security. The scientific novelty of the article lies in the application of an adaptive combination of classical time series models with scenario-based adjustment, which allows for the generation of robust forecasts of Ukraine's food security indicators under conditions of high uncertainty and a lack of up-to-date data.

▸ Materials and methods

Methodological principles for assessing and forecasting food security indicators in Ukraine. In the study, an officially approved methodology for assessing the main food security indicators (Resolution of the Cabinet of Ministers of Ukraine No. 1379, 2007) was used; however, its provisions were adapted for the purposes of forecasting analysis. At the first stage, based on available data up to 2021 from the State Statistics Service of Ukraine (n.d.), time series of key food system indicators were constructed. For each indicator, separate calculations were carried

out in accordance with standard formulas, in particular: Indicator 1 – the daily dietary energy value per person (reflecting the overall level of food provision of the population) – not less than 2,500 kcal per day. Indicator 2 – the adequacy of consumption of basic food products – the index should be no less than 1.0 (compliance of actual consumption with rational norms). This indicator was calculated using the formula:

$$I_2 = \frac{C\_actual}{C\_standard}, \quad (1)$$

where C_ actual – the actual annual consumption of the product per person (kg), and C_standard – the recommended consumption level (kg). A value of $I_2 \geq 1.0$ indicates sufficient consumption.

Indicator 3 – adequacy of grain stocks in state reserves – at least 17% of annual domestic consumption (equivalent to 60 days' consumption). Indicator 4 – economic accessibility of food – the proportion of household expenditure on food must not exceed 60% of total expenditure. Indicator 5 – differentiation in food costs across social groups – the ratio of expenditure between the poorest and richest households must not exceed a coefficient of 2.0. The study employed a quintile approach: average monthly food expenditure was compared for the 20% of households with the lowest (first quintile) and the 20% with the highest (fifth quintile) incomes. Indicator 6 – domestic market capacity for specific products – reflects the market's ability to meet the population's needs for key food groups. It was determined by comparing actual consumption with potential consumption (based on rational norms). It must not be lower than the food self-sufficiency standard. Indicator 7 – level of food independence (import dependence) – the share of imports in the consumption structure should not exceed 20% for key product groups (meat, milk, fish) and 30% – the permissible limit for other goods.

Following the development of the baseline indicators, a time-series analysis was conducted, alternative forecasting models were constructed, and scenario adjustments were made in line with wartime conditions. Official statistical data on key indicators of Ukraine's food security for 2022-2026 are unavailable, as confirmed by information provided by the State Statistics Service of Ukraine in response to a request. As noted in the letter from the State Statistics Service (State Statistics Service of Ukraine, 2025), the necessary statistical surveys were not carried out for the period 2022-2026, in particular sample surveys of household living conditions and their agricultural activities, and there was no reliable estimate of the average annual population. This made it impossible to compile balances of the population's staple foodstuffs, as well as the expenditure and resources of Ukrainian households, in accordance with the current Methodological Provisions for State Statistical Observation (State Statistics Service of Ukraine, 2022). Consequently, the analysis of food security during this period was constrained by the lack of comprehensive statistical data and required the use of alternative sources and expert assessments.

A consistent approach was used to forecast Ukraine's food security indicators for the period 2025-2026, based on the application of three classical time series models: the linear trend model, exponential smoothing (ETS) models, and ARIMA models. The time series used in the study differ in terms of observation period and internal structure depending on the specifics of each indicator. For indicators 1 and 3, data for 2000-2021 were used, whilst for the other indicators, given the limitations of official statistics in a comparable format, the period 2009-2021 was used. Indicators 2, 6 and 7 had a multi-component structure and were derived from several time series, for which individual modelling was carried out followed by aggregation of the results. Derived indicators were calculated as relative ratios between the underlying variables. Due to the lack of official statistical data for the period of full-scale war, forecast values after 2021 were derived within the framework of the "partial recovery" baseline scenario, which envisaged a slow restoration of logistics infrastructure, a partial reduction in import dependency, and a gradual stabilisation of the domestic market. Technically, the baseline scenario was implemented by adjusting the "peace-time" forecast, obtained using the selected model, by expert-determined shock coefficients for 2022-2023 and a gradual convergence of the indicators towards the projected trajectory of the pre-war trend in the medium term. Computational experiments and forecasting of food security indicators were carried out in the R programming environment, which made it possible to combine the mathematical accuracy of the models with the convenience of automated calculations. The use of the forecast, technical trading rules and stats packages ensured the correct estimation of parameters, the generation of forecasts and the calculation of accuracy criteria.

Specification and rationale for the selection of time series models for the development of a baseline forecast. In order to form a baseline forecast serving as the basis for scenario adjustment, three groups of classical time series models were applied: a linear trend model, the ETS exponential smoothing model, and an ARIMA model with drift. The use of these models ensures an optimal balance between statistical accuracy, economic interpretability, and robustness to short time series, which are typical of socio-economic indicators. The linear trend model reflects the long-term tendency of change in the indicator, assuming that its dynamics are determined by a constant average annual increase or decrease. For food-related indicators, this is a natural assumption, as the levels of consumption, diet, accessibility, and market capacity change gradually under the influence of demographic, structural, and institutional factors:

$$y_t = \beta_0 + \beta_1 t + \varepsilon_t, \quad (2)$$

where y_t – the value of the indicator in period t, β_0 – the initial level, β_1 – the average annual change of the indicator (trend), $\varepsilon_t \sim N(0,\sigma^2)$ – the random component. In the model parameters: β_0 – represents the baseline level of the series, β_1 reflects the intensity of the series ($\beta_1 > 0$ – growth, $\beta_1 < 0$ – decline) and σ^2 – the variance of the error term. Figure 1 presents the implementation of the linear trend model in the R programming language.

```
> model_trend <- lm(as.numeric(train) ~ t_train)
> t_train <- 1:length(train)
> model_trend <- lm(as.numeric(train) ~ t_train)
> fc_trend_test <- predict(model_trend,
+                          newdata = data.frame(
+                            t_train = (length(train)+1):(length(train)+length(test))
+                          ))
```

Figure 1. Practical implementation of a linear trend model
Notes: the model was created in R using the basic functions of the stats package
Source: developed by the authors

As the available time series are short, the use of complex models is not advisable. In this case, a linear trend model is appropriate due to its straightforward interpretation and its ability to reveal the underlying trend without excessive "overfitting".

Application of the exponential smoothing ETS model. The ETS (Error-Trend-Seasonal) model was constructed on the assumption that the behaviour of an economic indicator was determined by its level, trend, and noise, with more recent observations carrying greater weight. This reflected the realities of the food market, where new events (price fluctuations, yields, changes in imports) exerted a stronger influence on current dynamics. ETS could capture a damped trend, that is, a tendency towards stabilisation, which is characteristic of most socio-economic indicators. The ETS (A, Ad, N) specification was used as the forecasting model. It belongs to the class of exponential smoothing models and is characterised by three components: the type of error (E), the type of trend (T), and the type of seasonality (S). The abbreviation ETS (A, Ad, N) denotes: A (additive error), Ad (additive damped trend), and N (no seasonality). Thus, ETS (A, Ad, N) describes a time series with a level and a trend whose magnitude gradually decreases over time, while random fluctuations are added linearly to the forecast value. This model is defined by a system of three equations:

1) the observation equation:

$$y_t = \ell_{t-1} + \phi b_{t-1} + \varepsilon_t; \quad (3)$$

2) level update:

$$\ell_t = \ell_{t-1} + \phi b_{t-1} + \alpha\varepsilon_t; \quad (4)$$

3) trend update:

$$b_t = \phi b_{t-1} + \beta\varepsilon_t, \quad (5)$$

where l_t – level, b_t – trend, ϕ – damping coefficient, α and β – smoothing parameters, and ε_t – noise. In the model parameters: α represents the speed of level adjustment, β – the speed of trend adjustment, ϕ and –damping (if ϕ is close to 1, the trend is persistent; if, $\phi < 1$ – the trend slows down over time). Figure 2 presents the implementation of the exponential smoothing (ETS) model in the R programming language.

```
> model_ets <- ets(train)
> fc_ets_test <- forecast(model_ets, h = length(test))$mean
> model_ets_full <- ets(y_ts)
> fc_ets_full <- forecast(model_ets_full, h = H)$mean
```

Figure 2. Practical implementation of ETS (A, Ad, N)
Notes: the model was created in the R environment using the forecast package (ETS/forecast functions)
Source: developed by the authors

This model performed well on short time series, did not require stationarity, realistically modelled the stabilisation of indicators, and in 70-80% of cases provided the minimum forecast error for socio-economic indicators.

ARIMA model with drift (ARIMA (p, d, q)). ARIMA modelled the dependence of the current value of the indicator on previous values and the structure of random shocks. The model combined autoregression, integration and moving averages. Food security indicators were characterised by inertia – levels of consumption, stocks or availability rarely changed abruptly. This is precisely why ARIMA was suitable for short-term forecasting of such time series. The mathematical formalisation of the model took the following form:

$$\nabla^d y_t = c + \sum_{i=1}^{p} \phi_i \nabla^d y_{t-1} + \sum_{j=1}^{q} \theta_j \varepsilon_{t-j} + \varepsilon_t, \quad (6)$$

where p – the order of autoregression, d – differencing (removal of the trend), q – the order of the moving average, c – drift (an analogue of the trend after differencing), and ϕ_i, θ_j – model parameters. The model parameters were as follows: *AR(p)* – the strength of the influence of past values, *MA(q)* – the response to random shocks, d – the number of differences applied, and *c(drift)* – the average rate of change of the level. Figure 3 presents the implementation of the ARIMA model in the R programming language.

```
> model_arima <- auto.arima(train)
> fc_arima_test <- forecast(model_arima, h = length(test))$mean
> model_arima_full <- auto.arima(y_ts)
> fc_arima_full <- forecast(model_arima_full, h = H)$mean
```

Figure 3. Practical implementation of ARIMA (p, d, q)
Notes: the model was created in the R environment using the forecast package (functions auto.arima, Arima and forecast) and the stats package
Source: developed by the authors

The combination of a linear model, ETS and ARIMA made it possible to: capture three different types of indicator behaviour (trend, trend + damping, and inertia); ensure

an objective selection of the best model through cross-validation (MAPE for 2018-2021); avoid overfitting; guarantee the economic interpretability of forecasts, which became a necessary condition for scientific analysis; and obtain robust forecasts even in the presence of short time series. Due to the use of several alternative models, there arose a need for a quantitative comparison of their predictive capabilities. That is why the next stage of the study involved assessing the accuracy of the models on a test segment of the time series. Using the historical period 2018-2021 to test the predictive properties enabled an objective assessment of the adequacy of each model and allowed to identify the specification that best replicates the actual dynamics of the indicator. To this end, a set of forecasting accuracy metrics was applied, including the mean absolute percentage error (MAPE), root mean square error (RMSE) and the AIC information criterion.

Assessment of the models' forecasting accuracy and scenario adjustment of the baseline forecast. To objectively assess forecast accuracy, cross-validation was applied by dividing the time series into training and test samples. The training set covered the period 2000-2017, whilst the test set for 2018-2021 was used as an independent benchmark to verify the model's ability to predict the actual values of the indicator. This approach was economically and statistically sound because: 1) it avoided overfitting, where the model accurately "memorises" historical values but performs poorly in forecasting the future; 2) it ensured realistic modelling of situations where forecasts are made prior to events unknown to the model; 3) it allowed models to be compared against one another using a single criterion – the reproduction of test set values; 4) it has become standard practice in forecasting macro- and socio-economic time series. Formally, the cross-validation process can be represented as follows:

$$y_t = f(train, data), t = 2018 \dots 2021, \quad (7)$$

where $f(\cdot)$ – one of the models, and $\hat{y}_t$ – the model forecast, which is compared with the actual value y_t. To quantitatively assess model accuracy, three of the most commonly used metrics were applied: MAPE, RMSE, and AIC. These make it possible to compare forecast accuracy, the degree of error, and the efficiency of model parameterisation. MAPE shows the average percentage deviation of the forecast from the actual values:

$$MAPE = \frac{100}{n}\sum_{t=1}^{n}\left|\frac{y_t-\hat{y}_t}{y_t}\right|. \quad (8)$$

Figure 4 shows an implementation of the MAPE metric in the R programming language for a linear trend model.

```
> mape_trend <- mean(abs((test - fc_trend_test)/test))*100
```

Figure 4. Practical implementation of MAPE
Notes: the model was developed in the R environment based on forecast error calculations (own implementation/ forecast package)
Source: developed by the authors

MAPE < 10% was generally considered high accuracy for socio-economic data. RMSE assessed the average magnitude of error in natural units (kcal, kg, %):

$$RMSE = \sqrt{\frac{1}{n}\sum_{t=1}^{n}(y_t - \hat{y}_t)^2}. \quad (9)$$

Figure 5 presents the implementation of the RMSE metric in the R programming language for the ETS exponential smoothing model. RMSE is sensitive to "large" errors and therefore serves as a reliable indicator of model stability. AIC penalised models with a large number of parameters and helped to avoid overfitting:

$$AIC = 2k + n\ln(\hat{\sigma}^2), \quad (10)$$

where k – the number of model parameters, $\hat{\sigma}^2$ – the estimated variance of residuals, n – the number of observations.

Figure 6 presents the implementation of the AIC metric in the R programming language for the ARIMA model.

```
> rmse_arima <- sqrt(mean((test - fc_ets_test)^2))
```

Figure 5. Practical implementation of RMSE
Notes: the model was developed in the R environment based on forecast error calculations (own implementation/ forecast package)
Source: developed by the authors

```
> aic_arima <- AIC(model_arima)
```

Figure 6. Practical implementation of AIC
Notes: the model was developed in the R environment using the information criterion (AIC function from the stats package)
Source: developed by the authors

The minimum AIC value indicated the most balanced model. After determining the best model for each indicator, forecasting for 2025-2026 was carried out. As these values were formed without accounting for the shock of the war (due to the absence of data after 2021), they reflected a hypothetical trajectory assuming the continuation

of pre-war trends. For all indicators, forecasting was performed in the R environment using the forecast and stats packages. Given the wartime nature of the shock in 2022-2026 and the destabilisation of logistics, state reserves, and foreign trade, the baseline forecast was adjusted in accordance with a "partial recovery" scenario. The scenario assumed: 1) 2022 – a decline of most indicators by approximately 15%; 2) 2023 – partial recovery (10% of the peacetime forecast); 3) 2024 – convergence towards pre-war dynamics (5%); 4) 2025 – return to the forecast trajectory. The scenario was developed based on an analysis of Ukraine's macroeconomic dynamics in 2022-2024 and forecast assessments by international financial institutions, including the International Monetary Fund (2023), the World Bank *et al.* (2023), and the National Bank of Ukraine (n.d.). Additionally, analytical assessments by international institutions regarding the global food situation and economic recovery were taken into account (FAO, 2023; OECD, 2023). Adjustment coefficients were determined by aligning the scale of decline in key macroeconomic indicators with the sensitivity of food security indicators to economic shocks.

▸ Results and Discussion

Forecasting and analysis of trends in key food security indicators

In 2022, Ukraine's real GDP declined by approximately 29-30%, food inflation exceeded 25%, and the share of household expenditure on food increased to 64%. At the same time, a reduction in agricultural production volumes and disruptions to logistics chains were observed (OECD, 2023). Given that most food security indicators responded to macroeconomic shocks with lower amplitude than GDP (due to the inertia effect of consumption), the adjustment coefficient for 2022 was set at -15% of the pre-war trend. In 2023, a partial recovery of economic activity began (GDP growth of 3-5%), which made it possible to reduce the scale of deviation of indicators to –10% (International Monetary Fund, 2023; World Bank *et al.*, 2023; National Bank of Ukraine, n.d.). In 2024, taking into account the stabilisation of the currency market, a slowdown in inflation, and the gradual recovery of agricultural exports (FAO, 2023), the deviation was reduced to -5%. From 2025 onwards, a return of indicators to the pre-war trend trajectory was assumed. To demonstrate the practical implementation of the methodological approach and to further interpret forecasting results, an analysis and forecast were carried out for Indicator 1 – the daily dietary energy value per person. This indicator is a fundamental element of the food security system, as it reflects the level of provision of the population with minimum physiological energy requirements and is sensitive to changes in the economic accessibility of food, as well as to structural crises, including those of a wartime nature. Based on an integrated comparison of three accuracy metrics (MAPE, RMSE, and AIC), the exponential smoothing ETS model was identified as the best forecasting model (Fig. 7).

```
> cat("overall best model:", best_overall, "\n")
overall best model: ETS
> print(round(scenario_forecast, 2))
Time Series:
Start = 2022
End = 2026
Frequency = 1
[1] 2275.45 2409.30 2543.15 2596.69 2650.23
```

Figure 7. Forecast values for Indicator 1

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

The obtained forecast values, adjusted in accordance with the "partial recovery" scenario, demonstrated a clearly pronounced effect of an initial decline in the indicator under conditions of wartime shocks, followed by gradual recovery. In particular, according to the calculated forecast, the daily dietary energy value in 2025-2026 approached a stable trajectory, reaching 2,596.69 and 2,650.23 kcal respectively. Such dynamics reflect processes typical of crisis periods in the adaptation of the food system: a sharp initial decline, a phase of gradual stabilisation, and a transition to a new equilibrium point. To ensure a comprehensive presentation of the research results, full values of the daily dietary energy per person for 2000-2021 and the forecast values obtained on the basis of the ETS model and adjusted according to the selected development scenario are presented (Table 1).

Table 1. Dynamics of the caloric value of average daily food consumption of the population of Ukraine per person, kcal per day

Year	Total caloric value (kcal)	Year	Total caloric value (kcal)
2000	2,661	2012	2,954
2001	2,758	2013	2,969
2002	2,800	2014	2,939
2003	2,798	2015	2,799
2004	2,910	2016	2,742
2005	2,916	2017	2,707
2006	2,935	2018	2,706

Table 1, Continued

Year	Total caloric value (kcal)	Year	Total caloric value (kcal)
2007	2,940	2019	2,691
2008	2,998	2020	2,674
2009	2,946	2021	2,677
2010	2,933	**2025**	**2,596**
2011	2,951	**2026**	**2,650**

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

The forecast for Indicator 1 indicated a significant but temporary deterioration in the dietary energy value of the population under the impact of the wartime shock. At the same time, the results confirmed a gradual recovery trend that does not allow for a full return to the pre-war trajectory even in the medium term. This highlighted the need for state support to improve the economic accessibility of food and to strengthen Ukraine's food system. To assess changes in the structure and level of provision of the population with key food products, a forecast of the dynamics of Indicator 2 – the adequacy of consumption of basic food products per person per year – was carried out. This indicator reflected the quantitative characteristics of the actual diet and made it possible to evaluate the extent to which the population is provided with key product groups – meat, milk, eggs, bread products, potatoes, vegetables, fruit, fish, sugar, and oil. As each product group had its own consumption trajectory shaped by prices, accessibility, logistical risks, purchasing power, and cultural dietary patterns, forecasting was conducted separately for each product using three time series models (trend, ETS, ARIMA), with selection of the most accurate one. The application of the "partial recovery" scenario made it possible to account for wartime shocks in 2022-2026, which affected the population's ability to maintain pre-war dietary levels. The obtained forecast values demonstrated a differentiated response of various product groups to wartime shocks, followed by gradual recovery (Fig. 8).

```
> cat("\noverall best model:", overall_best, "\n")

overall best model: ARIMA
> cat("\nscenario forecast 'partial recovery' (2022-2026):\n")

 scenario forecast'partial recovery' (2022-2026):
> print(results_scen)
  Year     Meat    Milk     Eggs    Bread   Potato Vegetables   Fruits     Fish    Sugar      Oil
1 2022 45.86762 171.275 229.3581 77.49167 114.5905   143.6136 51.35214 10.31205 24.24125 12.28912
2 2023 49.43143 181.350 239.7519 80.67000 122.1160   154.8129 55.64571 10.88594 25.66721 13.12031
3 2024 53.09143 191.425 249.8015 83.69500 129.1997   166.3179 60.08071 11.45621 27.09316 13.96353
4 2025 55.14219 195.455 251.7217 83.96967 132.0303   172.7847 62.71743 11.66216 27.66354 14.37422
5 2026 57.23143 199.485 253.5042 84.18300 134.7933   179.3739 65.41071 11.86665 28.23393 14.78972
```

Figure 8. Forecast values for Indicator 2
Source: State Statistics Service of Ukraine (n.d.)

Forecast recovery towards pre-war trends in 2025-2026 showed that most products are nearly returning to the trajectory of the trend forecast: eggs increase to 253-258 units, vegetables to 172-179 kg, fruit to 62-65 kg, and meat to 55-57 kg. Thus, consumption has stabilised, but even in 2026 some products have not reached the levels of the potential pre-war forecast, in particular milk, fish, and sugar. This highlights the prolonged nature of the war's impact on the structure of consumption.

Forecasting and analysis of indicators of consumption adequacy, grain reserves, and economic accessibility of food

The formation of a generalised assessment of the adequacy of consumption of basic food products per person was carried out through the calculation of an integral indicator based on actual data for 2000-2021 and forecast values for the period 2025-2026. Table 2 presents the values of the consumption adequacy indicator for each product group, which made it possible to trace interannual dynamics, compare pre-crisis, wartime, and forecast periods, and assess the degree of deviation of individual components of the diet from the rational norm in the medium term. The analysis of the obtained coefficients indicated significant differentiation in the level of provision across different food products, both in the pre-war period and under the influence of wartime shocks. The most stable and closest to normative levels during 2025-2026 were the consumption of potatoes, bread products, and vegetables, for which the indicator values mostly fluctuated around or above 1. In contrast, the consumption of fish and fruit consistently lagged behind rational norms, indicating the presence of long-term structural constraints in the accessibility of these products for households. Overall, the results pointed to a noticeable but temporary deterioration in the adequacy of food consumption during 2022-2023, followed by gradual recovery in the medium term. This confirmed the importance of implementing food resilience mechanisms aimed at mitigating the effects of crisis phenomena and ensuring stable access to food for all segments of the population.

Table 2. Calculation of the indicator of adequacy of food consumption per person per year (units; norm ≥ 1.0; rational norms – kg per person per year)

	Meat and meat products (kg)	milk and dairy products (kg)	eggs (units)	bread products (units)	potatoes (kg)	vegetables and melons (kg)	fruit, berries and grapes (kg)	fish and fish products (kg)	sugar (kg)	oil (l)
rational dietary norms	80	380	290	101	124	161	90	20	38	13
2000	0.41	0.52	0.57	1.24	1.09	0.63	0.33	0.42	0.97	0.72
2001	0.95	1.03	1.08	1.04	1.03	1.03	0.90	1.31	1.07	1.06
2002	1.05	1.10	1.16	1.01	0.95	1.03	1.08	1.08	0.91	1.07
2003	1.06	1.00	1.02	0.95	1.04	1.05	1.16	1.01	1.01	1.06
2004	1.12	1.00	1.03	1.01	1.02	1.02	1.03	1.03	1.05	1.15
2005	1.02	1.00	1.08	0.98	0.96	1.04	1.09	1.17	0.99	1.04
2006	1.07	1.04	1.05	0.97	0.99	1.05	0.94	0.98	1.04	1.01
2007	1.09	0.96	1.00	0.97	0.98	0.93	1.21	1.09	1.01	1.05
2008	1.11	0.95	1.03	1.00	1.01	1.09	1.03	1.14	1.02	1.05
2009	0.98	0.99	1.05	0.97	1.01	1.06	1.05	0.86	0.93	1.03
2010	1.05	0.97	1.07	1.00	0.97	1.05	1.05	0.96	0.98	0.96
2011	0.98	0.99	1.07	0.99	1.08	1.13	1.10	0.92	1.04	0.93
2012	1.06	1.05	0.99	0.99	1.01	1.00	1.01	1.01	0.98	0.95
2013	1.03	1.03	1.01	0.99	0.97	1.00	1.06	1.07	0.99	1.02
2014	0.96	1.01	1.00	1.00	1.04	1.00	0.93	0.76	0.98	0.98
2015	0.94	0.94	0.90	0.95	0.98	0.99	0.97	0.77	0.98	0.94
2016	1.01	1.00	0.95	0.98	1.02	1.02	0.98	1.12	0.93	0.95
2017	1.01	0.95	1.02	1.00	1.03	0.98	1.06	1.13	0.91	1.00
2018	1.02	0.99	1.01	0.99	0.97	1.03	1.09	1.09	0.98	1.02
2019	1.02	1.01	1.03	0.98	0.97	1.00	1.02	1.06	0.97	1.01
2020	1.00	1.01	0.99	0.99	0.99	1.00	0.96	0.99	0.97	1.03
2021	0.99	1.00	0.98	0.96	0.99	1.01	1.04	1.06	1.03	1.11
2025	**1.04**	**1.02**	**1.01**	**1.00**	**1.02**	**1.04**	**1.04**	**1.02**	**1.02**	**1.03**
2026	**1.04**	**1.02**	**1.01**	**1.00**	**1.02**	**1.04**	**1.04**	**1.02**	**1.02**	**1.03**

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

For further analysis of the resilience of Ukraine's food system, it was important to assess Indicator 3 – the adequacy of grain reserves in state resources. This indicator characterised the volume of food grain stored in reserve funds and used as a tool for market stabilisation under conditions of supply shocks, crisis situations, and threats to national security. Given the high level of uncertainty after 2022, forecasting the dynamics of state grain reserves required a combination of time series models with scenario-based assumptions. Similarly to previous indicators, the forecast was constructed using three models (trend, ETS, ARIMA), selected based on their accuracy in reproducing historical data, and adjusted according to the "partial recovery" scenario, which accounted for wartime risks, disruptions to logistics, and fluctuations in domestic production. The results of forecasting the dynamics of state grain reserves and domestic consumption of bread and bread products are presented in Figure 9.

```
[1] "ARIMA"
> consum_out$best
[1] "ARIMA"
> print(result)
  Year Reserve_scen Consumption_base
1 2022      936.500          4971.75
2 2023     1008.538          4826.50
3 2024     1080.577          4681.25
4 2025     1253.469          4536.00
5 2026     1282.285          4390.75
```

Figure 9. Forecast values for Indicator 3
Source: State Statistics Service of Ukraine (n.d.)

According to the modelling results, the ARIMA model was identified as the most accurate for forecasting the volume of food grain in reserves and domestic consumption of bread and bread products in grain equivalent, as it produced the lowest error during the test period. This indicated that the dynamics of grain consumption in Ukraine

exhibited pronounced inertia and a gradual, smooth decline, which the ARIMA model reproduced most accurately. In 2025-2026, the volume of grain continued to decrease, which was fully consistent with the long-term trend of declining bread consumption in Ukraine. Table 3 presents the actual values for 2009-2021 and the forecast indicators for 2025-2026 obtained using the ARIMA model. This made it possible to trace changes over the long term and to assess the impact of wartime events on the adequacy of state food grain reserves.

Table 3. Volume of state food grain reserves

Year	Volume of food grain in reserves, thousand tonnes	Average annual domestic consumption of bread and bread products in grain equivalent, thousand tonnes	Indicator of adequacy of grain reserves, %
2009	1,536	6,860	22
2010	1,105	6,808	16
2011	1,558	6,730	23
2012	1,680	6,653	25
2013	1,500	6,578	23
2014	1,245	6,224	20
2015	1,179	5,897	20
2016	1,349	5,745	23
2017	1,422	5,655	25
2018	1,630	5,610	29
2019	1,567	5,470	29
2020	1,426	5,379	27
2021	1,533	5,117	29
2025	**1,253**	**4,536**	**27**
2026	**1,282**	**4,390**	**29**

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

The forecast data showed that the indicator demonstrated a further positive trend: 27% in 2025 and 29% in 2026. Following the analysis of the adequacy of grain reserves, it is appropriate to assess another key parameter of food security – the economic accessibility of food. This indicator directly reflects the extent to which the financial capacity of households allows them to maintain a rational diet under conditions of changing incomes, inflationary pressure, and the overall socio-economic environment (FAO *et al.*, 2022). To evaluate the economic accessibility of food, a forecast of the dynamics of two key indicators was carried out: total household expenditure and expenditure on food products. Both time series covered the period 2009-2021, demonstrating steady growth under the influence of inflationary processes, rising food prices, and increasing household incomes. Given the absence of official data during the wartime period, the forecast for 2025-2026 was constructed using time series models with subsequent adjustment according to the "partial recovery" scenario (Fig. 10). The ARIMA model proved to be the most accurate for both indicators.

```
> cat("best model for TOTAL:", total_out$best, "\n")
best model for TOTAL: ARIMA
> cat("best model for FOOD :", food_out$best,  "\n")
best model for FOOD : ARIMA
> print(result)
  Year Total_scen Food_scen
1 2022    7303.93   4731.04
2 2023    8340.78   5005.99
3 2024    9445.49   5280.93
4 2025   11547.15   5555.88
5 2026   12416.55   5830.82
```

Figure 10. Forecast values for Indicator 4
Source: State Statistics Service of Ukraine (n.d.)

The obtained forecast values showed that even under conditions of wartime shocks, total household expenditure and spending on food products would continue to increase in the coming years. In 2022, both indicators experienced a scenario-based decline; however, from 2023 onwards, the forecast reflected a gradual recovery of households' consumption capacity. By the end of 2026, total household expenditure may exceed UAH 12,000, while expenditure on food may reach approximately UAH 5,800 per month. Table 4 presents the actual and forecast values of key indicators of the economic accessibility of food products. The data cover the period 2009-2021 and also include forecasts for 2025-2026 based on the ARIMA model. This made it possible to assess the impact of wartime events on the financial capacity of households, as well as to identify trends in the economic accessibility of food in the medium term.

Table 4. Total household expenditure on food products and non-alcoholic beverages

Year	Average monthly total expenditure per household, UAH	Average monthly expenditure on food products per household, UAH	Share of expenditure on food products and non-alcoholic beverages in the structure of total household expenditure, %
2009	2,415.13	1,156.77	48
2010	2,773.08	1,328.95	48
2011	3,124.69	1,497.03	48
2012	3,591.76	1,802.01	50
2013	3,813.96	1,913.52	50
2014	4,048.99	2,097.44	52
2015	4,951.99	2,633.97	53
2016	5,720.37	2,852.69	50
2017	7,139.41	3,423.71	48
2018	8,308.61	3,962.53	48
2019	8,900.83	3,832.75	43
2020	8,883.81	3,932.90	44
2021	10,558.22	4,456.10	42
2025	**11,547.15**	**5,555.88**	**48**
2026	**12,416.55**	**5,830.82**	**46**

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

The analysis of Table 4 showed that in the pre-war period the share of expenditure on food products gradually decreased – from 48-53% in 2009-2015 to 42% in 2021, indicating an improvement in the economic accessibility of food and an increase in purchasing power. In 2025-2026, the forecast indicated gradual recovery: the share of food expenditure declined to 48% in 2025 and 46% in 2026, pointing to stabilisation of household incomes and a slowdown in inflationary processes. The fifth indicator – differentiation in the cost of food across social groups – reflected the level of socio-economic inequality in access to food and was based on a comparison of food expenditure between households with the lowest and highest incomes (first and fifth quintiles). The greater the difference in these expenditures, the higher the risk of food vulnerability among low-income groups and the more significant the structural disparities in the economic accessibility of food products. Figure 11 presents the forecast dynamics of average monthly food expenditure for two social groups – the lowest-income 20% of households and the highest-income 20%. The forecast for 2025-2026 was carried out using the ARIMA model, which proved to be the most accurate for both series, with subsequent adjustment according to the "partial recovery" scenario. The model made it possible to assess how wartime and economic shocks affected social inequality in access to food products.

```
> cat("best model (LOW): ", low_out$best, "\n")
best model (LOW):  ARIMA
> cat("best model (HIGH):", high_out$best, "\n")
best model (HIGH): ARIMA
> print(result)
  Year Low_scen High_scen
1 2022  2720.09   4159.23
2 2023  3191.21   4738.31
3 2024  3699.74   5354.41
4 2025  4617.19   6533.20
5 2026  5056.30   7012.87
```

Figure 11. Forecast values for Indicator 5
Source: State Statistics Service of Ukraine (n.d.)

The obtained results demonstrated that expenditure on food increased across all social groups; however, the rates of growth remained uneven, leading to a widening differentiation in access to food. During 2025-2026, both indicators showed gradual recovery and growth, although expenditure by wealthier households increased at a faster rate. By the end of 2026, the gap between groups is expected to widen further: UAH 5,056 versus UAH 7,012, reflecting a deepening of structural inequality. The forecast indicated that social differentiation in the cost of food would intensify as a result of the uneven impact of inflationary and economic shocks on different population groups. Table 5 presents the dynamics of household food expenditure across different income levels, as well as an indicator of the differentiation in the cost of food – the ratio of expenditure between the top 20% of households by income and the bottom 20%. Analysis of the data showed that, in the pre-war period, the food cost differential ranged between 1.55 and 1.93 times, reflecting a consistently high level of socio-economic inequality in access to food. The forecast predicted a gradual further reduction in the disparity to 1.41 times in 2025 and to 1.39 times in 2026, indicating a partial levelling of opportunities for different social groups in terms of access to food. Overall,

the forecast results indicated that social inequality in food expenditure would tend to decrease in the medium term. However, the level of differentiation remained significant, highlighting the need to support low-income households and to formulate policies aimed at ensuring equal access to quality food.

Table 5. Economic accessibility of food products

Year	Average monthly food expenditure of the lowest-income 20% of households, UAH	Average monthly food expenditure of the highest-income 20% of households, UAH	Differentiation in the cost of food across social groups, times
2009	1,023.31	1,586.17	1.55
2010	1,250.85	1,841.15	1.47
2011	1,211.33	2,142.95	1.77
2012	1,298.83	2,172.03	1.67
2013	1,347.85	2,415.72	1.79
2014	1,570.31	2,504.50	1.59
2015	1,984.84	3,092.21	1.56
2016	1,908.60	3,354.69	1.76
2017	2,338.83	4,066.49	1.74
2018	2,706.94	4,997.33	1.85
2019	2,873.16	5,547.56	1.93
2020	3,227.78	5,575.71	1.73
2021	3,810.63	6,028.61	1.58
2025	**4,617.19**	**6,533.20**	**1.41**
2026	**5,056.30**	**7,012.87**	**1.39**

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

Forecasting and analysis of domestic market capacity and food self-sufficiency

Following an analysis of the socio-economic aspects of food accessibility, the capacity of the domestic market for staple foods was assessed. Unlike previous indicators characterising accessibility, differentiation and household expenditure, this indicator reflected the actual capacity of the domestic market to provide the population with the necessary volumes of food. To assess the potential dynamics of the domestic food market under wartime conditions, forecasts were made of consumption volumes for the main food groups (Fig. 12).

```
> cat("\nbest models:\n")

best models:
> print(best_models)
      Meat       Milk       Eggs      Bread     Potato Vegetables     Fruits
   "Trend"    "ARIMA"    "Trend"    "Trend"    "Trend"    "ARIMA"    "ARIMA"
      Fish      Sugar        Oil
   "ARIMA"    "Trend"      "ETS"
>
> cat("\nscenario forecast(2022-2026):\n")

scenario forecast(2022-2026):
> print(results)
  Year Meat_scen Milk_scen Eggs_scen Bread_scen Potato_scen Vegetables_scen
1 2022   1818.58   7173.18     530.62     3108.07     5029.89          5843.90
2 2023   1906.48   7595.13     549.55     3179.83     5306.71          6192.45
3 2024   1992.26   8017.08     567.11     3239.25     5581.43          6539.44
4 2025   2013.63   8185.86     565.81     3187.75     5678.40          6678.89
5 2026   2034.16   8354.64     563.96     3131.31     5774.53          6817.66
  Fruits_scen Fish_scen Sugar_scen Oil_scen
1     1974.37    465.54     941.54   479.06
2     2090.51    492.93     947.64   507.24
3     2206.65    520.32     948.26   535.42
4     2253.11    531.27     915.10   546.69
5     2299.56    542.22     879.76   557.96
```

Figure 12. Forecast values for Indicator 6

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

The obtained forecast values of domestic market capacity across the main product groups demonstrated a moderate but steady recovery trend following the shock of 2022. The most stable growth was observed for vegetables, fruit, and potatoes, indicating a return of consumption to its pre-war structure and an increased role of local production. Categories of meat and dairy products recovered more slowly, reflecting the impact of high inflation and reduced purchasing power. Consumption of eggs and oil showed consistent positive trends, which is associated with their accessibility and essential role in the diet. The segment of fish and fish products grew gradually;

however, its level remained below pre-war values. Sugar remained the only group with a gradual decline in demand, corresponding to broader European and national trends towards dietary rationalisation. Overall, the forecast confirmed that the domestic food market, despite the challenges of the wartime period, retained the capacity for recovery, and its structure gradually stabilised. Table 6 summarises the dynamics of the domestic food market capacity in Ukraine by major food groups for 2009-2026, including both actual values (2009-2021) and forecast estimates based on the selected models and the "partial recovery" scenario (2025-2026).

Table 6. Assessment of domestic market capacity, thousand tonnes

Year	Meat and meat products	Milk and dairy products	Eggs	Bread products	Potatoes	Vegetables and melons	Fruit, berries and grapes	Fish and fish products	Sugar	Oil
2009	2,290.0	9,780.1	722.0	5,145.1	6,125.8	6,311.8	2,100.7	696.9	1,745.0	711.3
2010	2,384.0	9,469.8	767.0	5,105.9	5,913.8	6,581.3	2,203.2	667.0	1,704.0	680.0
2011	2,339.4	9,363.0	818.0	5,046.8	6,368.3	7,440.0	2,405.0	614.3	1,758.3	625.3
2012	2,478.0	9,797.1	810.0	4,989.9	6,393.9	7,452.2	2,432.3	620.1	1,713.4	590.5
2013	2,550.0	10,050.0	813.0	4,933.2	6,160.6	7,430.5	2,560.1	662.5	1,686.0	603.5
2014	2,325.4	9,581.1	771.0	4,667.7	6,061.3	7,019.1	2,248.6	479.4	1,559.1	561.2
2015	2,178.7	8,995.0	694.0	4,422.8	5,891.5	6,889.8	2,178.9	367.2	1,527.6	525.1
2016	2,195.0	8,995.0	659.0	4,308.7	5,966.3	6,984.1	2,118.7	410.2	1,420.4	497.3
2017	2,195.2	8,495.9	670.0	4,284.5	6,090.5	6,783.0	2,241.5	460.0	1,290.4	496.5
2018	2,232.1	8,354.8	671.0	4,207.3	5,893.1	6,927.2	2,444.6	497.1	1,260.1	500.9
2019	2,252.2	8,427.9	683.0	4,102.7	5,705.2	6,923.8	2,469.0	523.9	1,212.2	504.4
2020	2,244.1	8,430.3	670.0	4,034.2	5,593.1	6,845.5	2,356.9	517.4	1,161.3	512.4
2021	2,191.2	8,337.3	650.0	3,837.6	5,480.2	6,866.1	2,440.4	547.7	1,180.5	563.6
2025	**2,147.1**	**8,354.6**	**565.8**	**3,187.8**	**5,678.4**	**6,678.9**	**2,390.7**	**536.7**	**556.7**	**536.7**
2026	**2,034.2**	**8,354.6**	**564.0**	**3,131.3**	**5,774.5**	**6,817.7**	**2,506.6**	**542.2**	**579.8**	**558.0**

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

The overall analysis indicated that Ukraine's domestic food market had the potential for gradual recovery. Demand for most product groups increased or stabilised, reflecting households' adaptation to wartime economic conditions and the preservation of basic dietary needs. The highest growth rates were expected for vegetables, fruit, and potatoes, while bread, fish, and sugar remained the most sensitive categories. Overall, Table 6 demonstrated both structural changes in consumption and the prospects for recovery of Ukraine's food system in the medium term. Following the analysis of domestic consumption dynamics and market capacity, the indicator of food independence (import dependence) was examined. Unlike previous indicators, which characterised internal aspects of consumption and food accessibility, this indicator made it possible to assess the resilience of the national food system in the external economic dimension. To determine the level of food independence, it was first necessary to analyse and forecast import volumes for the main food product groups. After establishing actual and forecast import volumes, the next step was to determine their share within the structure of domestic consumption. Based on forecast values of import volumes and domestic market capacity for key food products, the level of food independence (import dependence) was determined for the period of uncertainty in 2025-2026. According to the comparison of forecasting accuracy, the ARIMA model proved to be the overall best model, ensuring the most stable ability to reproduce the dynamics of import flows. On the basis of this model, the forecast was carried out with adjustment according to the "partial recovery" scenario (Fig. 13).

```
> cat("\noverall best model:", overall_best_model, "\n")

overall best model:
> print(best_models)
[1] "ARIMA"

> print(results)
  Year  Meat   Milk Eggs  Bread Potato Vegetables Fruits   Fish  Sugar    Oil
1 2022 221.0 490.40 4.77 257.93  85.89     288.68 958.67 164.70 142.79 215.44
2 2023 234.0 257.00 5.05 281.20  90.94     305.66 943.36 182.65 151.19 228.12
3 2024 247.0 108.91 5.33 305.37  95.99     322.64 939.25 201.52 159.58 240.79
4 2025 252.2 136.73 5.45 320.53  98.01     329.44 936.08 214.67 162.94 245.86
5 2026 257.4 293.02 5.56 336.05 100.04     336.23 960.96 228.19 166.30 250.93
```

Figure 13. Forecast values for Indicator 6
Source: State Statistics Service of Ukraine (n.d.)

The forecasted import volumes indicated a gradual increase in external supplies across almost all major product groups. The most dynamic growth was observed for meat, fruit and berries, fish products, and oil, which

remained the most import-dependent categories. For eggs, potatoes, and dairy products, more moderate or minor fluctuations were observed. Overall, the forecast demonstrated that food imports would maintain an upward trend, which may indicate structural imbalances in domestic production and an increased sensitivity of food security to external factors. The obtained forecast values of imports by major food product groups made it possible to form a generalised picture of potential changes in the structure of external supplies in 2025-2026. The consolidated forecasting results are presented in Table 7, where for each product group both actual data for 2009-2021 and expected values for the period of wartime uncertainty (2025-2026) are provided. This made it possible to trace import dynamics by product category, assess the scale of potential import dependence, and evaluate the further impact of external supplies on the country's food security.

Table 7. Imports of food products, thousand tonnes

Year	Meat and meat products	Milk and dairy products	Eggs	Bread products	Potatoes	Vegetables and melons	Fruit, berries and grapes	Fish and fish products	Sugar	Oil
2009	439	455	7	136	15	232	1,139	–	92	316
2010	378	273	7	175	30	311	1,130	425	90	319
2011	244	257	3	273	41	285	1,163	–	48	249
2012	423	410	4	228	23	213	1,171	–	10	231
2013	332	548	5	242	23	237	1,172	–	11	296
2014	201	357	7	263	40	225	856	–	7	223
2015	158	78	11	190	17	95	588	237	4	160
2016	182	105	5	240	27	136	732	–	5	219
2017	233	132	7	255	24	129	819	338	7	239
2018	283	180	4	280	28	188	878	394	3	259
2019	261	337	5	291	278	313	1,052	417	4	250
2020	230	691	4	352	325	292	1,150	424	4	245
2021	260	781	4	377	252	343	1,183	461	168	289
2025	**252**	**137**	**5**	**321**	**98**	**329**	**936**	**215**	**163**	**246**
2026	**257**	**293**	**5**	**336**	**100**	**336**	**961**	**228**	**166**	**251**

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

The analysis of actual and forecast import volumes demonstrated that in 2025-2026 external supplies for most food groups would maintain a gradual upward trend. The highest import pressures were projected for fruit and berries, fish products, oil, and meat, indicating a structural shortage of domestic production in these segments. For other product groups – eggs, potatoes, milk, and bread products – imports remained relatively stable, reflecting a higher level of self-sufficiency. Overall, Table 7 confirmed the increasing sensitivity of the domestic market to external supplies under wartime conditions and highlighted the importance of further calculating the level of food independence. Food independence for a specific product was defined as the ratio between the volume of imports of that product in physical terms and the capacity of its domestic market, according to the formula:

$$P_i = \frac{I_i}{C_i} \cdot 100\%, \quad (11)$$

where P_i – the share of food imports of product *i*; *i* – the type of food product; I_i – the import volume of product *i*; C_i – the domestic market capacity of product *i*.

Based on forecast import values and projections of domestic market capacity, Table 8 presents the calculation of the food independence indicator, which determines the share of imports in domestic consumption and allows for the assessment of the level of strategic resilience of Ukraine's food system in 2025-2026.

Table 8. Calculation of import dependence by food groups, %

Year	Meat and meat products	Milk and dairy products	Eggs	Bread products	Potatoes	Vegetables and melons	Fruit, berries and grapes	Fish and fish products	Sugar	Oil
2009	19.17	4.65	0.97	2.64	0.24	3.68	54.22	–	5.27	44.43
2010	15.86	2.88	0.91	3.43	0.51	4.73	51.29	63.72	5.28	46.91
2011	10.43	2.74	0.37	5.41	0.64	3.83	48.36	–	2.73	39.82
2012	17.07	4.18	0.49	4.57	0.36	2.86	48.14	–	0.58	39.12
2013	13.02	5.45	0.62	4.91	0.37	3.19	45.78	–	0.65	49.05
2014	8.64	3.73	0.91	5.63	0.66	3.21	38.07	–	0.45	39.74
2015	7.25	0.87	1.59	4.30	0.29	1.38	26.99	64.54	0.26	30.47
2016	8.29	1.17	0.76	5.57	0.45	1.95	34.55	–	0.35	44.04
2017	10.61	1.55	1.04	5.95	0.39	1.90	36.54	73.48	0.54	48.14
2018	12.68	2.15	0.60	6.66	0.48	2.71	35.92	79.26	0.24	51.71

Table 8, Continued

Year	Meat and meat products	Milk and dairy products	Eggs	Bread products	Potatoes	Vegetables and melons	Fruit, berries and grapes	Fish and fish products	Sugar	Oil
2019	11.59	4.00	0.73	7.09	4.87	4.52	42.61	79.60	0.33	49.56
2020	10.25	8.20	0.60	8.73	5.81	4.27	48.79	81.95	0.34	47.81
2021	11.87	9.37	0.62	9.82	4.60	5.00	48.48	84.17	14.23	51.28
2025	**11.74**	**1.64**	**0.88**	**10.07**	**1.73**	**4.93**	**39.15**	**40.06**	**29.28**	**45.84**
2026	**12.63**	**3.51**	**0.89**	**10.73**	**1.73**	**4.93**	**38.34**	**42.05**	**28.63**	**44.98**

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

An analysis of trends in import dependency across key food categories revealed significant variations in the domestic market's reliance on external supplies. The most vulnerable product groups remained fruits and berries, fish and fish products, and vegetable oil, for which imports consistently exceeded 30-50% of domestic consumption throughout the entire period. This indicated a structural shortfall in domestic production and high sensitivity of the relevant market segments to external risks and logistical disruptions. For categories such as eggs, potatoes and bread products, the level of import dependency remained minimal (mostly below 2-7%), indicating a high degree of self-sufficiency in these segments. Moderate levels of import dependency were observed for milk and meat products, where the share of imports fluctuated between 3% and 20%, showing a trend towards gradual stabilisation. Forecast figures for 2025-2026 showed no sharp spikes in import dependency overall; however, the persistence of a high share of imports in key product groups indicated the need to strengthen food security through the development of domestic production, the diversification of import flows and the establishment of strategic reserves.

In contemporary research on the impact of war on Ukraine's food system, considerable attention has been devoted to the quantitative assessment of agricultural production losses and the forecasting of food security risks. In particular, B. Chen *et al.* (2024) and G.-H. Kwak & N.-W. Park (2024), using satellite data and spatio-economic analysis methods, assessed the extent of the reduction in cropland area and cereal production in 2022-2023, demonstrating significant regional disparities and structural losses in agricultural potential. The results confirmed the need to account for war-related shocks in forecasting models of food indicators. D. Saccone & E. Vallino (2025) reviewed the impact of the pandemic, war and climate change on global food security, systematising the multifactorial nature of contemporary shocks. The authors' approach highlighted the need for multi-scenario analysis in conditions of high uncertainty, which is methodologically consistent with the forecasting models used in the article. V. Rusan & L. Zhurakovska (2024) conducted a comprehensive assessment of the state of Ukraine's agricultural sector in 2023, identifying the key factors behind its relative stability and the systemic risks to its future development. The analytical assessments presented formed the empirical basis for quantitative modelling of food indicators during the war. T. Ben Hassen & H. El Bilali (2022) analysed the global implications of Russia's war against Ukraine for food security, demonstrating its impact on price volatility, logistical disruptions and increased risks for import-dependent countries. The authors emphasised the need to transition to more resilient and diversified food systems, which methodologically correlated with the use of a scenario-based approach in this study. K. Deininger *et al.* (2023) proposed an approach to near real-time assessment of agricultural production losses under conditions of limited statistical information, which is methodologically similar to scenario modelling and adaptive forecasting in crisis conditions. In turn, L. Novotná *et al.* (2023) investigated the impact of the war on Ukrainian wheat prices, applying econometric methods of time series analysis to assess volatility and shock effects, which directly correlated with approaches to modelling food indicators based on trend and autoregressive models. E. Shebanina *et al.* (2024) substantiated the management mechanisms for implementing sustainable land use projects in accordance with EU requirements, emphasising the importance of institutional adaptation and environmental modernisation of the agricultural sector. The results obtained broadened the understanding of the structural prerequisites for the long-term sustainability of the food system, which became conceptually important for interpreting the projected trajectories of food security indicators during the war and post-war periods. O. Shebanina & O. Zhebko (2022) investigated the structural trends in the development of Ukraine's grain market, identifying its role as a fundamental element in shaping food security and the state's strategic reserves. The patterns of dynamics in grain production, exports and domestic consumption identified by the authors provided an analytical basis for modelling the indicator of the adequacy of state grain reserves and assessing import dependency within the scope of this study. W. Leal Filho *et al.* (2023) summarised the global consequences of the war for food security, emphasising the systemic nature of the destabilisation of logistics chains, price imbalances and reduced food availability. O. Kiforenko (2025) focused on the transformation of Ukraine's national food system under wartime conditions and the need to develop adaptive forecasting and management mechanisms. Thus, contemporary academic works have confirmed the validity of using quantitative forecasting methods and a scenario-based approach to assess food security indicators in conditions of military uncertainty. In contrast to the aforementioned studies, this study carried out a comprehensive modelling of Ukraine's food security indicator system using alternative econometric time-series models (Trend, ETS, ARIMA) and their subsequent scenario-based adjustment, which enabled the formulation of a coherent medium-term development trajectory for the food system for 2025-2026.

▸ Conclusions

The obtained research data made it possible to form a comprehensive assessment of the dynamics of food security indicators in Ukraine and to derive quantitatively grounded forecast values for 2025-2026. The modelling results indicated that after the deep shock of 2022, the system gradually stabilised; however, a full return to the pre-war trajectory did not occur. In 2025, the daily energy value of the diet amounted to 2,596 kcal, and in 2026 it began to increase to 2,650 kcal, approaching the 2021 level (2,677 kcal), though not exceeding it. The adequacy index of consumption of basic products in 2025-2026 remained within the range of 1.00-1.04 for most core groups, indicating the restoration of the normative level of consumption, although a structural shortage of fish and fruit and berry products persisted. The volume of state grain reserves increased to 1,253 thousand tonnes in 2025 and to 1,282 thousand tonnes in 2026, ensuring the recovery of the reserve adequacy indicator to 27-29%. The share of household expenditure on food gradually decreased to 48% in 2025 and 46% in 2026 after a peak of 64% in 2022, reflecting an improvement in the economic accessibility of food. The indicator of social differentiation of expenditure demonstrated a tendency towards a reduction in the interquintile gap in 2025-2026, indicating a gradual easing of social tension in the sphere of consumption.

The analysis of domestic market capacity confirmed the recovery of consumption volumes for most commodity groups in 2025-2026, in particular vegetables, potatoes, and fruit, while fish and certain import-dependent segments showed slower dynamics. The calculation of the level of food independence showed that in 2025-2026 import dependence remained high for fruit and berries (38-39%), fish (40-42%), and oil (45-46%), whereas for bread products, potatoes, and eggs it did not exceed 2-11%, confirming the preservation of a basic level of self-sufficiency. Thus, it can be argued that Ukraine's food security during wartime was characterised by a combination of high short-term vulnerability and medium-term potential for stabilisation. A prospect for further research would be to improve adaptive food security forecasting models by incorporating operational data following the end of hostilities and expanding the range of scenarios.

▸ Acknowledgements

None.

▸ Funding

None.

▸ Conflict of interest

None.

▸ References

[1] Artemenko, L., Marynenko, N., Kramar, I., & Hats, L. (2023). Food security of Ukraine under the war aggression: Current state and future perspectives. *Socio-Economic Problems and the State*, 28(1), 115-128. doi: 10.33108/sepd2023.01.115.

[2] Ben Hassen, T., & El Bilali, H. (2022). Impacts of the Russia-Ukraine war on global food security: Towards more sustainable and resilient food systems? *Foods*, 11(15), article number 2301. doi: 10.3390/foods11152301.

[3] Béné, C. (2020). Resilience of local food systems and links to food security – a review of some important concepts in the context of COVID-19 and other shocks. *Food Security*, 12, 805-822. doi: 10.1007/s12571-020-01076-1.

[4] Chen, B., Tu, Y., An, J., Wu, S., Lin, S., & Gong, P. (2024). Quantification of losses in agriculture production in Eastern Ukraine due to the Russia-Ukraine war. *Communications Earth & Environment*, 5, article number 336. doi: 10.1038/s43247-024-01488-3.

[5] Clapp, J., & Moseley, W.G. (2020). This food crisis is different: COVID-19 and the fragility of the neoliberal food security order. *The Journal of Peasant Studies*, 47(7), 1393-1417. doi: 10.1080/03066150.2020.1823838.

[6] Deininger, K., Ali, D.A., Kussul, N., Shelestov, A., Lemoine, G., & Yailimiva, H. (2023). Quantifying war-induced crop losses in Ukraine in near real time to strengthen local and global food security. *Food Policy*, 115, article number 102418. doi: 10.1016/j.foodpol.2023.102418.

[7] FAO, IFAD, UNICEF, WFP, & WHO. (2022). *The state of food security and nutrition in the world 2022*. Rome: FAO; IFAD; UNICEF; WFP; WHO. doi: 10.4060/cc0639en.

[8] FAO. (2023). *The impact of the war in Ukraine on global food security and related matters under the mandate of the Food and Agriculture Organization of the United Nations (FAO)*. Rome: FAO.

[9] International Monetary Fund. (2023). Ukraine: 2023 Article IV consultation, second review under the extended arrangement under the extended fund facility, and requests for modification of performance criteria and a waiver of nonobservance of performance criterion-press release; staff report; and statement by the executive director for Ukraine. *IMF Country Report No. 23/399*. Retrieved from https://www.imf.org/-/media/files/publications/cr/2023/english/1ukrea2023003.pdf.

[10] Kiforenko, O. (2025). The influence of war on the agricultural production of Ukraine: Analysis and projection scenarios. *WSB Journal of Business and Finance*, 59(1), 93-105. doi: 10.2478/wsbjbf-2025-0008.

[11] Kvasha, S., Pavlenko, O., Vakulenko, V., Moroz, M., & Liu, X. (2024). Diet of Ukrainian citizens as a component of food security in the conditions of the martial law. *Agricultural and Resource Economics: International Scientific E-Journal*, 10(1), 228-259. doi: 10.51599/are.2024.10.01.10.

[12] Kwak, G.-H., & Park, N.-W. (2024). Assessing the potential of multi-temporal conditional generative adversarial networks in SAR-to-optical image translation for early-stage crop monitoring. *Remote Sensing*, 16(7), article number 1199. doi: 10.3390/rs16071199.

[13] Leal Filho, W., Fedoruk, M., Paulino Pires Eustachio, J.H., Barbir, J., Lisovska, T., Lingos, A., & Baars, C. (2023). How the war in Ukraine affects food security. *Foods*, 12(21), article number 3996. doi: 10.3390/foods12213996.

[14] Martin-Shields, C.P., & Stojetz, W. (2019). Food security and conflict: Empirical challenges and future opportunities for research and policy making on food security and conflict. *World Development*, 119, 150-164. doi: 10.1016/j.worlddev.2018.07.011.
[15] Meyfroidt, P., *et al.* (2022). Ten facts about land systems for sustainability. *Proceedings of the National Academy of Sciences*, 119(7), article number e2109217118. doi: 10.1073/pnas.2109217118.
[16] National Bank of Ukraine. (n.d.). *Inflation report*. Kyiv: National Bank of Ukraine.
[17] Novotná, L., Rowland, Z., & Janek, S. (2023). Impacts of the war on prices of Ukrainian wheat. *Agricultural Economics*, 69(10), 404-415. doi: 10.17221/121/2023-AGRICECON.
[18] O'Hara, S., & Toussaint, E.C. (2021). Food access in crisis: Food security and COVID-19. *Ecological Economics*, 180, article number 106859. doi: 10.1016/j.ecolecon.2020.106859.
[19] OECD. (2023). *Ukraine Country Programme*. Paris: OECD.
[20] Resolution of the Cabinet of Ministers of Ukraine No. 1379 "Methodology for Determining the Main Indicators of Food Security". (2007, December). Retrieved from https://www.kmu.gov.ua/npas/99719937.
[21] Rusan, V., & Zhurakovska, L. (2024). The agricultural sector of Ukraine in 2023: Stability components, problems and prospective tasks. *National Institute for Strategic Studies*. Retrieved from https://niss.gov.ua/en/node/5201.
[22] Saccone, D., & Vallino, E. (2025). Global food security in a turbulent world: Reviewing the impacts of the pandemic, the war and climate change. *Agricultural and Food Economics*, 13, article number 47. doi: 10.1186/s40100-025-00388-0.
[23] Shebanina, E., Kormyshkin, I., Kliuchnyk, A., Reshetilov, G., & Zhebko, O. (2024). Management of sustainable land use projects in accordance with EU requirements. *Scientific Horizons*, 27(10), 148-161. doi: 10.48077/scihor10.2024.148.
[24] Shebanina, O., & Zhebko, O. (2022). Grain market: Trends and potential of its development. *Accounting & Finance*, 4, 121-130. doi: 10.33146/2307-9878-2022-4(98)-121-130.
[25] Shubravska, O., & Prokopenko, K. (2022). Ensuring food security of Ukraine: Post-war context. *Economy of Ukraine*, 65(7), 21-42. doi: 10.15407/economyukr.2022.07.021.
[26] Sobkevych, O., Shevchenko, A., Rusan, V., & Zhurakovska, L. (2023). *Priority measures to ensure the resilience of industry and the agricultural sector of Ukraine under full-scale war*. Kyiv: National Institute for Strategic Studies. doi: 10.53679/niss-analytrep.2023.04.
[27] State Statistics Service of Ukraine. (2022). *Methodological provisions of the state statistical observation "Household living conditions survey"*. Retrieved from https://surli.cc/paqqjd.
[28] State Statistics Service of Ukraine. (2025). Retrieved from https://drive.google.com/file/d/1r70fuQl9O1PeEUo_wNpAV8q1lY_2mU_E/view?usp=sharing.
[29] State Statistics Service of Ukraine. (n.d.). *Balances of main plant and animal products*. Retrieved from https://ukrstat.gov.ua/metaopus/2021/2_03_07_25_2021.htm.
[30] Svanidze, M., Götz, L., Djuric, I., & Glauben, T. (2019). Food security and the functioning of wheat markets in Eurasia: A comparative price transmission analysis for the countries of Central Asia and the South Caucasus. *Food Security*, 11, 733-752. doi: 10.1007/s12571-019-00933-y.
[31] World Bank, Government of Ukraine, European Union, & United Nations. (2023). *Second Ukraine rapid damage and needs assessment (RDNA2): February 2022-February 2023 (English)*. Washington, D.C.: World Bank Group.
[32] Ye, L. (2023). Editorial: Enhancing food production system resilience for food security facing a changing environment. *Frontiers in Sustainable Food Systems*, 7, article number 1204098. doi: 10.3389/fsufs.2023.1204098.
[33] Zalizniuk, V. (2019). Assessment of the indicators of food security of Ukraine. *Investment: Practice and Experience*, 2, 128-133. doi: 10.32702/2306–6814.2019.2.128.

Прогнозування динаміки індикаторів продовольчої безпеки України у воєнний період 2025-2026 років

Олена Шебаніна
Доктор економічних наук, професор
Миколаївський національний аграрний університет
54008, вул. Георгія Гонгадзе, 9, м. Миколаїв, Україна
https://orcid.org/0000-0001-7663-5991
Олександр Жебко
Аспірант
Миколаївський національний аграрний університет
54008, вул. Георгія Гонгадзе, 9, м. Миколаїв, Україна
https://orcid.org/0009-0009-1604-5952
Єлизавета Жданова
Студент
Відокремлений структурний підрозділ «Технолого-економічний фаховий коледж МНАУ»
54000, вул. Георгія Гонгадзе, 9, м. Миколаїв, Україна
https://orcid.org/0009-0007-3514-5460

► **Анотація.** Стаття присвячена прогнозуванню ключових індикаторів продовольчої безпеки України у 2025-2026 роках в умовах воєнної невизначеності. Метою дослідження була побудова адаптивних прогнозних моделей, що дозволили оцінити вплив воєнних шоків та визначити можливі траєкторії відновлення продовольчої системи у середньостроковій перспективі. Методологія ґрунтувалася на комбінованому застосуванні трьох класичних моделей часових рядів – лінійного тренду, експоненційного згладжування та моделі авторегресійної інтегрованої ковзної середньої. Для кожного індикатора було сформовано три альтернативні прогнозні моделі на основі щорічних даних до 2022 року, а їхню точність було оцінено за допомогою критеріїв середньої абсолютної відсоткової помилки, кореневої середньоквадратичної помилки та інформаційного критерію AIC. З огляду на відсутність офіційної статистики за 2022-2026 роки, базові прогнози було скориговано за сценарієм «partial recovery», який враховував короткострокове падіння (2022 рік) та поступову стабілізацію показників у 2023-2026 роках. Отримані результати свідчили про те, що у 2025-2026 роках продовольча система України продемонструвала ознаки стабілізації, однак повного повернення до довоєнної траєкторії не відбулося. Зокрема, добова енергетична цінність раціону у 2025 році становила 2596 ккал, а у 2026 році зросла до 2650 ккал, що наблизилося до рівня 2021 року. Індекс достатності споживання за більшістю ключових продуктів у 2025-2026 роках коливається в межах 1,00-1,04, що свідчило про відновлення раціонального рівня споживання. Обсяг державних запасів зерна у 2025 році зросло до 1253 тис. т, а у 2026 році – до 1282 тис. т, що забезпечило відновлення індикатора достатності резервів до 27-29 %. Частка витрат домогосподарств на харчування поступово знизилося до 48 % у 2025 році та до 46 % у 2026 році. Імпортозалежність у 2025-2026 роках становить 38-39 % для плодів та ягід, 40-42 % для риби та 45-46 % для олії, тоді як для хлібних продуктів, картоплі та яєць вона не перевищувала 2-11 %, що підтвердило збереження високого рівня внутрішнього самозабезпечення за базовими видами продовольства

► **Ключові слова:** сценарне моделювання; воєнні економічні шоки; державні продовольчі резерви; економічна доступність харчування; імпортозалежність продовольства; стійкість аграрної системи

Received: 09.10.2025. Revised: 05.01.2026. Accepted: 12.02.2026. Published: 05.03.2026.

EKONOMIKA APK

https://doi.org/10.32317/ekon.apk/1.2026.37

Ekonomika APK, 33(1), 37-46

UDC 338.48:338.43

ISSN: 2221-1055; E-ISSN: 2413-2322

Trends in the development and diversification of Ukraine's oils export markets

Tetiana Romanovska*
PhD in Technical Sciences, Associate Professor
National University of Food Technologies
01033, 68 Volodymyrska Str., Kyiv, Ukraine
https://orcid.org/0000-0003-3364-2408

Nataliia Romanovska
PhD in Economics, Associate Professor
State Institution "Institute of Economics and Forecasting of the National Academy of Sciences of Ukraine"
01011, 26 Panasa Myrnoho Str., Kyiv, Ukraine
https://orcid.org/0000-0002-1377-7551

▸ **Abstract.** This article analysed trends in the development and diversification of Ukraine's oils export markets. It examined the impact of globalisation processes, economic integration, and international competition on the structure of exports, as well as the role of state support mechanisms for exporters. The study employed a combination of statistical, analytical, and comparative methods, along with a systematic approach to assessing the competitiveness of oil and fat products in global markets. Export diversification was carried out in three main directions: expanding the geography of supply and increasing the number of importing countries, reorienting logistics routes and utilising alternative transport corridors, and diversifying the product structure by increasing the share of different types of oils and their processed products. A gradual increased in exports of soybean and rapeseed oil, meals, and oilcake was noted, contributing to higher added value and the formation of a more resilient system of foreign markets. The main constraints hindering effective diversification were identified as stricter technical and phytosanitary requirements, an insufficient level of transport and logistics infrastructure development, fluctuations in global prices, and a high level of competition. To overcome these barriers, a set of state support measures was proposed, including the modernisation of logistics, the development of trade and economic diplomacy, marketing support, and the stimulation of deep processing of oilseed crops. Market diversification is a strategic tool for ensuring economic resilience and enhancing the competitiveness of Ukraine's oil and fat industry in the context of global instability and the transformation of the international trading system. The practical significance lies in identifying effective directions for diversifying foreign markets for Ukraine's oil and fat products, which can be used by public authorities and industry enterprises to improve export competitiveness and resilience

▸ **Keywords:** export diversification; oil and fat industry; sunflower oil; international markets; logistics routes; processed oilseed products

▸ Introduction

The escalation of geopolitical instability, the transformation of supply chains and increased competition in global markets are creating additional challenges for domestic manufacturers. In such circumstances, reliance on a limited number of export markets increases economic risks and undermines the resilience of foreign trade operations. At the same time, the role of diversification as a tool for ensuring the continuity of exports and maintaining foreign exchange earnings is growing. This applies primarily to the oil and fat industry, which is the main component of Ukraine's exports of processed agricultural products by food industry enterprises. The issue of export diversification is particularly relevant for countries with a significant share of agricultural and raw material products in their

▸ **Suggested Citation**: Romanovska, T., & Romanovska, N. (2026). Trends in the development and diversification of Ukraine's oils export markets. *Ekonomika APK*, 33(1), 37-46. doi: 10.32317/ekon.apk/1.2026.37.

*Corresponding author

foreign trade structure. The need to establish new logistics routes and access alternative markets determines the practical significance of this study. Research into trends in the diversification of foreign markets is vital for ensuring the country's economic stability.

The issue of the development of foreign trade and Ukraine's integration into global economic processes is examined in the work by O. Bykonia & N. Romanovska (2023), which analyses the prospects for the development of Ukraine's trade in the context of European integration and the expansion of international economic ties. The development of sectors with high export potential is of particular importance, notably the oil and fat sector of the food industry. Ukraine's oil and fat sector plays a significant role in shaping the export potential of the agricultural sector, accounting for a substantial share of foreign exchange earnings from foreign trade (Makarchuk, 2022; Shandrivska *et al.*, 2024). At the same time, dependence on a limited number of foreign markets creates certain risks to the stability of the sector's development.

Modern researchers view the diversification of production and the structure of oilseed cultivation as an important tool for enhancing the competitiveness and resilience of the agricultural sector. In their work, L. Stepasiuk & M. Stepasiuk (2024) highlighted the potential of niche oilseed crops for expanding the production base of agricultural enterprises. The authors argue that the introduction of innovative technologies for growing non-traditional crops reduces dependence on major oilseed crops whilst opening up new market segments. Prominent attention is given to the economic efficiency of this approach and the opportunities for integrating agricultural production with the food industry, which contributes to increasing the added value of products and the development of local markets. O.O. Petrova (2020) investigated the regional aspect of oilseed business diversification, specifically using the example of the Kherson region. The author analysed existing production and market constraints that hinder the scaling up of non-traditional oilseed crops, and proposes practical ways to overcome these obstacles through the modernisation of technologies, the formation of cooperative structures among farmers, and the promotion of state support. Particular emphasis is placed on the importance of developing logistics and marketing strategies that ensure the entry of products into foreign markets.

The authors V. Gamayunova *et al.* (2024) examined the global prospects for the diversification of oilseed crops. The researchers have analysed current trends in the agricultural sector aimed at identifying new types of oilseed crops and optimising their cultivation. They emphasise that strategic diversification contributes not only to increased economic efficiency but also to strengthened food security, as it ensures more sustainable productivity in the face of climatic fluctuations and market instability. The authors proposed conceptual approaches to crop planning and risk management that are relevant for the scientifically sound development of the agricultural sector. Research by C. Arndt *et al.* (2023), V.I. Mytsenko (2024) and F. Boz *et al.* (2026) confirmed that current processes of global trade fragmentation, heightened geopolitical risks and the transformation of global production chains are creating new challenges for national economies. In these circumstances, the diversification of export markets takes on particular importance, as it allows for a reduction in dependence on individual importing countries, an increase in the resilience of foreign trade flows, and the assurance of stable sectoral development.

Despite a significant body of academic research devoted to the issues of international trade and export support, a number of questions remain under-researched. In particular, current trends in the fragmentation of world trade, the intensification of geopolitical risks and the transformation of global production chains are creating new challenges for national economies. In these circumstances, the search for effective tools to help export-oriented sectors adapt to changes in the structure of international markets becomes particularly relevant. One such tool is the diversification of export markets, which helps reduce dependence on individual importing countries, enhance the resilience of foreign trade flows, and ensure the sector's stable development. In this regard, it is relevant to study the mechanisms for diversifying sales markets for the oil and fat industry's products, as well as to analyse the possibilities for adapting international experience in supporting exporters to national conditions.

The aim of the study was to identify trends in the development and diversification of foreign markets for the oil and fat industry of Ukraine, as well as to substantiate effective directions for expanding export geography, ways to improve the commodity structure of exports, and methods for enhancing competitiveness in the context of global trade transformation.

▸ Materials and methods

The study was conducted within the framework of the theory of international trade development, the economics of the agricultural sector and the theory of competitive advantages, which enabled an assessment of the factors influencing the competitiveness of Ukrainian oil and fat products in foreign markets. To achieve the objective, the following methods were applied: descriptive statistical analysis (assessment of the volumes and structure of oil and fat product exports by country, identification of trends in the development of foreign markets); analytical method (systematisation of data from various sources, identification of factors influencing the effectiveness of market diversification); a comparative method (comparison of Ukrainian export practices with international experience to identify optimal strategies); and a systematic approach (integration of economic, logistical, technological and institutional factors into a comprehensive assessment of product competitiveness). The Herfindahl-Hirschman Index (*HHI*) was used for a quantitative assessment of the level of concentration:

$$HHI = \sum_{i=1}^{n} s_i^2, \quad (1)$$

where s_i – the country's share of total exports, n – the total number of entities.

The source base of the study encompassed both official statistics as well as sectoral analytics and information resources. The foundation consisted of data from state authorities, in particular materials from the State Service of Ukraine on Food Safety and Consumer Protection (2026),

which reflect current results of the functioning of the export system and the processes of digitalisation within the sector. The heuristic potential of these sources lies in their applicability for assessing state policy and the institutional environment. At the same time, their limitation is the aggregated nature of the data and the lack of detailed breakdowns by individual market segments.

Sectoral analytical resources were also of considerable importance, in particular materials from AgroPortal.ua (2025) and Grain Trade Online (2025), which provided up-to-date information on the structure of exports, Ukraine's position in global markets (including its share in the global sunflower oil trade), and the dynamics of changes in 2024-2025. Their heuristic value lies in reflecting current market trends, their rapid response to changes in market conditions, and their usefulness for analysing Ukraine's competitive position. However, such sources also have limitations related to the lack of a unified calculation methodology, possible differences in statistical approaches, and partial reliance on expert assessments.

In addition, materials from industry associations, in particular the Ukroilprom Association (2022), were used, making it possible to trace long-term trends in the development of foreign trade in oil and fat products and the market structure in 2021-2023. These sources proved valuable for retrospective analysis and for assessing sector-specific features; however, their limitations include a certain time lag in the data and potential institutional bias. The combination of official statistics, sectoral analytics, and information resources ensures a sufficient level of representativeness of the study, enables a multidimensional analysis of export processes, and enhances the reliability of the results obtained. At the same time, the use of heterogeneous sources requires careful interpretation of data and comparison of indicators in order to minimise methodological discrepancies.

▸ Results

The global economy underwent significant structural changes during the 2010s and 2020s, driven by the development of information and communication technologies, the growing importance of innovation, and the emergence of global value chains. In such conditions, international trade is characterised by high dynamism, which requires national economies to be able to adapt quickly to changes in global market conditions. One of the key tools for such adaptation is export diversification, which involves broadening the geographical scope of foreign trade, expanding the range of export products, and entering new segments of the global market. Export diversification is a key factor in ensuring economic resilience and reducing the national economy's vulnerability to external shocks. Excessive concentration of exports on a limited number of goods or markets can lead to significant economic risks associated with fluctuations in world prices, changes in partners' trade policies, or heightened political instability. In this context, export diversification is one of the aspects of international trade policy that determines the structure and nature of foreign trade relations.

According to data from the State Service of Ukraine on Food Safety and Consumer Protection, between the start of 2022 and 2025, 75 new foreign markets were opened for Ukrainian exports, indicating the preservation and gradual expansion of Ukraine's presence in international trade even under martial law (State Service of Ukraine on Food Safety and Consumer Protection, 2026). To a large extent, these results were made possible by the systematic work of the State Service of Ukraine on Food Safety and Consumer Protection, aimed at harmonising veterinary and phytosanitary requirements with the competent authorities of foreign states, conducting international audits, and expanding access for Ukrainian products to foreign markets. According to the 2025 report by the Head of the State Service of Ukraine on Food Safety and Consumer Protection, work was carried out to open markets for the export of goods to Vietnam, Turkey, the United Kingdom, the United States, the Philippines, Peru, Canada, Egypt, the Republic of Korea and Chile. Ukrainian products covered by these initiatives include cereals and oilseeds, flour, fresh apples, planting material, meat and meat products, dairy products, honey, animal feed, hatching eggs, live animals, fish and shellfish. Particular attention is being paid to opening up the Canadian market for exports of Ukrainian wheat, soya, maize and rapeseed. Efforts are being made to expand export opportunities to South American countries and the EU. In particular, regarding opportunities to export mustard seeds to Peru, maize grain to Chile, and maple seedlings to the EU (State Service of Ukraine on Food Safety and Consumer Protection, 2026). This helps to support the national economy, develop the food, processing, meat and dairy industries, and increase the state's foreign exchange earnings.

Within the structure of Ukrainian agricultural exports, oilseed processing products occupy a special place, accounting for a significant share of foreign exchange earnings and characterised by a high level of international competitiveness. In 2024, Ukraine's main export items were products of the oil and fat sector of the food industry and agricultural produce, namely:

- sunflower oil – 6 million tonnes worth USD 5.1 billion (21%);
- maize – 29.6 million tonnes worth USD 5 billion (21%);
- wheat – 20.6 million tonnes worth USD 3.7 billion (15%);
- rapeseed – 3.8 million tonnes worth USD 1.8 billion (7%);
- soybeans – 3.4 million tonnes worth USD 1.3 billion (5%);
- oilcake and meal – 4.7 million tonnes worth USD 1 billion (4%) (Grain Trade Online, 2025).

For this reason, the processes of opening up new foreign markets and expanding trade opportunities are of particular importance to the oilseed and oil industry (Fig. 1). First and foremost, the expansion of the geographical scope of oilseed product exports should be noted. Whilst until 2023 a significant proportion of supplies was directed towards a limited number of major importers, the structure of export markets subsequently became considerably more diversified. In 2023, Ukraine exported sunflower oil to 128 countries, whereas in 2024 this figure rose to 134 countries worldwide (AgroPortal.ua, 2025), indicating the sector's expanding international presence and the formation of a broader network of trading partners.

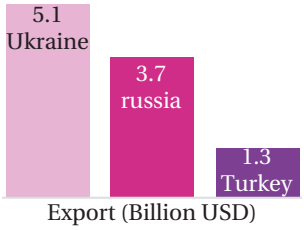

Figure 1. Leading exporters of sunflower oil in 2024, USD billions
Source: compiled by the authors based on data from AgroPortal.ua (2025)

According to data from the Ukroilprom Association, in 2024 the export volume of Ukraine's oil and fat products amounted to approximately USD 7.5 billion, which is 2.7% higher compared to 2023. A positive foreign trade balance confirms the strong export orientation of the sector. An important place in the structure of oil and fat exports is occupied by sunflower oil, which traditionally serves as the main commodity of the industry in international markets and accounts for around 21% of Ukraine's total food exports, indicating a high level of competitiveness of domestic products in the global market. The total trade turnover of sunflower oil in 2024 amounted to USD 6.74 billion. An analysis of the export structure of sunflower oil indicates significant geographical diversification of sales markets (Fig. 2). Approximately 65% of the physical export volume and nearly 60% of foreign currency revenues are concentrated in seven leading importing countries. The largest buyer of Ukrainian sunflower oil remains India, accounting for about 14.3% of exports in physical terms (over 858 thousand tonnes) and nearly 13.9% of foreign currency earnings. Significant export volumes are also directed to countries of the European Union. In particular, Spain imported around 686.9 thousand tonnes of Ukrainian sunflower oil (11.4% of exports), Romania over 572 thousand tonnes (9.5%), the Netherlands 512.2 thousand tonnes (8.5%), Italy 470.1 thousand tonnes (7.8%), and Poland approximately 412 thousand tonnes (6.8%). Turkey also remains a notable market, importing over 380 thousand tonnes of the product, which accounts for about 6.4% of total exports (Fig. 2).

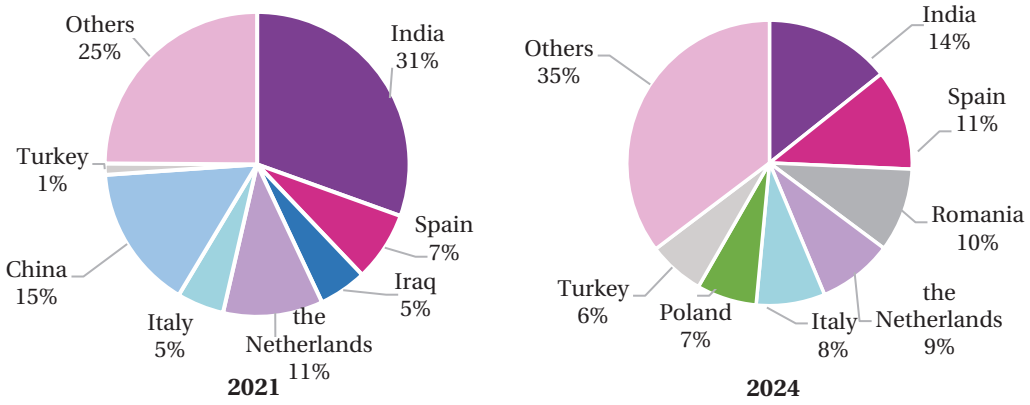

Figure 2. Main importers of Ukrainian oil in 2021 and 2024
Source: compiled by the authors based on data from the Ukroilprom Association (2022) and AgroPortal.ua (2025)

An important direction in the diversification of export markets is the strengthening of positions in Mediterranean markets, particularly in Spain, Italy, and Turkey. Collectively, these countries account for a significant share of Ukrainian sunflower oil exports and serve as key hubs for the processing and subsequent re-export of the oil within the European and global markets. Significant volumes of supplies to Spain and Italy indicate stable demand for Ukrainian products from the food industry in these countries. At the same time, Turkey, as an importer of sunflower oil, acts as an important regional trade hub through which part of the produce can reach other markets in the Middle East and the Mediterranean (Ukraine's oil and fat complex, 2025).

The high level of demand from India has a clear economic basis and is confirmed by statistical data. In particular, India is one of the world's largest importers of oils: according to various estimates, domestic production covers only 35-40% of demand, whilst the remainder is met through imports. Total oil imports exceed 14-16 million tonnes annually, making the country systematically dependent on external supplies. Palm, soya and sunflower oils dominate the consumption mix, with the share of the latter gradually increasing. An additional factor is the steady growth in domestic consumption from 8.2 kg in 2001 to the current 23.5 kg per capita, driven by both demographic factors (a population of over 1.4 billion) and rising incomes and changing dietary preferences. In recent years, there has been a trend towards diversification in oil consumption, notably an increase in the use of sunflower oil in the food industry and the HoReCa sector as an alternative to palm oil (Mukherjee, 2025)

In this context, imports of sunflower oil from Ukraine, which exceed 850,000 tonnes per year, are part of a broader trend of growing demand for this product. Given India's significant share in the structure of Ukrainian exports (around 14% in 2024) and its high import dependency, this market can be characterised as one of the key export destinations that significantly influences the formation of Ukraine's oil and fat product export structure. The level of development of transport and logistics infrastructure also remains a significant problem, complicating the effective facilitation of foreign trade operations (Table 1). Disruptions to traditional logistics routes caused by military

operations, rising transport costs, and limited capacity of transport corridors and port infrastructure significantly increase exporters' costs and reduce the competitiveness of products on global markets. In such conditions, the development of alternative transport routes, the modernisation of logistics systems and integration into international transport networks take on particular importance. Furthermore, fluctuations in global prices for agricultural products and energy resources, as well as increased competition from major oil exporters, notably Argentina, Brazil, Indonesia and Malaysia, are having a significant impact on the operations of Ukrainian exporters of oil and fat products. Changes in the logistics structure of exports have a significant impact on the process of diversifying sales markets. Following the outbreak of full-scale war, a significant portion of shipments was redirected to alternative routes: Danube ports and rail transport through European Union countries. Subsequently, with the partial resumption of operations at Black Sea ports, their role began to grow again; however, alternative logistics routes continue to account for a significant portion of exports, enhancing the flexibility and resilience of the export system.

Table 1. Share of sunflower oil actually exported from the customs territory of Ukraine by mode of transport according to the PIC "Control over Delivery" UAIS (March 2022 to March 2026)

Modes of transport	% by year			
	2022	2023	2024	2025
Ports	63.29133	70.11909	70.81223	83.17019
Road	18.70827	14.68894	14.671	8.386823
Rail	15.22708	10.74581	10.60772	6.98712
Ferry	2.773322	4.446154	3.909047	1.455871

Source: authors' calculations based on UGA data (n.d.)

Another important trend is the transformation and diversification of the product structure of oil and fat exports. Alongside traditional sunflower oil, the role of other types of oils and processed oilseed products is gradually increasing, in particular soybean and rapeseed oil, as well as meals and oilcake. In 2024, exports of soybean oil increased by 25.8% and meals and oilcake by 6.3%, indicating a gradual expansion of the export product range and a higher level of raw material processing. At the same time, an analysis of the geographical structure of sunflower meal exports shows that the main importers remain countries in Asia and the European Union. In particular, the largest buyer is China, which accounts for 1,470.5 thousand tonnes of products, or 30.6% of total exports, equivalent to USD 324.4 million (31.5%). Significant volumes are also supplied to Poland – 597.5 thousand tonnes (12.5%) worth USD 126.4 million, and to France – 471.0 thousand tonnes (9.8%) worth USD 101.9 million. Taken together, these three countries account for 52.9% of the physical export volume and 53.7% of its value, indicating a relatively high level of market concentration. At the same time, nearly half of exports (47.1%) are directed to other countries, confirming the presence of a relatively broad geographical distribution of sales (Ukraine's oil and fat complex, 2025).

Calculation of *HHI* based on the data provided (the top three countries and the aggregated "others" group) yielded an *HHI* value of approximately 0.34, which corresponds to a high level of concentration. This means that, despite the presence of dominant markets, the export structure is not critically dependent on one or two destinations. This implies that, despite the presence of a significant group of other importing countries, exports are largely dependent on a limited number of key markets. Thus, the diversification of export destinations is partial in nature and is accompanied by the persistence of concentration trends in the export structure.

Similar trends are observed in soybean oil exports. The total export volume amounts to 386.8 thousand tonnes, valued at USD 317.0 million. A dominant position is held by Poland, which imports 269.2 thousand tonnes (69.6%) worth USD 218.5 million (68.9%). Significantly smaller volumes are supplied to the Netherlands – 12.8 thousand tonnes (3.3%) and to the United Arab Emirates – 9.3 thousand tonnes (2.4%). The combined share of the three leading importers amounts to 75.3% of total soybean oil exports, indicating a high level of concentration in this market segment (Ukraine's oil and fat complex, 2025). *HHI* is approximately 0.55, corresponding to a very high level of concentration. This indicates a critical dependence of soybean oil exports on a single market – Poland – which significantly limits the degree of diversification within this segment.

Exports of rapeseed oil are characterised by a somewhat more balanced geographical structure. In 2024, the total export volume amounted to 270.0 thousand tonnes, valued at USD 238.9 million. The largest importers are Poland – 69.8 thousand tonnes (25.9%), China – 58.1 thousand tonnes (21.5%), and Belgium – 38.7 thousand tonnes (14.3%). Taken together, these countries account for 61.7% of the physical export volume and 60.7% of its value. The remaining 38.3% of supplies is distributed among other countries, indicating a relatively broader geographical distribution compared to soybean oil (Ukraine's oil and fat complex, 2025). The calculation of the Herfindahl–Hirschman Index for rapeseed oil shows a lower level of concentration, at approximately 0.28, which still exceeds the threshold for high concentration but is significantly lower than in the soybean oil segment. This indicates a relatively more balanced, although still insufficiently diversified, geographical structure of exports.

Thus, the results of the analysis confirm that, alongside the traditional export of sunflower oil, the role of other processed oilseed products is gradually increasing. At the same time, the analysis of concentration levels shows that diversification is uneven in nature: while rapeseed oil demonstrates a relatively broader geographical distribution, soybean oil exports remain highly concentrated. Whereas previously a significant share of exports consisted

of raw materials, there is now a clear trend towards an increasing share of products with a higher level of processing. In particular, according to sectoral analytical estimates, the share of processed products (oil, meal, oilcake) in the structure of oilseed exports increased from approximately 55-60% in 2018-2019 to over 70-75% in 2023-2024, indicating a gradual shift from the export of raw materials (rapeseed and soybean seeds) to products with higher added value. At the same time, the share of oilseed exports in the form of raw seed declined from around 40-45% to 25-30%. The role of refined and packaged oil, specialised food fats, and by-products of processing, such as meal and oilcake, widely used in the feed industry, is increasing. The growth in exports of soybean oil and meal is driven by a combination of factors. Firstly, rising external demand from EU and Asian countries for protein feed and vegetable oils, linked to the development of livestock farming and the food industry. Secondly, changes in logistics: in 2022-2024, exports of processed products proved more adaptable to new transport conditions compared to exports of raw seeds, as they have a higher value per unit of weight and better transportability. Thirdly, the expansion of processing capacities in Ukraine and the reorientation of enterprises towards deeper processing of raw materials under conditions of restrictions on seed exports. Fourthly, price conditions: higher global prices for oils and protein components stimulated exports specifically of processed products. The expansion of the product range of exports contributes to increasing the level of added value and strengthening the position of industry enterprises within global value chains. The growing role of products with a higher level of processing has not only a quantitative but also a structural basis, reflecting the transformation of Ukraine's export model from a raw-material orientation to a more technologically oriented one.

Alongside the emergence of positive trends in the diversification of markets for oil and fat products, a number of significant economic, institutional, and infrastructural constraints can be observed. One of the major obstacles is the tightening of technical and phytosanitary requirements for imported food products. Many importing countries establish strict standards regarding safety, quality, traceability, and environmental sustainability of production. This requires enterprises in the oil and fat industry to implement modern food safety and quality management systems, adapt production processes to international certification standards, and enhance control at all stages of the production and logistics chain, as also confirmed in studies devoted to the principles of safe food production and the requirements for food safety management systems in industrial production (Romanovska *et al.*, 2022a; 2022b).

In particular, updated regulatory requirements are in force in the European Union, which significantly strengthen product quality and safety controls. For example, European Commission Regulation No. 2023/915 (2023) sets strict maximum levels for contaminants (mycotoxins, heavy metals, processing contaminants) in food products; exceeding these levels prevents the product from entering the EU market. In parallel, Regulation (EC) No. 396/2005 (2005) on maximum residue levels of pesticides is in force, which provides for mandatory laboratory testing of raw materials and finished products. Furthermore, as part of the European Green Deal (2019), new requirements for environmental sustainability and product traceability are being introduced, including Digital Product Passports and mandatory disclosure of information on the origin, composition and carbon footprint of goods. Failure to comply with these requirements may result in restrictions on market access for products within the EU.

The analysis conducted leads to the conclusion that the current stage of development of the oil and fat industry is characterised by a gradual diversification of exports, which manifests itself in three main areas:

- expansion of the geographical scope of exports and an increase in the number of importing countries;
- reorientation of logistics routes and the use of alternative transport corridors;
- diversification of the product structure through an increased share of various types of oils and their processed products.

To ensure the stable development of the oil and fat industry and enhance its competitiveness, a comprehensive set of measures to support exporters must be implemented. The development of export infrastructure – the modernisation of ports, transport corridors and logistics centres – is particularly relevant. Responsible institutions: Ministry of Community, Territorial and Infrastructure Development of Ukraine, Sea Port Administrations, regional transport departments. Intensifying trade diplomacy will facilitate the conclusion of new free trade agreements and the removal of technical barriers in foreign markets. Implementation tools here may include not only bilateral and multilateral negotiations and participation in international trade forums, but also the simplification of certification procedures in accordance with Law of Ukraine No. 124-VIII (2015) (Articles 8-10) and Law of Ukraine No. 959-XII (1991) (Articles 4, 7). Another tool is the promotion of Ukrainian products at international exhibitions through state export support programmes, participation in international exhibitions, information campaigns and B2B platforms. Finally, encouraging the deep processing of oilseeds – increasing the added value of exports and expanding the product range.

At the same time, the entry of Ukrainian products into new international markets is accompanied by a range of economic, technical and regulatory challenges. The main difficulties include: lengthy administrative procedures related to obtaining certificates, audits and risk assessments (in particular, certification); logistical and market constraints, including costs of transporting and storing products, as well as a high level of competition; technical difficulties in modernising product safety control systems; coordination issues in the process of exchanging information between government bodies and foreign partners. Each of these tools is clearly linked to a specific problem and the expected outcome: for example, harmonisation of standards removes technical barriers, digitalisation reduces administrative delays, and the development of infrastructure and logistics lowers transport costs. This comprehensive strategy allows for the minimisation of risks, the enhancement of product competitiveness, and the securing of stable access to new markets.

▸ Discussion

The results obtained generally confirm the key provisions of contemporary international trade theory regarding the role of diversification as a tool for enhancing economic resilience, while at the same time revealing a number of specific features characteristic of Ukraine's oil and fat industry in the context of the wartime and post-crisis period. In particular, the findings are consistent with the conclusions of R. Baldwin (2016), who substantiates the concept of "new globalisation" and emphasises the growing role of global value chains. Indeed, the analysis conducted demonstrates that the Ukrainian oilseed and oil industry is gradually integrating into these chains through an increase in the share of processed products (oil, meal, oilcake) within the export structure. Thus, the conclusions drawn by the researcher are entirely relevant, as they confirm the trend of transition from a raw material model to a model with higher added value.

At the same time, the approach of O. Cadot *et al.* (2011) regarding the evolution of export diversification is partially confirmed, but requires clarification. The author argues that at a certain stage of development, countries transition from diversification to specialisation. However, the analysis presented above paints a different picture, as even given the significant role of sunflower oil, Ukraine is compelled to simultaneously expand both the product and geographical structure of its exports. This is explained not only by the level of economic development but also by external shocks (war, logistical constraints), which alter the classical trajectory of structural transformation. Similarly, the results are partly consistent with the findings of J. Imbs & R. Wacziarg (2003), who demonstrate the cyclical nature of diversification and specialisation. However, these conclusions do not fully align with the results of the present analysis, as Ukraine is currently experiencing a simultaneous combination of two processes: on the one hand, the preservation of specialisation in sunflower oil, and on the other, forced diversification due to geopolitical risks. The reason for this discrepancy lies in the specific nature of the economy's functioning under martial law, which was not taken into account in classical models.

The approaches of K. Bagwell & R. Staiger (2016), which emphasise the importance of international trade agreements, also play a significant role in explaining the findings. In the context of this study, these conclusions are confirmed by Ukraine's expanded access to new markets (75 new export destinations in 2022-2025). Thus, the authors' assertions are well-founded, as institutional interaction at the international level does indeed contribute to export diversification. At the same time, the study's findings expand upon D. Rodrik's (2024) approach regarding the state's role in export development. The author emphasises the need for an active industrial policy. The analysis conducted confirms this thesis, yet at the same time shows that, in the Ukrainian context, state support must be complemented by the development of logistics infrastructure and adaptation to the regulatory requirements of export markets. Thus, this researcher's technical solutions, taking into account the results of this study, can be viewed in a broader context – as a combination of industrial, trade and logistics policies. The results also correlate with the research by A. Parteka & M. Tamberi (2013), which demonstrates the positive impact of diversification on economic stability. The conclusions drawn are entirely relevant, as it has been found that expanding the geography of exports to over 130 countries helps to reduce dependence on individual markets. At the same time, the analysis reveals a different picture at the sectoral level, as soya oil exports are characterised by very high concentration ($HHI \approx 0.55$), indicating that risks remain.

In terms of institutional support, the results are consistent with the findings of G.J. Felbermayr & E. Yalcin (2013) regarding the role of export credit instruments. This is confirmed by the fact that Ukrainian enterprises' limited access to financial resources hinders export diversification. At the same time, unlike the author's studies, in the domestic context the main constraining factor is not only financing but also logistical constraints, which highlights the complex nature of the problem.

Among Ukrainian researchers, the findings of this study align with the conclusions of V.V. Venger & O.M. Kushnirenko (2025) regarding the importance of infrastructure development through public-private partnership mechanisms. Their conclusions are relevant, as the analysis confirms that logistical constraints remain one of the key barriers to diversification. At the same time, unlike their approach, this study places greater emphasis on the transformation of transport flows (Danube ports, railways, roads), which is a new aspect in the context of military challenges. The study by L. Stepasiuk & M. Stepasiuk (2024) on production diversification is also corroborated. Their conclusions are supported, as the growing role of soya and rapeseed oil does indeed indicate a broadening of the commodity structure of exports. At the same time, the analysis demonstrates that production diversification does not always automatically lead to market diversification, as evidenced by the high concentration of soya oil exports. It should be noted separately that the study's results partly diverge from the conclusions of O.O. Petrova (2020) regarding regional opportunities for diversification. The author's assertions appear debatable, as current conditions significantly complicate the implementation of regional strategies due to logistical constraints and changes in trade routes. The reason for the discrepancies is a significant change in the external environment after 2022.

Thus, the comparative analysis conducted shows that most contemporary theoretical approaches to export diversification are confirmed; however, their application to Ukrainian realities requires consideration of specific factors, in particular military risks, logistical constraints and the tightening of regulatory requirements. Consequently, the research findings not only complement existing academic approaches but also refine them in the context of the transformation of global trade and the functioning of the economy under conditions of instability. The globalisation of economic processes, the deepening of international integration and the growth of competition in global markets necessitate the search for new approaches to the development of foreign economic activity.

▸ Conclusions

The conducted study has shown that the diversification of export markets is one of the key instruments for ensuring

the stability of foreign economic activity and enhancing the competitiveness of the national economy in conditions of global economic instability. In the context of the transformation of the global trading system, increasing geopolitical risks, and the growing complexity of logistics chains, export diversification makes it possible to reduce dependence on individual markets, mitigate the impact of global price fluctuations, and ensure a more balanced development of foreign trade.

It has been established that the oil and fat industry occupies a strategically important place in Ukraine's export structure, accounting for a significant share of the state's foreign exchange earnings and demonstrating a high level of competitiveness in the global market. Sunflower oil plays a particularly significant role in the commodity structure of exports, accounting for a substantial portion of exports of oilseed processing products; at the same time, there is an increase in the share of products undergoing further processing, which enhances the added value of exports. The geographical structure of exports indicates a gradual expansion of the circle of trading partners and the formation of a diversified system of foreign markets, among which the countries of the European Union, the Mediterranean region and Asia occupy an important place. There has also been a rise in exports to countries in South-East Asia and the Middle East, which demonstrates the effectiveness of strategies to expand market presence.

The diversification of oil and fat product exports is taking place in several interrelated directions. Firstly, there is an expansion of the geographical scope of supplies and an increase in the number of importing countries, which helps to reduce the concentration of exports in individual markets. Secondly, there is a reorientation of logistics routes, linked to the need to adapt the export system to the new operating conditions of the transport infrastructure. Thirdly, the product structure of exports is gradually diversifying due to the growing role of various types of oils and products of further processing of oilseeds.

The process of expanding sales markets for oil and fat products is accompanied by a number of economic, institutional and infrastructural constraints. The main ones include stricter technical and phytosanitary requirements in foreign markets, the increasing complexity of logistics processes, the underdevelopment of transport infrastructure, and fluctuations in global prices for agricultural products. Comprehensive export diversification (geographical, logistical and product-based), together with the effective use of state support instruments, is a key factor in enhancing the competitiveness of the oil and fat industry and ensuring the stable development of Ukraine's foreign economic activity.

Prospects for further research should be linked to an in-depth analysis of structural changes in the global oil market, an assessment of the competitive positions of Ukrainian producers in specific regional markets, and a study of the impact of logistical, institutional and trade factors on the efficiency of oil and fat product exports. Another important area for further research is the development of economic models for forecasting demand for oils in various countries. Furthermore, it is advisable to investigate the role of financial instruments for state support of exports, in particular export credits, guarantees and insurance mechanisms, as well as the effectiveness of institutional initiatives such as export credit agencies and state programmes to stimulate foreign economic activity. This will enable the formulation of well-founded strategic recommendations for enhancing the competitiveness of Ukrainian exporters in international markets.

▸ Acknowledgements

None.

▸ Funding

The article was prepared within the framework of the research projects "Industrial Development Policy of Ukraine in the Context of Global Trade Fragmentation" (state registration number 0126U001107) and "Development of an Innovative Technology for the Production of Lipid-Containing Food Products and Cosmetic Products".

▸ Conflict of interest

None.

▸ References

[1] AgroPortal.ua. (2025). *Ukraine accounts for 37% of global sunflower oil trade*. Retrieved from https://agroportal.ua/en/news/ukraina/ukrajina-zabezpechuye-37-svitovoji-torgivli-sonyashnikovoyu-oliyeyu.

[2] Arndt, C., Diao, X., Dorosh, P., Pauw, K., & Thurlow, J. (2023). The Ukraine war and rising commodity prices: Implications for developing countries. *Global Food Security*, 36, article number 100680. doi: 10.1016/j.gfs.2023.100680.

[3] Bagwell, K., & Staiger, R. (2016). The design of trade agreements. *NBER Working Paper*, article number 22087. doi: 10.3386/w22087.

[4] Baldwin, R. (2016). *The great convergence: Information technology and the new globalization*. Cambridge: Harvard University Press. doi: 10.2307/j.ctv24w655w.

[5] Boz, F., Yilmaz, B., Özekicioğlu, H., Topuz, H., & Ünlü, U. (2026). Global sunflower oil trade under COVID-19 and the russia – Ukraine conflict: A complex network analysis of food system resilience and sustainable finance dynamics. *Frontiers in Environmental Science*, 14, article number 1757181. doi: 10.3389/fenvs.2026.1757181.

[6] Bykonia, O., & Romanovska, N. (2023). Prospects of the trade development prospects of the trade development in Ukraine as a country candidate for the EU membership. *Scientific Bulletin of International Association of Scientists. Series: Economy, Management, Security, Technologies*, 2(3). doi: 10.56197/2786-5827/2023-2-3-4.

[7] Cadot, O., Carrère, C., & Strauss-Kahn, V. (2011). Export diversification: What's behind the hump? *Review of Economics and Statistics*, 93(2), 590-605. doi: 10.1596/5484.

[8] European Commission Regulation No. 2023/915 "On Maximum Levels for Certain Contaminants in Food and Repealing Regulation (EC) No. 1881/2006". (2023, April). Retrieved from https://lnk.ua/TFFl2fPi9.

[9] European Green Deal. (2019, December). Retrieved from https://lnk.ua/yE9FV1D5H.
[10] Felbermayr, G.J., & Yalcin, E. (2013). Export credit guarantees and export performance: An empirical analysis for Germany. *The World Economy*, 36, 967-999. doi: 10.1111/twec.12031.
[11] Gamayunova, V., Khonenko, L., Mykolaichuk, V., & Kuvshinova, A. (2024). Prospects and directions of diversification of oilseed group crops. *Scientific Horizons*, 27(10), 102-112. doi: 10.48077/scihor10.2024.102.
[12] Grain Trade Online. (2025). *In 2024, the share of agricultural products in Ukraine's exports grew to 59%*. Retrieved from https://graintrade.com.ua/en/novosti/u-2024-r-chastka-agroproduktcii-v-eksporti-ukraini-virosla-do-59.html.
[13] Imbs, J., & Wacziarg, R. (2003). Stages of diversification. *American Economic Review*, 93, 63-86. doi: 10.1257/000282803321455160.
[14] Law of Ukraine No. 124-VIII "On Technical Regulations and Conformity Assessment". (2015, January). Retrieved from https://zakon.rada.gov.ua/laws/show/124-19#Text.
[15] Law of Ukraine No. 959-XII "On Foreign Economic Activity". (1991, April). Retrieved from https://zakon.rada.gov.ua/laws/show/959-12#Text.
[16] Makarchuk, O. (2022). Sunflower oil market in Ukraine: State and challenges. *Economics and Business Management*, 13(2), 91-100. doi: 0.31548/bioeconomy13(2).2022.91-100.
[17] Mukherjee, V. (2025). *Every Indian now consumes 24 kg edible oil a year, triple the 2001 level*. Retrieved from https://www.business-standard.com/industry/agriculture/india-edible-oil-consumption-tripled-imports-health-obesity-palm-oil-125042100484_1.html.
[18] Mytsenko, V.I. (2024). The nature of thegenesis of the concept of global value chains, *Economics and Organization of Management*, 1, 153-171. doi: 10.31558/2307-2318.2024.1.16.
[19] Parteka, A., & Tamberi, M. (2013). Product diversification, relative specialisation and economic development: Import-export analysis. *Journal of Macroeconomics*, 38(Part A), 121-135. doi: 10.1016/j.jmacro.2013.09.011.
[20] Petrova, O.O. (2020). Diversification of oil business and development of non-traditional oils in Kherson region. *AgroWorld*, 21, 41-48. doi: 10.32702/2306-6792.2020.21.41.
[21] Regulation of the European Parliament and of the Council No 396/2005 "On Maximum Residue Levels of Pesticides in or on Food and Feed of Plant and Animal Origin and Amending Council Directive 91/414/EEC Text with EEA Relevance". (2005, February). Retrieved from https://lnk.ua/sEzaQYlkd.
[22] Rodrik, D. (2004). *Industrial policy for the twenty-first century*. Harvard University Press. doi: 10.2139/ssrn.617544.
[23] Romanovska, T., Romanovska, N., & Romanovskyi, N. (2022b). Principles of safe food production. *Scientific Bulletin of International Association of Scientists. Series: Economy, Management, Security, Technologies*, 1(1). doi: 10.56197/2786-5827/2022-1-1-6.
[24] Romanovska, T.I., Oseiko, M.I., Romanovska, N.I., & Romanovskyi, N.O. (2022a). Basic requirements for safety management systems in industrial production. *Scientific Works of NUFT*, 28(2), 7-23. doi: 10.24263/2225-2924-2022-28-2-3.
[25] Shandrivska, O., Pytulyak, N., & Hreb, O. (2024). Sunflower oil market research in the world and Ukraine. *Management and Entrepreneurship in Ukraine*, 6(2), 365-382. doi: 10.23939/smeu2024.02.365.
[26] State Service of Ukraine on Food Safety and Consumer Protection. (2026). *From export to digitalization: The State Service presented the results of 2025*. Retrieved from https://dpss.gov.ua/news/vid-eksportu-do-tsyfrovizatsii-derzhprodspozhyvsluzhba-prezentuvala-rezultaty-2025-roku.
[27] Stepasiuk, L., & Stepasiuk, M. (2024). Diversification of agribusiness through the expansion of niche oilseed. *Economy and Society*, 67. Retrieved from doi: 10.32782/2524-0072/2024-67-166.
[28] UGA. (n.d.). *Export indicators*. Retrieved from https://uga.ua/eksportni-pokazniki/.
[29] Ukraine's oil and fat complex. (2025). Foreign trade in 2024 in figures. *Grain Products and Mixed Fodder's*, 25(1), 18-26. doi: 10.15673/gpmf.v25i1.3071.
[30] Ukroilprom Association. (2022). *Foreign trade in 2021*. Retrieved from https://ukroilprom.org.ua/news/zovnishnya-torgivlya-u-2021-rotsi-poperedni-dani-281/.
[31] Venger, V.V., & Kushnirenko, O.M. (2025). Formation of a public-private partnership model as the basis for Ukraine's investment policy. *Economic Bulletin of Donbas*, 1(79), 86-94. doi: 10.12958/1817-3772-2025-1(79)-86-94.

Тенденції розвитку та диверсифікації зовнішніх ринків олії України

Тетяна Романовська
Кандидат технічних наук, доцент
Національний університет харчових технологій
01033, вул. Володимирська, 68, м. Київ, Україна
https://orcid.org/0000-0003-3364-2408
Наталія Романовська
Кандидат економічних наук, доцент
Державна установа «Інститут економіки та прогнозування Національної академії наук України»
01011, вул. Панаса Мирного, 26, м. Київ, Україна
https://orcid.org/0000-0002-1377-7551

Анотація. Стаття присвячена аналізу тенденцій розвитку та диверсифікації зовнішніх ринків олії України. Розглянуто вплив глобалізаційних процесів, економічної інтеграції та міжнародної конкуренції на структуру експорту, а також роль державних механізмів підтримки експортерів. У роботі використано комплекс статистичних, аналітичних і порівняльних методів, а також системний підхід для оцінки конкурентоспроможності олійножирової продукції на світових ринках. Диверсифікація експорту здійснюється у трьох основних напрямах: розширення географії постачань та збільшення кількості країн-імпортерів, переорієнтація логістичних маршрутів та використання альтернативних транспортних коридорів, а також диверсифікація товарної структури за рахунок збільшення частки різних видів олій та продукції їхньої переробки. Відзначено поступове зростання експорту соєвої та ріпакової олії, шротів і макухи, що сприяє підвищенню доданої вартості продукції та формуванню більш стійкої системи зовнішніх ринків. Встановлено головні обмеження, що стримують ефективну диверсифікацію: посилення технічних та фітосанітарних вимог, недостатній рівень розвитку транспортно-логістичної інфраструктури, коливання світових цін, високий рівень конкуренції. Для подолання цих бар'єрів запропоновано комплекс заходів державної підтримки, що включає модерн ізацію логістики, розвиток торговельно-економічної дипломатії, маркетингову підтримку та стимулювання глибокої переробки олійних культур. Диверсифікація ринків збуту є стратегічним інструментом забезпечення економічної стійкості та підвищення конкурентоспроможності олійножирової галузі України в умовах глобальної нестабільності та трансформації міжнародної торговельної системи. Практичне значення полягає в пошуку ефективних напрямів диверсифікації зовнішніх ринків збуту олійножирової продукції України, що можуть бути використані органами державного управління та підприємствами галузі для підвищення конкурентоспроможності та стійкості експорту

Ключові слова: диверсифікація експорту; олійножирова галузь; соняшникова олія; міжнародні ринки; логістичні маршрути; продукція переробки олійних культур

Received: 06.10.2025. Revised: 02.01.2026. Accepted: 12.02.2026. Published: 05.03.2026.

EKONOMIKA APK

https://doi.org/10.32317/ekon.apk/1.2026.47

Ekonomika APK, 33(1), 47-56

UDC 338.43:339.564:330.55(477)

ISSN: 2221-1055; E-ISSN: 2413-2322

Modelling of the factor influence of grain market performance indicators on Ukraine's GDP

Svitlana Cheremisina*
Doctor of Economics, Associate Professor
National Scientific Centre "Institute of Agrarian Economics"
03127, 10 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0003-1546-7714

▸ **Abstract.** The study addressed the impact of grain market performance indicators on the dynamics of Ukraine's gross domestic product in the context of structural transformations and military challenges. The study aimed to quantitatively determine the strength, direction and nature of the impact of production, export and structural indicators of grain market development on the country's macroeconomic performance, using economic and mathematical tools. The research methods included statistical analysis of the dynamics of indicators for 2010-2025, correlation analysis, and correlation-regression modelling. A distinctive feature of the methodological approach was the use of variational modelling, which involved constructing several alternative models with different sets of factor variables and testing them against criteria of statistical significance. The results of the study showed that Ukraine's grain market has transformed into a highly specialised, export-oriented sector: gross grain harvest increased from 39.27 million tonnes in 2010 to 86.01 million tonnes in 2021, and exports – from 2.47 to USD 12.34 billion. The study established that the most significant impact on GDP was exerted by agricultural exports (r = 0.608), whereas the impact of grain exports was moderate (r = 0.415) and had a negative coefficient in the regression models (-21.4…-23.0), indicating a raw material orientation effect. The study demonstrated that production indicators do not have a direct statistically significant impact (r = 0.104) but are realised through export channels. At the same time, a 1% increase in the share of grain in agricultural exports is accompanied by a USD 335 million decrease in GDP, whereas an increase in the share of grain in total exports leads to a 242 million USD rise in GDP. The application of a variational approach to econometric modelling has revealed that the impact of the grain market on GDP is non-linear and structurally determined, with the decisive factors being not production volumes but the parameters of export integration. The practical significance of the results lies in their potential application in the formulation of state agricultural policy, particularly for the transition from a raw material export model to a model with higher added value, which will contribute to improving the efficiency of the grain sector and strengthening macroeconomic stability

▸ **Keywords:** agricultural sector; agricultural exports; econometric modelling; structural factors; raw material orientation; macroeconomic indicators

▸ Introduction

The development of Ukraine's economy is characterised by the growing role of the agricultural sector as a key factor in macroeconomic stability and international competitiveness. The grain market is a notable element within this structure, ensuring the country's food security, generating a significant share of foreign exchange earnings and export potential, and influencing the country's gross domestic product. At the same time, the grain market operates amid military risks, logistical constraints, instability in global market conditions and structural transformations of the economy. This highlights the need for scientific research into the actual contribution of the grain market to Ukraine's gross domestic product (GDP), in particular through an assessment of the direct and indirect effects of its development. It is necessary to determine whether growth in grain production and exports leads to a corresponding increase in value added. Therefore, research into the factor-level impact of grain market indicators on GDP, using economic and mathematical methods, is both timely and of practical significance.

▸ **Suggested Citation**: Cheremisina, S. (2026). Modelling of the factor influence of grain market performance indicators on Ukraine's GDP. *Ekonomika APK*, 33(1), 47-56. doi: 10.32317/ekon.apk/1.2026.47.

*Corresponding author

Studies on the global significance of grain markets occupy a prominent place in contemporary academic discourse. S. Kozlovskyi *et al.* (2024) argued that disruptions to Ukrainian grain supplies have a negative impact on food security and exacerbate the risks of malnutrition in importing countries. A. Rose *et al.* (2023) quantified the economic consequences of reduced grain exports due to the war and identified a multiplier effect on the global economy. D. Prajapati *et al.* (2022) highlighted the significance of transportation routes and grain supply chain optimisation as a key factor in enhancing the efficiency of the agricultural sector in the context of globalisation. S. Jagtap *et al.* (2022) also confirm that logistical disruptions in the Black Sea region have led to rising global food prices and the destabilisation of global supply chains. P. Khatri *et al.* (2024) expand on this approach, emphasising the interconnected nature of contemporary risks in agriculture and food systems, where geopolitical, climatic and logistical factors reinforce one another. S.R. Tushar *et al.* (2023) highlight the importance of stable grain storage as an element of food security and supply continuity. The study emphasised the impact of geopolitical factors on agricultural markets. For instance, O. Polat *et al.* (2023) established a close correlation between the level of geopolitical tension and the volatility of agricultural commodity markets, confirming the grain sector's high sensitivity to external shocks.

At the same time, an analysis of academic sources has shown that most studies focus either on sector-specific aspects of the grain market's development or on macroeconomic analysis without detailing sector-specific factors. At the same time, issues relating to the comprehensive quantitative assessment of the impact of grain market performance indicators on Ukraine's GDP, incorporating their structural differentiation, remain underdeveloped. In particular, the scientific literature lacks a unified approach to distinguishing between the direct and indirect effects of production and export factors; assessing the role of the structural characteristics of the grain market; and constructing variable econometric models whilst accounting for the problem of multicollinearity. Thus, there is an objective need to deepen research in the direction of a comprehensive economic and mathematical analysis of the impact of grain market performance indicators on macroeconomic outcomes. This justifies the conduct of this study and determines its scientific novelty and practical significance.

The study aimed to quantitatively assess the impact of grain market performance indicators on Ukraine's gross domestic product using economic and mathematical modelling, and to identify the key drivers of economic growth in the context of structural transformations and military challenges. Achieving this aim necessitated addressing the following research objectives:

1) to analyse the trends and structural changes in the indicators of the Ukrainian grain market's performance between 2010 and 2025, in particular production, export and structural indicators;

2) to assess the role of the grain market in shaping macroeconomic outcomes by identifying trends in the share of grain exports within GDP and the country's foreign trade structure, and to determine the strength and direction of the relationship between grain market indicators and Ukraine's GDP;

3) to develop and test alternative econometric models (export, export-production and structural-export models), and to assess their parameters, statistical significance and predictive capabilities.

▸ Literature review

The functioning of the grain market and its impact on macroeconomic indicators are the subject of active academic research. Contemporary academic approaches demonstrate that the grain sector is central in ensuring food security, formation export potential and maintaining macroeconomic stability in countries with an agricultural focus. In particular, Yu.O. Voloshchuk & O.V. Shedlovska (2024) argued that Ukraine's grain market is a system-forming element of the agri-food system, the efficiency of which is determined by institutional, organisational and market factors. V. Nedashkivskyi *et al.* (2024) also view the grain market as a key component of Ukraine's agri-food market, emphasising its strategic importance for ensuring the stability of agricultural production. K.V. Bliumska-Danko & M.A. Zaidenko (2023) argue that the development of grain production directly influences the competitiveness of the agricultural sector and the stability of domestic food security. Yu.I. Haida & B.L. Shainiuk (2023), analysing global trends in the development of the grain market, highlight the growing role of international competition and structural transformations in the global trade in grain crops.

A separate area of research focuses on the foreign trade aspects of the grain market. L.O. Kibalnyk & A.V. Cherkashchenko (2025) established that grain exports are one of Ukraine's main sources of foreign exchange earnings, but their effectiveness depends significantly on the state of the logistics infrastructure and the conditions of global markets. G. Filiuk (2025) demonstrates that, in the context of the Russian armed aggression, Ukrainian grain exports have undergone significant changes in terms of geographical concentration, supply routes and foreign trade risks. A. Panfilova *et al.* (2025) also noted that the war caused a transformation in the geography of exports, an increase in transport costs and a reorientation of sales channels. O. Sheremetynska (2025) emphasises that maintaining the export capacity of the grain sector has become one of the key factors in Ukraine's macro-financial stability during the crisis.

A separate area of research concerns the application of economic and mathematical methods to assess the impact of sectoral factors on economic growth. O. Lyutak *et al.* (2024) demonstrate the effectiveness of multi-factor modelling of the impact of economic and structural factors on countries' economic growth. D.L. Tarasenko (2018) emphasises the importance of modelling complex socio-economic processes for the formulation of sound management decisions. The results obtained indicate that export-oriented sectors can be significant for economic development; however, their impact depends on the level of domestic processing, productivity and value added.

▸ Materials and methods

The methodological framework of the study comprised a combination of general scientific and specialised research

methods, which was used for a comprehensive analysis of the impact of grain market performance indicators on Ukraine's gross domestic product. The information base for the study consisted of data from the Official website of the State Statistics Service of Ukraine (n.d.), information materials from the Ministry of Finance (n.d.) and the Ministry of Economy of Ukraine (n.d.), reflecting the retrospective dynamics of the functioning and development of Ukraine's grain market in 2010-2025.

To achieve the stated objective, a range of scientific research methods were used: comparative analysis to assess trends in key indicators (yield, gross harvest, exports, and sub-indicators), as well as their variation over time; correlation analysis to determine the strength and direction of the relationship between indicators of the grain market's development and Ukraine's GDP, as well as to identify multicollinearity among the explanatory variables; econometric (correlation-regression) modelling to quantitatively assess the impact of selected factors on the outcome indicator (GDP), construct functional relationships and determine the strength of influence of individual indicators; a variant approach to modelling, involving the development of several alternative models (export, export-production and structural-export), differing in the composition of their explanatory variables, with the aim of enhancing the reliability of the results and avoiding the problem of multicollinearity; methods of economic and statistical hypothesis testing, in particular, the use of the coefficient of determination (R^2), Fisher's criterion and Student's t-test, p-values and 95% confidence intervals at a significance level of $\alpha = 0.05$ to assess the adequacy of the models and the statistical significance of their parameters; graphical and tabular methods to visualise the research results and summarising the data obtained.

In the modelling process, Ukraine's GDP Y was used as the outcome variable, whilst the explanatory variables comprised indicators of the functioning of the grain market, grouped into three categories: export, production and structural. The general form of the multiple regression model can be expressed as follows:

$$Y_t = \beta_0 + \sum_{i=1}^{n} \beta_i X_{it} + \varepsilon_t, \quad (1)$$

where Y_t – gross domestic product in period t; X_{it} – i-th factor variable; β_0 – free variable; β_i – model parameters; ε_t – random error. Export model:

$$Y_t = \beta_0 + \beta_1 X_{1t} + \beta_2 X_{2t} + \beta_3 X_{3t} + \varepsilon_t, \quad (2)$$

where X_1 – exports of agricultural products; X_2 – total exports of goods; X_3 – grain exports. Export-oriented production model:

$$Y_t = \beta_0 + \beta_1 X_{1t} + \beta_2 X_{2t} + \beta_3 X_{3t} + \beta_4 X_{4t} + \varepsilon_t, \quad (3)$$

where X_4 – gross grain harvest. Structural export model:

$$Y_t = \beta_0 + \beta_1 X_{1t} + \beta_2 X_{2t} + \beta_3 X_{3t} + \beta_4 X_{4t} + \varepsilon_t, \quad (4)$$

where X_1 – grain export; X_2 – proportion of grain in agricultural exports; X_3 – proportion of grain in total exports; X_4 – share of grain exports in GDP.

In the econometric analysis, Ukraine's gross domestic product was used as the dependent variable (Y). To assess the impact of the grain market, three variable models with different sets of explanatory variables were employed. In the export model, the factors included were: X_1 – agricultural exports, X_2 – total merchandise exports, X_3 – grain exports. In the export-production model, the production factor X_4 – gross grain harvest – was additionally covered. The structural-export model utilised the following variables: X_1 – grain exports, X_2 – the share of grain in agricultural exports, X_3 – the share of grain in the country's total merchandise exports, X_4 – the share of grain exports in Ukraine's GDP. These factors were selected considering the economic significance of the indicators, the results of correlation analysis, and the need to minimise multicollinearity between variables. The practical implementation of calculations, statistical data processing, and the construction of econometric models was conducted using the Microsoft Excel software package.

Results

An analysis of trends in indicators of the Ukrainian grain market's performance between 2010 and 2025 reveals the presence of distinct structural transformations, reflecting both internal shifts in production and the influence of external economic and institutional factors. First and foremost, it is worth noting that the area under grain crops remained relatively stable throughout the period under review (14.5-15.9 million hectares in 2010-2021), indicating an extensively stabilised pattern of land use. At the same time, since 2022, there has been a significant reduction in sown areas (to 11.8 million hectares) due to the war and the loss of some agricultural land. A gradual recovery is projected for 2024-2025 (to 11.6 million hectares), although figures remain below pre-war levels (Table 1).

Table 1. Trends in indicators of the Ukrainian grain market, 2010-2025

Indicators	2010	2012	2014	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Area harvested for grain crops, thousand hectares	14576	14792	14627	14337	14560	14794	15292	15283	15948	11773	10836	11106	11572
Gross grain harvest, million tonnes	39.27	46.22	63.86	66.09	61.69	70.06	75.14	64.93	86.01	53.86	59.77	56.25	60.79
Gross wheat harvest, million tonnes	16.85	15.76	24.11	26.04	26.16	24.61	28.37	24.88	32.15	20.73	21.63	22.44	23.51
Gross corn harvest, million tonnes	11.95	20.96	28.5	28.01	25.67	35.8	35.88	30.29	42.11	26.19	31.03	26.86	29.06
Yield of cereal crops, tonnes per hectare	26.9	31.2	43.7	46.1	42.5	47.4	49.1	42.5	53.9	45.8	55.2	50.6	52.5

Table 1, Continued

Indicators	2010	2012	2014	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Grain exports, billion USD	2.47	7	6.54	6.07	6.5	7.24	9.63	9.41	12.34	9.11	8.31	9.42	7.27
including wheat	0.91	2.36	2.29	2.72	2.76	3	3.66	3.6	5.07	2.68	2.94	3.74	2.99
corn	0.79	3.89	3.35	2.65	2.99	3.51	5.22	4.88	5.89	5.93	4.97	5.07	3.9
Share of grain in agricultural exports, %	24.9	39.2	39.2	39.8	36.6	38.9	43.5	42.4	44.5	38.9	37.8	38.1	30
Share of wheat and corn in grain exports, %	68.8	89.3	86.2	88.5	88.5	89.9	92.2	90.1	88.8	94.5	95.2	93.5	94.8
Share of grain in total exports, %	4.8	10.17	12.13	16.69	15.03	15.3	19.2	19.1	18.1	20.6	23	22.5	18
Grain production per business entity, tonnes	682.7	945.6	1262.1	1314.1	1135.6	1360.5	1467.6	1279.6	1741	1494.5	1365.1	1404.4	1533.1
Exports of agricultural products, USD	9.93	17.87	16.67	15.27	17.76	18.62	22.14	22.19	27.73	23.42	21.98	24.72	24.23
Total merchandise exports, USD	51.43	68.81	53.9	36.37	43.26	47.32	50.16	49.27	68.18	44.22	36.13	41.87	40.39
GDP, USD	134.9	175.5	132.2	95.4	112.1	131.9	147.9	155.2	203.4	143.5	176.3	189.2	215.2
Share of grain exports in the country's GDP, %	1.83	3.99	4.95	6.36	5.8	5.49	6.51	6.06	6.07	6.35	4.71	4.98	3.38

Source: compiled based on State Statistics Service of Ukraine (n.d.), Ministry of Finance of Ukraine (n.d.) and Ministry of Economy of Ukraine (n.d.)

In contrast to harvested areas, the gross harvest of cereal crops was characterised by greater fluctuations during the period under review. Production volumes rose from 39.27 million tonnes in 2010 to 86.01 million tonnes in 2021, before falling to 53.86 million tonnes in 2022 and partially recovering to 60.79 million tonnes in 2025. This trend indicates that grain production is highly sensitive to a combination of economic, technological and external factors. Grain crop yields during this period rose from 26.9 cwt/ha in 2010 to 53.9 cwt/ha in 2021, reaching a peak of 55.2 cwt/ha in 2023, which may indicate an increase in production efficiency and the growing role of intensive factors in the sector's development. Wheat and maize dominate the structure of production and exports, with their combined share of grain exports consistently exceeding 85%, reaching 94-95% in 2022-2025, which characterises a high level of market specialisation.

A key focus of the analysis was the export component of the grain market. The value of grain exports rose from USD 2.47 billion in 2010 to USD 12.34 billion in 2021, indicating a significant increase in the role of foreign markets in the sector's development. In 2022-2025, the indicator showed volatile trends within the range of USD 7.27-9.42 billion, which was due to logistical constraints, changes in supply routes and fluctuations in global market conditions.

The grain market is substantial in shaping the country's foreign trade potential. The share of grain in agricultural exports has ranged from 35% to 45% over the years, whilst its share in total goods exports has risen from 4.8% in 2010 to over 20% in 2022-2024, indicating the growing importance of the grain sector in the national economy. The share of grain exports in GDP, which rose from 1.83% in 2010 to over 6% in 2015-2022 is noteworthy. This reflects the growing role of the grain market in generating export revenues and ensuring the country's macroeconomic stability. At the same time, in 2023-2025, this figure decreased to 3.38%, driven by a decline in export volumes and a relative recovery in GDP. Further evidence of structural changes is the growth in grain production per business entity – from 682.7 tonnes in 2010 to 1,741 tonnes in 2021, which may indicate the consolidation of agricultural production and an increase in the concentration of resources.

During the period under review, Ukraine's grain market evolved from a relatively stable, extensive model to an intensive, export-oriented system characterised by a high degree of specialisation and a significant contribution to GDP. Despite the significant destabilising factors of the war period, the sector has demonstrated its ability to adapt, confirming the relevance of further research into the impact of its indicators on the country's macroeconomic performance.

An analysis of trends in indicators of the Ukrainian grain market's performance has revealed significant structural changes in both the production and export components of the sector and has confirmed its significant role in shaping macroeconomic outcomes, particularly gross domestic product. The identified trends – rising yields, intensification of production, a strong export orientation and a significant share of grain exports in GDP – highlight a potentially close correlation between indicators of the grain market's development and the dynamics of the country's economic growth.

At the same time, the descriptive analysis is predominantly qualitative in nature and does not provide a quantitative assessment of the strength, direction and

statistical significance of the impact of individual factors on GDP. In particular, the question remains as to which specific indicators (production, structural or external economic) make the greatest contribution to changes in macroeconomic parameters, and to what extent this influence is stable across different periods, including the pre-crisis and wartime periods.

The construction of correlation matrices for various groups of factors was used for a preliminary quantitative assessment of the strength and direction of the relationships between indicators of the grain market's performance and Ukraine's gross domestic product, as well as the identification of potential multicollinearity issues in subsequent modelling. Analysis of the correlation matrix shows that the indicator of agricultural exports (r = 0.608) has the strongest direct statistical relationship with Ukraine's GDP, indicating a moderately high positive correlation between these variables. At the same time, the correlation between GDP and grain exports (r = 0.415), as well as total goods exports (r = 0.398), is moderate, indicating a direct but less pronounced relationship between the indicators (Table 2). The conclusions regarding the strength of the factors' influence on the resulting indicator are confirmed by the results of further regression analysis and the testing of the statistical significance of the model parameters.

Table 2. Correlation matrix showing the relationship between the factors influencing grain market performance indicators and Ukraine's GDP (export model)

Factors	Ukrainian GDP, billion USD	Exports of agricultural products, USD	Total merchandise exports, USD	Grain exports, billion USD
Ukrainian GDP, billion USD	1	-	-	-
Exports of agricultural products, USD	0.60833	1	-	-
Total merchandise exports, USD	0.39751	-0.09288	1	-
Grain exports, billion USD	0.414517	0.935252	-0.02307	1

Source: calculated by the author

At the same time, within the factor space, there is a high degree of multicollinearity between grain exports and agricultural exports (r = 0.935), which is entirely logical given the dominant role of grain products in the structure of agricultural exports. This limits the possibility of simultaneously including these variables in a single regression model without prior transformation or selection. Overall, the results confirm that export indicators have a significant but heterogeneous impact on GDP formation, and their influence requires further differentiation in the modelling process.

Extension of the model to include a production indicator – gross grain harvest – addressed the relationship between production and macroeconomic outcomes. The results show that the direct relationship between gross grain harvest and GDP is weak (r = 0.104), indicating that production volumes have no direct impact on economic growth. This means that production potential alone does not automatically translate into a macroeconomic effect without the effective sale of products on external markets (Table 3). At the same time, gross harvest has a significant correlation with grain exports (r = 0.664) and agricultural exports (r = 0.538), confirming its role as the resource base for export potential. Thus, the results of the analysis concluded that the impact of production factors on GDP is indirect, via export channels, which is of fundamental importance for the construction of econometric models.

Table 3. Correlation matrix of the interrelationships between the factors influencing the indicators of the grain market's performance and Ukraine's GDP (export-production model)

Factors	Ukrainian GDP, billion USD	Exports of agricultural products, USD	Total merchandise exports, USD	Grain exports, billion USD	Gross grain harvest, million tonnes
Ukrainian GDP, billion USD	1				
Exports of agricultural products, USD	0.60833	1			
Total merchandise exports, USD	0.39751	-0.09288	1		
Grain exports, billion USD	0.414517	0.935252	-0.02307	1	
Gross grain harvest, million tonnes	0.10384	0.537708	0.062273	0.664497	1

Source: calculated by the author

An analysis of structural indicators addressed not only the volume but also the quality and extent of the grain market's integration into the country's economy. In particular, the study established that the correlation between GDP and grain exports is moderate (r = 0.415); structural indicators (the share of grain in agricultural exports and total exports) show a weak or even negative relationship with GDP (r = -0.120; r = 0.155); the ratio of grain exports to GDP has a moderate inverse relationship (r = -0.393) (Table 4).This finding is notable and suggests that an increase in the relative importance of grain exports is not always accompanied by GDP growth; in some cases, it may reflect structural imbalances in the economy, particularly a growing reliance on raw materials. Furthermore, within this model, there is a significant correlation between the structural indicators themselves (up to 0.874), which also highlights the risk of multicollinearity and requires caution when including them in regression equations.

Table 4. Correlation matrix of the interrelationships between the factors influencing grain market performance indicators and Ukraine's GDP (structural-export model)

Factors	Ukrainian GDP, billion USD	Grain exports, billion USD	Share of grain in agricultural exports, %	Share of grain in total exports, %	Share of grain exports in the country's GDP, %
Ukrainian GDP, billion USD	1				
Grain exports, billion USD	0.414517	1			
Share of grain in agricultural exports, %	-0.11984	0.767047	1		
Share of grain in total exports, %	0.154959	0.7926	0.603123	1	
Share of grain exports in the country's GDP, %	-0.39286	0.657028	0.874053	0.707836	1

Source: calculated by the author

The results obtained justify the continued use of variational correlation-regression modelling, incorporating the identified relationships and multicollinearity constraints, which will provide a more accurate identification of the key drivers of the grain market's influence on the country's macroeconomic dynamics. The results of the correlation-regression modelling indicate a substantial and statistically significant impact of grain market performance indicators on the dynamics of Ukraine's gross domestic product. The variational models constructed can be used for the assessment of both direct and indirect effects of various groups of factors (Table 5).

Table 5. Performance metrics of the correlation and regression analysis of the factor effects of grain market performance indicators on Ukraine's GDP

Equation	Multiple correlation coefficient R	Coefficient of determination R^2	Fisher's coefficient (F-test)	Student's t-test	Influencing factors
Export model					
$Y = -65.9994 + 15{,}628X_1 + 1.759X_2 - 23.002X_3$	0.925	0.856	factual: 23.828 critical 3.490	$tx_1 = 6.58$ $tx_2 = 4.97$ $tx_3 = 4.82$ $t_{critical}$ 2.13	x_1 – Exports of agricultural products, billion USD x_2 – Total merchandise exports, billion USD x_3 – Grain exports, billion USD
Export-oriented production model					
$Y = -53.437 + 15{,}23X_1 + 1.7665X_2 - 21.432X_3 - 0.274X_4$	0.927	0.860	factual: 16.83 critical 3.36	$tx_1 = 5.92$ $tx_2 = 4.83$ $tx_3 = -3.69$ $tx_4 = -0.51$ $t_{critical}$ 2.13	x_1 – Exports of agricultural products, billion USD x_2 – Total merchandise exports, billion USD x_3 – Grain exports, billion USD x_4 – Gross grain harvest, million tonnes
Structural export model					
$Y = -5.23 + 0{,}019X_1 - 0.335X_2 + 0.242X_3 + 0.152_4$	0.934	0.872	factual: 18.69 critical 3.36	$tx_1 = 0.87$ $tx_2 = -2.21$ $tx_3 = 4.82$ $tx_4 = 3.02$ $t_{critical}$ 2.13	x_1 – Grain exports, billion USD x_2 – Share of grain in agricultural exports, % x_3 – Share of grain in total exports, % x_4 – Share of grain exports in the country's GDP, %

Source: calculated by the author

The resulting regression equation, within the context of the export model, is characterised by high-quality indicators: the multiple correlation coefficient is 0.925, and the coefficient of determination $R^2 = 0.856$, indicating that 85.6% of the variation in GDP is explained by the selected influencing factors. The actual value of Fisher's L-test statistic (23.828) significantly exceeds the critical value (3.490), confirming the overall statistical significance of the model.

All factors are statistically significant ($t > t_{cr}$), which are therefore eligible for economic interpretation. Thus, the modelling revealed that agricultural exports (X_1) have the greatest positive impact – a USD 1 billion increase in this indicator is accompanied by a USD 15.63 billion rise in GDP, confirming its role as a key driver of the economy. The dynamics of total goods exports (X_2) also have a positive impact on GDP, although the effect is less pronounced – a USD 1 billion increase in this indicator leads to a USD 1.76 billion rise in GDP. At the same time, the grain export indicator (X_3) shows a negative coefficient (-23.002), indicating possible structural imbalances, in particular the effect of "raw material specialisation", where growth in exports of low-value-added products does not provide an adequate increase in value added. Thus, the export model reflects the contradictory nature of the impact of grain exports on economic growth.

Expansion of the model by including the production indicator yielded the following equation:

$$Y_t = -54{,}437 + 15{,}23X_1 + 1{,}7665X_2 - 21{,}432X_3 - 0{,}274X_4. \quad (5)$$

The quality of the corresponding export-production model remains high – $R = 0.927$, $R^2 = 0.860$, and the actual value of Fisher's L-test statistic is 16.83, which is five times higher than the critical value (3.36). At the same time, analysis of the t-statistic indicates that agricultural exports and total exports remain statistically significant

factors; grain exports retain a negative influence and are significant, whereas gross grain harvest (X_4) is statistically insignificant ($t = -0.51 < t_{cr}$). This formed a fundamental conclusion – grain production volumes do not have an independent impact on GDP, but their role is implemented indirectly, through export channels. The negative coefficient in the equation (-0.274) for X_4 further confirms that increasing production without corresponding sales efficiency does not ensure economic growth. The construction of a corresponding structural-export model, which includes the grain export growth rate and a set of relevant structural indicators (the share of grain in agricultural exports, in total exports and in the country's GDP) as influencing factors, yielded the following equation:

$$Y_t = -5{,}23 + 0{,}019X_1 - 0{,}335X_2 + 0{,}24X_3 + 0{,}152X_4, \quad (6)$$

This model demonstrated the highest level of explanatory power. The obtained multiple correlation and determination coefficients were 0.934 and 0.872, respectively, and the actual value of the Fisher's F-test exceeded the critical level by a factor of 5.7 ($F_{fact} = 18.69 > F_{cr} = 3.36$). However, not all variables are statistically significant. Thus, the trend in grain exports (X_1) is insignificant (t = 0.87), the share of grain in agricultural exports (X_2) has a negative and significant effect (t = -2.21), the share of grain in total exports (X_3) and the share of grain exports in GDP (X4) are positive and significant.

The results obtained formed the following structural conclusions:

- The rise in the relative share of grain in agricultural exports has a negative impact on GDP, highlighting the risks of excessive specialisation (a 1% increase in the share of grain in agricultural exports reduces GDP by USD 335 million).
- At the same time, the growing role of the grain sector in total exports and GDP could act as a driver of economic growth, provided there is effective integration into the economy (an increase in the share of grain in total merchandise exports leads to a rise in the country's GDP of USD 242 million, whilst a corresponding increase in the share of grain exports in GDP boosts this macroeconomic indicator by USD 152 million);
- The lack of significance in the dynamics of grain exports confirms that it is not the volume but the structural role of Ukraine's grain sector that is decisive.

Thus, the model that accounts for structural and export parameters is the most appropriate from an economic perspective, as it can show not only the quantitative but also the qualitative aspects of the grain market's functioning. The results of the correlation-regression modelling indicate the presence of a stable but heterogeneous influence of grain market performance indicators on Ukraine's gross domestic product. The high values of the multiple correlation coefficients for all the models constructed (R = 0.925-0.934) and coefficients of determination (R^2 = 0.856-0.872) confirm the significant explanatory power of the selected explanatory variables, which can be used to interpret the results as statistically reliable.

At the same time, a comparative analysis of the model parameters reveals fundamental differences in the nature of the impact of individual factors. Within the export model, it has been established that agricultural exports ($\beta_1 = 15.628$) and total merchandise exports ($\beta_2 = 1.759$) have a positive impact on GDP, which is consistent with the classical view of exports as a driver of economic growth. At the same time, the coefficient for the grain export variable has a negative value ($\beta_3 = -23.002$), indicating the presence of a structural imbalance: growth in the volume of raw material exports does not translate into a corresponding increase in gross value added.

The inclusion of the production factor (gross grain harvest) in the export-production model did not lead to a significant increase in the model's explanatory power (R^2 rose only from 0.856 to 0.860), and the coefficient itself proved to be statistically insignificant (t = -0.51 < t-crit). This provides grounds for asserting that an increase in grain production volumes is not a determining factor of economic growth, which is consistent with the concept of the limited effectiveness of the raw materials-export model of economic development.

The structural-export model demonstrated the highest explanatory power ($R^2 = 0.872$), highlighting the decisive role of structural characteristics of exports. In particular, the share of grain in total exports ($\beta_3 = 0.242$; t = 4.82) and the share of grain exports in GDP ($\beta_4 = 0.152$; t = 3.02) have a statistically significant positive impact, whilst the share of grain in agricultural exports ($\beta_2 = -0.335$; t = -2.21) demonstrates a negative effect. This indicates the presence of an over-specialisation effect, whereby an increase in the concentration of the grain segment within the structure of agricultural exports reduces the overall efficiency of the sector.

Discussion

The findings of this study confirm that Ukrainian grain markets remain central in shaping the country's macroeconomic performance; however, the nature of this influence is more complex than a simple correlation between production or export volumes and GDP trends. The econometric modelling showed that, alongside absolute indicators, the structural characteristics of the market are significant, in particular the share of grain in agricultural exports, the share of grain exports in total goods exports, and the ratio of grain exports to GDP. This highlights that the grain sector should be viewed not merely as a source of foreign exchange earnings, but as a multi-factor system whose impact on the economy is mediated by the internal structure of value-added creation.

The findings generally align with the position of Yu.O. Voloshchuk & O.V. Shedlovska (2024), identifying the Ukrainian grain market as a systemic element of the agri-food system. Indeed, the results of this study have shown the existence of a statistically significant correlation between key indicators of the grain market and Ukraine's GDP. At the same time, the analysis conducted reveals a broader picture: the system-forming role of the industry is determined not only by the scale of production but also by the quality of the sector's integration into the national economy. Therefore, the assertion that increasing grain exports has an unquestionably positive effect appears somewhat simplistic, as growth in raw material exports is not always accompanied by an equivalent increase in domestic value added.

A similar line of reasoning was presented by K.V. Bliumska-Danko & M.A. Zaidenko (2023), which highlights the importance of grain production for the competitiveness of the agricultural sector. The findings of this study support this conclusion, but also provide a different perspective on it. It is advisable to assess the competitiveness of the grain market not only in terms of production volumes, but also in terms of the sector's ability to generate a sustainable macroeconomic effect. In this context, structural indicators proved to be more informative than individual absolute production parameters.

It is necessary to compare this with studies focusing on the external economic aspects of the grain market. For instance, L.O. Kibalnyk & A.V. Cherkashchenko (2025) argued that grain exports are one of Ukraine's leading sources of foreign exchange earnings. The results obtained fully confirm this conclusion, as the growth in grain exports was accompanied by an increase in its share of the country's total merchandise exports. However, the analysis conducted above paints a different picture regarding the macroeconomic effect: the foreign exchange significance of grain exports is not equivalent to its long-term impact on economic growth. The reason for the differing interpretations may lie in the fact that the foreign trade effect is short-term, whereas the impact on GDP depends on the level of product processing, the tax multiplier and the domestic investment cycle.

Similar findings were reported by O. Sheremetynska (2025), which highlights Ukraine's role as a key player in the global grain market. This assertion is notable as Ukraine has traditionally held a significant position in the global trade in grain crops. However, the findings of this study indicate that the status of a major exporter does not guarantee maximum domestic economic benefit. This does not contradict previous research, but shifts the focus from Ukraine's global role to the issue of domestic efficiency in utilising export potential.

A comparison with the studies by S. Jagtap *et al.* (2022), A. Panfilova *et al.* (2025) and I. Savchuk (2025), which examine the impact of the war and logistical shocks on the grain market, is noteworthy. The conclusions drawn by these authors are entirely relevant, as the results of the analysis also revealed a sharp decline in certain export indicators in 2022 and instability in subsequent years. At the same time, the conducted modelling demonstrates that even under conditions of logistical constraints, the grain market maintained a statistically significant link with macroeconomic indicators. This indicates the sector's high adaptive potential and its ability to rapidly restructure export routes and market behaviour.

The findings of this study also align with the conclusions of A. Rose *et al.* (2023) and S. Kozlovskyi *et al.* (2024), who highlight the global implications of the decline in Ukrainian grain exports for food security and the global economy. However, this paper emphasised the reverse direction of analysis – the impact of the grain market on Ukraine's domestic economy. This approach complements existing academic definitions and views the grain sector simultaneously as both a global and a domestic economic factor.

The methodological aspect of the study is of particular significance. In contrast to the studies by O. Makarenko & M. Kurchenko (2023), A. Azarova *et al.* (2024), and I. Fedyshyn & N. Harmatii (2024), which primarily assess the impact of foreign trade on GDP as a whole, this study employs a variant approach to modelling, distinguishing between export, export-production and structural-export models. This addressed the problem of multicollinearity and compared the informative value of different groups of factors. This approach can be regarded as a methodological advantage of the present study.

Thus, the findings of this study indicate that the grain market's impact on Ukraine's GDP is shaped by a combination of production, export and structural factors. In contrast to the common approach, which regards export volumes or gross harvest as the primary indicator of the sector's success, the analysis has highlighted the importance of the market's structural characteristics. This provides a basis for the conclusion that government policy in the grain sector should be geared not only towards increasing production, but also towards developing processing, diversifying the export basket and increasing the share of value added in Ukraine's agricultural economy.

▸ Conclusions

The study established that indicators of the functioning of Ukraine's grain market have a significant, though varied, impact on macroeconomic dynamics. The econometric models constructed demonstrate a high level of explanatory power ($R^2 = 0.856$-0.872), confirming the relevance of the selected set of factors for analysing the impact on GDP. The most significant positive impact comes from agricultural exports ($\beta = 15.628$), whilst total goods exports have a moderate stimulating effect ($\beta \approx 1.76$).

At the same time, a structural imbalance has been identified: grain exports are characterised by a negative coefficient within the baseline model ($\beta = -23.002$), indicating the limited capacity of commodity exports to generate added value and ensure sustainable economic growth. This result confirms the hypothesis of the existence of a "resource trap", in which an increase in the physical volume of exports does not translate into corresponding GDP growth.

The study also determined that the inclusion of the production factor (gross grain harvest) has no statistically significant impact on the outcome variable ($t = -0.51$), indicating that production parameters are secondary in shaping the macroeconomic effect. Instead, the structural characteristics of exports are of decisive importance: in particular, the share of grain in total exports ($\beta = 0.242$) and the share of grain exports in GDP ($\beta = 0.152$) demonstrate a statistically significant positive impact, whereas an increase in the share of grain in agricultural exports ($\beta = -0.335$) has a negative effect, indicating the risks of excessive sectoral concentration.

The findings formulated a fundamentally relevant conclusion: the decisive factor in the grain market's impact on economic growth is not so much the scale of production or exports as their structural quality and the degree of integration into value-added chains. In this context, the current model of the Ukrainian grain market is characterised by a structural paradox, whereby

quantitative growth is not accompanied by a qualitative transformation of economic outcomes.

Future research should refine econometric tools, in particular the use of dynamic models (VAR/VECM), analyse lag effects, and consider institutional and geopolitical factors, which will provide a more comprehensive analysis of the mechanisms underlying the interaction between the grain market and macroeconomic dynamics.

▸ Acknowledgements

None.

▸ Funding

None.

▸ Conflict of interest

None.

▸ References

[1] Azarova, A., Nikiforova, L., Ruzakova, O., & Khymych, V. (2024). Econometric modeling of the impact of export-import operations on the level of GDP of Ukraine. *Herald of Khmelnytskyi National University. Economic Sciences*, 336(6), 363-369. doi: 10.31891/2307-5740-2024-336-57.

[2] Bliumska-Danko, K.V., & Zaidenko, M.A. (2023). Organizational and economic parameters of the grain market in Ukraine. *Bulletin of the Sumy National Agrarian University. Series 'Economics and Management'*, 1(93), 28-33. doi: 10.32782/bsnau.2023.1.6.

[3] Fedyshyn, I., & Harmatii, N. (2024). Modeling the influence of the dynamics of exports and trade turnover of Ukraine on macroeconomic indicators of the national economy. *Socio-economic Problems and the State*, 1(30), 75-85. doi: 10.33108/sepd 2024.01.075.

[4] Filiuk, G. (2025). Export of Ukrainian grain in the conditions of armed aggression of the Russian Federation: Dynamics, concentration, global challenges. *Collection of Scientific Works of the State Tax University*, 1, 79-85. doi: 10.32782/2617-5940.1.2025.12.

[5] Haida, Yu.I., & Shainiuk, B.L. (2023). Grain market in retrospect and perspective: Global analysis. *Innovation and Sustainability*, 4, 30-40. doi: 10.31649/ins.2023.4.30.40.

[6] Jagtap, S., *et al.* (2022). The Russia-Ukraine conflict: Its implications for the global food supply chains. *Foods*, 11(14). doi: 10.3390/foods11142098.

[7] Khatri, P., Kumar, P., Shakya, K.S., Kirlas, M.C., & Tiwari, K.K. (2024). Understanding the intertwined nature of rising multiple risks in modern agriculture and food system. *Environment, Development and Sustainability*, 26(9), 24107-24150. doi: 10.1007/s10668-023-03638-7.

[8] Kibalnyk, L.O., & Cherkashchenko, A.V. (2025). Analysis of the dynamics of grain exports of Ukraine under modern challenges and threats. *Economic Space*, 205, 97-102. doi: 10.30838/EP.205.97-102.

[9] Kozlovskyi, S., Yousuf, A., Butenko, V., Kulinich, T., Bohdaniuk, O., Nikolenko, L., & Lavrov, R. (2024). The influence of the world grain market on prevalence of mankind's undernourishment in the times of war on the Ukraine. *Problems of Sustainable Development*, 19(1), 31-42. doi: 10.35784/preko.5748.

[10] Lyutak, O., Baula, O., Nebaba, N., Fedorenko, O., & Hrytsay, O. (2024). Modeling the influence of ecological and economic factors on the growth of GDP of countries. *Current Problems of Economy*, 7(277), 143-151. doi: 10.32752/1993-6788-2024-1-277-143-151.

[11] Makarenko, O., & Kurchenko, M. (2023). Econometric modeling of the impact of foreign economic activity (export and import) on the GDP of Ukraine. *Young Scientist*, 12(124), 180-183. doi: 10.32839/2304-5809/2023-12-124-1.

[12] Minfin website. (n.d.). Retrieved from https://index.minfin.com.ua/ua/markets/.

[13] Nedashkivskyi, V., Prysiazhniuk, N., Ivanovskyi, A., Fedoruk, Yu., & Panchenko, T. (2024). The grain market as a system-forming link of the agri-food market of Ukraine. *Economic Analysis*, 34(2), 488-497. doi: 10.35774/econa2024.02.488.

[14] Official website of the Ministry of Economy of Ukraine. (n.d.). Retrieved from https://me.gov.ua/?lang=uk-UA.

[15] Official website of the State Statistics Service of Ukraine. (n.d.). Retrieved from http://www.ukrstat.gov.ua.

[16] Panfilova, A., Poltorak, A., Kuvshynova, A., Burkovska, A., & Dotsenko, N. (2025). Trends in global trade of grain and seeds and Ukraine's position on the world market. *Scientific Horizons*, 28(5), 142-157. doi: 10.48077/scihor5.2025.142.

[17] Polat, O., Basar, B.D., Torun, E., & Eksi, I.H. (2023). Dynamic interlinkages between geopolitical stress and agricultural commodity market: Novel findings in the wake of the Russian Ukrainian conflict. *Borsa ˙Istanbul Review*, 23(1), 74-83. doi: 10.1016/j.bir.2023.05.007.

[18] Prajapati, D., Chan, F.T., Daultani, Y., & Pratap, S. (2022). Sustainable vehicle routing of agro-food grains in the e-commerce industry. *International Journal of Production Research*, 60(24), 7319-7344. doi: 10.1080/00207543.2022.2034192.

[19] Rose, A., Chen, Z., & Wei, D. (2023). The economic impacts of Russia-Ukraine War export disruptions of grain commodities. *Applied Economic Perspectives and Policy*, 45(2), 645-665. doi: 10.1002/aepp.13351.

[20] Savchuk, I. (2025). Ukraine's grain economy in the context of Russia's full-scale invasion. *Polish Geographical Journal*, 96(2), 217-234. doi: 10.12657/czageo-96-09.

[21] Sheremetynska, O. (2025). Ukraine as a key player in the global grain market: Challenges and transformations. *Economy and Society*, 75. doi: 10.32782/2524-0072/2025-75-61.

[22] Tarasenko, D.L. (2018). Modeling ecological and economic processes to ensure effective social policy in sustainable regional growth. *Economics of Nature Use and Environmental Protection*, 29(68), 129-133.

[23] Tushar, S.R., Alam, M.F.B., Zaman, S.M., Garza-Reyes, J.A., Bari, A.M., & Karmaker, C.L. (2023). Analysis of the factors influencing the stability of stored grains: Implications for agricultural sustainability and food security. *Sustainable Operations and Computers*, 4, 40-52. doi: 10.1016/j.susoc.2023.04.003.
[24] Voloshchuk, Yu.O., & Shedlovska, O.V. (2024). Strategic guidelines for the development of the grain market of Ukraine. *Podilian Bulletin: Agriculture, Engineering, Economics*, 1(42), 74-81. doi: 10.37406/2706-9052-2024-1.11.

Моделювання факторного впливу індикаторів функціонування зернового ринку на ВВП України

Світлана Черемісіна
Доктор економічних наук, доцент
Національний науковий центр «Інститут аграрної економіки»
03127, вул. Героїв Оборони, 10, м. Київ, Україна
https://orcid.org/0000-0003-1546-7714

► **Анотація.** У статті досліджено вплив індикаторів функціонування зернового ринку на динаміку валового внутрішнього продукту України в умовах структурних трансформацій та воєнних викликів. Метою дослідження було кількісне визначення сили, напряму та характеру впливу виробничих, експортних і структурних показників розвитку зернового ринку на макроекономічні результати країни на основі застосування економіко-математичного інструментарію. Методи дослідження включали статистичний аналіз динаміки показників за 2010-2025 рр., кореляційний аналіз, а також кореляційно-регресійне моделювання. Особливістю методичного підходу було використання варіативного моделювання, що передбачало побудову декількох альтернативних моделей із різними наборами факторних змінних та їх перевірку за критеріями статистичної значущості. Результати дослідження засвідчили, що зерновий ринок України трансформувався у високоспеціалізований експортно орієнтований сектор: валовий збір зерна зріс з 39,27 млн т у 2010 р. до 86,01 млн т у 2021 р., а експорт – з 2,47 до 12,34 млрд дол. США. Встановлено, що найбільш вагомий вплив на ВВП мав експорт агропродукції (r = 0,608), тоді як вплив експорту зерна був помірним (r = 0,415) і в регресійних моделях мав від'ємний коефіцієнт (-21,4…-23,0), що свідчить про ефект сировинної орієнтації. Доведено, що виробничі показники не мають прямого статистично значущого впливу (r = 0,104), а реалізуються через експортні канали. Водночас зростання частки зерна в агроекспорті на 1 % супроводжується зниженням ВВП на 335 млн дол. США, тоді як підвищення частки зерна у загальному експорті забезпечує його приріст на 242 млн дол. Застосування варіативного підходу до економетричного моделювання, який дозволило виявити, що вплив зернового ринку на ВВП має нелінійний та структурно зумовлений характер, а визначальними є не обсяги виробництва, а параметри експортної інтеграції. Практична значущість отриманих результатів полягає у можливості їх використання при формуванні державної аграрної політики, зокрема для переходу від сировинної моделі експорту до моделі з вищою доданою вартістю, що сприятиме підвищенню ефективності зернового сектору та зміцненню макроекономічної стабільності

► **Ключові слова:** аграрний сектор; експорт агропродукції; економетричне моделювання; структурні фактори; сировинна орієнтація; макроекономічні показники

Received: 13.10.2025. Revised: 09.01.2026. Accepted: 12.02.2026. Published: 05.03.2026.

EKONOMIKA APK

https://doi.org/10.32317/ekon.apk/1.2026.57

Ekonomika APK, 33(1), 57-68

UDC 658.14:631.11

ISSN: 2221-1055; E-ISSN: 2413-2322

Assessment of the financial condition of agricultural enterprises and ways to strengthen it in wartime conditions

Valeriy Mykytuyk*
Doctor of Economics, Professor
Polissia National University
10008, 7 Staryi Blvd., Zhytomyr, Ukraine
https://orcid.org/0009-0009-3567-7795

► **Abstract.** The purpose of this study was to determine the factors of formation of the financial condition of agricultural enterprises in Ukraine in the context of military transformations. The research methodology was based on the use of statistical, comparative, structural, and system analysis, in addition to the case study method, which allowed examining macroeconomic trends, industry changes, and financial indicators of individual enterprises. The results of the study showed that the share of the agricultural sector in the gross domestic product of Ukraine decreased from 10.89% in 2021 to 7.11% in 2024 (-3.78%). The volume of agricultural production decreased from UAH 1.344 trillion in 2021 to UAH 1.004 trillion in 2022 (-25.3%), with further fluctuations of UAH 1.115 trillion in 2023 and UAH 1.078 trillion in 2024. The income of agricultural enterprises increased from UAH 796 billion in 2022 to UAH 2.4 trillion in 2024, while profit increased from UAH 88.6 billion to UAH 327 billion, which corresponds to a profitability of about 13.6%. Production costs reached UAH 30-32 thousand per 1 ha, and the need for financing in 2025 amounted to UAH 210-220 billion. The volume of lending in 2024 amounted to UAH 104.5 billion (13,088 enterprises), while in 2025 – more than UAH 60 billion (9,282 enterprises). The total losses of the sector exceeded USD 80 billion. The reduction in production reached about 40%. The study shows that the financial condition of agricultural enterprises is determined by a combination of resource constraints, access to financing, and the scale of activities, which makes it necessary to improve the mechanisms of financial support and resource management. The practical importance of the study lies in the possibility of using its results by agricultural enterprises, banks, and state authorities to optimise financing and support the agricultural sector of Ukraine

► **Keywords:** liquidity; profitability; cash flows; lending; capital; production

► Introduction

The activity of agricultural enterprises in Ukraine is taking place in the context of growing uncertainty associated with military events, changes in logistics routes, currency fluctuations, and the transformation of foreign sales markets. Such conditions affect the formation of income, the structure of expenses, and the ability to ensure the continuity of operating activities, which requires a reassessment of approaches to analysing the financial condition of enterprises. Further, there is an increasing need to improve methods for assessing financial stability, in view of the increased level of risks and limited access to financial resources.

Limited access to financial resources, high cost of lending, and changes in the structure of sources of financing in the context of military instability determine the transformation of investment activities of agricultural enterprises. Y. Negoda & D. Konyukhov (2025) assessed the financial support of investment activities of agricultural enterprises, analysing the dynamics of capital investments in 2020-2024 and the structure of their financing. The authors determined that companies' own funds remain the primary source of investment, accounting for 70-75% of the total in the pre-crisis period, whilst bank lending was limited due to the high cost of borrowed capital. In the paper of L. Kostyrko *et al.* (2024), the methodological foundations of integrated risk analysis as a tool for forming a financial strategy were substantiated, a system of indicators for assessing the impact of internal and external factors was formed, the use of scenario analysis for predicting changes in financial results was proposed, along with use

► **Suggested Citation**: Mykytuyk, V. (2026). Assessment of the financial condition of agricultural enterprises and ways to strengthen it in wartime conditions. *Ekonomika APK*, 33(1), 57-68. doi: 10.32317/ekon.apk/1.2026.57.

*Corresponding author

of an integral indicator of market value, considering risks and reserves of financial stability. The results obtained demonstrate the dependence of financial stability on the dynamics of profitability, asset structure, and availability of financial resources, in addition to the need to combine risk management and strategic planning tools.

The uncertainty of the financial environment, limited access to financing and insufficient development of analytical and forecast support complicated managerial decisions, leading to the need to investigate their internal potential. M. Sobchenko (2025) justified approaches to assessing the internal potential of analytical and forecast support, identified its structural components (information, analytical, technological, personnel, organisational), and proposed a system of indicators and an integral assessment methodology based on normalisation, weighing, and generalisation of indicators. Thereby, the author has established a relationship between the level of development of analytical support and the effectiveness of financing the development of enterprises. O. Dyvnych & M. Martynyuk (2023) analysed the transformation of land use in wartime conditions, recorded losses of agricultural land in a number of regions of Ukraine, outlined changes in the structure of acreage and the movement of enterprises to the western territories. In addition, the growth of the share of oilseeds and related resource imbalances caused by differences in the level of profitability and logistics costs were noted. The results obtained reflect the influence of military factors on the production and economic parameters of enterprises' activities.

The decline in resource efficiency, rising costs, and restricted access to financial and credit resources during wartime make it difficult to maintain a stable level of corporate profitability and to determine their financial performance, thereby necessitating a refinement of the approaches used to assess it. N. Oliinyk & T. Lyzhenkova (2024) analysed the essence and approaches to determining the profitability of enterprises in military conditions, justified the feasibility of using various groups of indicators (cost, revenue and resource) depending on the economic environment. The expediency of focusing on indicators of personnel profitability as a factor in assessing the effectiveness of activities under martial law was also highlighted. The results obtained showed that profitability acts as a generalising indicator of the efficiency of the enterprise's functioning and reflects the impact of external restrictions and internal management decisions. Features of the formation of financial results of enterprises in the conditions of crisis phenomena were analysed by L. Shovkun-Zablotska *et al.* (2024), determining the influence of external and internal factors on profitability. The role of adaptive mechanisms for financial management was substantiated, and approaches to improving the efficiency of using financial resources were proposed. The results obtained reflect the dependence of financial stability on changes in the market environment, cost structure, and effectiveness of management decisions.

Deterioration of access to food, destruction of agricultural infrastructure, and restriction of economic opportunities of the population in the context of military operations lead to changes in the functioning of agricultural systems and food supply. The investigation of these processes was conducted by Z. Dardona *et al.* (2025), who analysed the impact of the 2023-2024 armed conflict in the Gaza Strip on food security, nutrition, and access to resources. The researchers established that the military action caused the destruction of agricultural land and infrastructure, disruption of food supplies, rising prices, and reduced food diversity and availability of basic products, increasing the population's dependence on humanitarian aid. A. Hassoun *et al.* (2024) also analysed the impact of the 2023-2024 war in the Gaza Strip on food security and the achievement of the sustainable development goals, noting that the military action caused massive destruction of agricultural land and food infrastructure, including bakeries, mills, and processing facilities. As a result, a disruption of the food system functioning, a reduction in production volumes, and restrictions on physical access to food were recorded. In addition, there was an increase in prices for basic products and a decrease in the purchasing power of the population, which led to the transition of a significant part of households to a state of acute food danger and dependence on humanitarian aid.

Nevertheless, an integrated assessment of the financial condition of agricultural enterprises, its combination with mechanisms for strengthening financial stability in the context of military factors, in addition to improving approaches to assessing creditworthiness and financing, require further research. This study aimed to determine the factors of ensuring the financial condition of agricultural enterprises in Ukraine and their changes under the influence of military challenges. The following tasks were defined to achieve this goal: analyse the system of indicators that characterise the liquidity, financial stability and efficiency of agricultural enterprises; evaluate the influence of external and internal factors on the formation of financial results of enterprises; justify the directions for improving the efficiency of using financial resources and strengthening the financial stability of agricultural enterprises.

▸ Materials and methods

The study was empirical in nature and covered the time period of 2021-2025, which was due to the need to consider the pre-crisis period (2021), the stage of sharp transformation of business conditions under the influence of a full-scale war (2022), and further processes of adaptation and partial restoration of enterprises in 2023-2025, which allowed tracing the dynamics of changes in financial indicators in different phases of the economic environment.

Within the framework of the study, an analysis of the financial condition of agricultural enterprises was conducted using the method of statistical analysis and generalisation of open macroeconomic data, which enabled the examination of the dynamics of the share of value added of the agricultural sector in gross domestic product (GDP) and determine the change in the role of the industry in the economy (Global Economy, n.d.). The assessment of financial results of enterprises was conducted using a comparative analysis of income, profit and profitability indicators to identify changes in the ratio of income and expenses under the influence of external factors (Ukraine's agricultural sector..., 2025). The cost structure was reviewed using structural analysis to determine the

impact of material and technical resources on the formation of cost and financial resource requirements (Institute of Agricultural Economics, 2025).

The analysis of access to financial resources was performed using an economic and statistical method based on data on lending volumes, which allowed assessing the role of bank financing in ensuring the activities of enterprises (Ministry of Agricultural Policy and Food of Ukraine, 2025). The review of the resource support of production was conducted using a quantitative analysis of fuel and fertiliser use indicators to assess the material consumption of production. The influence of military factors was evaluated by the method of system analysis to establish the relationship between resource losses, reduced production, and changes in financial indicators. Production trends were analysed using time series analysis, whilst the structure of the industry was analysed using structural analysis (Sikachyna & Gagalyuk, 2025). Resource efficiency was evaluated using the relative indicator method.

Two agro-industrial companies of the Zhytomyr region – Cygnet Agrocompany (n.d.) and Agricultural Company "Nadiya VP" LLC (n.d.), which were selected for comparison, in particular, the structure of assets and capital, liquidity indicators, financial stability, and efficiency of enterprises, organisational structure, and level of operational efficiency. The choice of these enterprises was determined by the availability of open financial statements, the ability to track the dynamics of indicators in 2021-2024, in addition to differences in performance, which enabled the examination of the financial condition differentiation of agricultural enterprises. For Cygnet Agrocompany, the analysis was conducted using the financial analysis method based on the company's official financial statements to assess the dynamics of its financial condition and performance (KyivAudit, 2021; 2022; 2023). The analysis also covered financial statements for 2024 (KyivAudit, 2024), which ensured the completeness of the time sample for 2021-2024. 2025 was excluded from the analysis due to the lack of statistical data at the time of the study. The following indicators were analysed: income, cost, gross profit, operating profit, net profit, total asset value, current liquidity, autonomy ratio, and return on sales. A system of financial coefficients was calculated to assess financial stability and efficiency. The current liquidity ratio was defined as (1):

$$R_{cl} = \frac{\text{Current assets}}{\text{Current liabilities}}. \quad (1)$$

The coefficient of autonomy was calculated by the formula (2):

$$R_{aut} = \frac{\text{Equity}}{\text{Assets}}. \quad (2)$$

The return on sales was defined as (3):

$$P_s = \frac{\text{Net profit}}{\text{Income}} x100\%. \quad (3)$$

The use of the financial analysis method provides for the examination of the structure of income and expenses, assessing the level of financial independence, and determining the ability of an enterprise to generate profit. For Agricultural Company "Nadiya VP" LLC, the analysis was conducted using the method of financial coefficients and economic and statistical analysis based on open data of the enterprise to assess the financial stability, capital structure and efficiency of resource use. The dynamics of the following indicators were analysed: income, net profit, profitability, assets, liabilities, equity, autonomy coefficient, financial dependence coefficient, return on assets, number of employees, and income per employee, the autonomy coefficient (Formula 2), financial dependence coefficient and return on sales (Formula 3). The financial dependence coefficient was defined as (4):

$$R_{fd} = \frac{\text{Obligations}}{\text{Assets}}. \quad (4)$$

The use of these methods allowed assessing the level of dependence of the enterprise on borrowed capital, the efficiency of asset use and labour productivity. The further stage of the study included the analysis of directions for strengthening the financial condition of agricultural enterprises using the method of institutional analysis, which allowed investigating the mechanisms of state financial support. In particular, the programme "Affordable loans 5-7-9%", along with the grant programmes "eWork" and "Own business" (Ministry of Economy of Ukraine, 2025), which provide access to financial resources and contribute to supporting business activities, were considered.

The analysis of the structure of bank lending was conducted using the method of generalisation and descriptive analysis to determine the role of major financial institutions in providing the agricultural sector with resources. The participation of leading banks, in particular, Oschadbank, PrivatBank, and Raiffeisen Bank, was considered. Other financial institutions – PUMB and ProCredit Bank – were also reviewed. Based on the generalisation of the results obtained using the synthesis method, directions for improving the efficiency of using the financial resources of agricultural enterprises were developed, forming approaches to strengthening their financial condition. The use of this method ensured the integration of the results of macroeconomic, industry, and micro-level analysis to determine coordinated management decisions. This helped justify the directions of optimising the capital structure, improving the efficiency of using resources and expanding access to financial instruments.

▸ Results and Discussion

Fundamentals of assessing the financial condition of agricultural enterprises

The financial condition of the enterprise reflects the results of the formation, distribution, and use of financial resources and is characterised by a system of indicators that determine the level of liquidity, solvency, financial stability, and efficiency of activities. Within the agricultural sector, these indicators are formed under the influence of production, resource, and market factors, which are aggravated in wartime conditions. Statistical data indicate a change in the role of agriculture in the Ukrainian economy. The share of value added of the agricultural sector in GDP in 2021-2024 was characterised by fluctuations (Fig. 1).

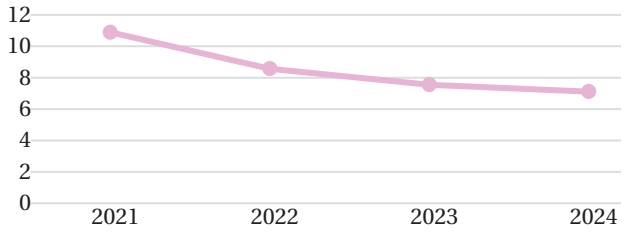

Figure 1. Share of agricultural sector value added in GDP, %
Source: compiled by the author on the basis of Global Economy (n.d.)

According to the above data, there is a steady decline in the share of value added of the agricultural sector in the GDP of Ukraine during 2021-2024. Thus, in 2021, the indicator was 10.89%, in 2022, it decreased to 8.57% (-2.32%), in 2023 – to 7.55% (-1.02%), and in 2024 – to 7.11% (-0.44%). In general, during the analysed period, the reduction was 3.78 percentage points, which reflects a decrease in the contribution of the agricultural sector to the formation of GDP. The financial results of agricultural enterprises of Ukraine in 2022-2024 indicate changes. In 2022, revenue amounted to UAH 796 billion, and profit – UAH 88.6 billion, while in 2023 revenue increased to UAH 920.9 billion, while profit decreased to UAH 65.8 billion. In 2024, revenue grew to UAH 2.4 trillion and profit to UAH 327 billion, which corresponds to an average net profitability of about 13.6%. Such changes indicate fluctuations in the ratio of income and expenses and adaptation of enterprises to changes in the external environment (Ukraine's agricultural sector..., 2025). The cost structure of agricultural enterprises is formed under the influence of material and technical resources, among which the largest share is occupied by mineral fertilisers (20-25%), fuel (10-12%), seeds (about 10%), and plant protection products (7%). In 2024, the cost of growing basic crops amounted to up to UAH 30-32 thousand per 1 ha, which determines the high level of demand for financial resources. In 2025, spending on spring field work is projected to increase to UAH 210-220 billion compared to about UAH 200 billion in the previous year, due to changes in resource prices and increased labour costs (Institute of Agricultural Economics, 2025).

The financial condition of enterprises is also determined by access to financial resources. In 2024, 13,088 agricultural enterprises attracted about UAH 104.5 billion in bank loans. In 2025, more than 9,282 enterprises received more than UAH 60 billion in credit resources, including 4,273 enterprises – UAH 26.8 billion. This indicates a significant role of lending in ensuring the financial activities of enterprises. An additional factor in the formation of the financial condition is the resource support of production. Agriculture consumes more than 25% of diesel fuel, while in 2024 the volume of its use amounted to 900-1000 thousand tonnes. The application of mineral fertilisers reached 1.8 million tonnes in active substance, which corresponds to 85-90 kg per 1 ha. Such indicators characterise the material intensity of production and affect the cost structure and financial results of enterprises (Ministry of Agricultural Policy and Food of Ukraine, 2025).

The financial condition of agricultural enterprises is formed under the influence of macroeconomic conditions, production structure, resource provision, and external restrictions, which was especially evident during the period of military transformations. A summary of statistical data indicates losses in the agricultural sector, the total volume of which exceeded USD 80 billion, of which USD 10.3 billion were direct losses of assets, including destroyed infrastructure, equipment, and storage facilities. As a result, in 2021-2024, production decreased by about 40%, which directly affected the formation of income of enterprises and their financial stability. In 2024, the volume of agricultural production amounted to about USD 33 billion. The sector's share of GDP reached 13.7%, while the contribution to overall GDP dynamics remained negative at -7.3%, reflecting the continued structural imbalances in the functioning of the economy. Analysis of the production structure shows a shift in the role of different categories of farms in the formation of financial results. In 2024, agricultural enterprises accounted for 57.4% of total production, farms – 13.6%, while the share of households was 29%, which is lower than 43.6% in 2010. This transformation indicates an increase in the concentration of production in the corporate sector and a change in the revenue structure, which affects the formation of financial indicators, in particular, liquidity, profitability, and solvency of enterprises (Sikachyna & Gagalyuk, 2025). The dynamics of agricultural production in 2021-2024 reflects changes in the financial results of agricultural enterprises under the influence of military factors and the transformation of economic conditions (Fig. 2).

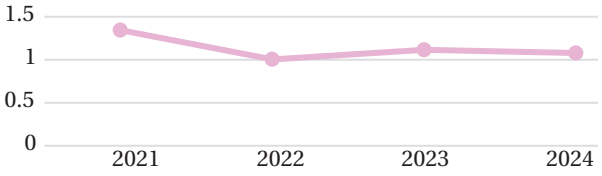

Figure 2. Volume of agricultural production, trillion UAH
Source: compiled by the author on the basis of O. Sikachyna & T. Gagalyuk (2025)

The dynamics of production volumes reflects the instability of the financial results of agricultural enterprises in the study period. In 2021, the volume of production amounted to UAH 1.344 trillion, after which in 2022 it decreased to UAH 1.004 trillion (-25.3%), which is due to the loss of production resources, a decrease in acreage, and disruption of logistics chains. In 2023, there was a partial recovery to UAH 1.115 trillion, but in 2024, the indicator again decreased to UAH 1.078 trillion, underlining the lack of stable positive dynamics and the dependence of financial results on external factors.

Structural analysis of the industry indicates different sensitivity of individual activities to crisis conditions. Crop production declined by 21.6%, while livestock production declined by 11.3%, due to varying levels of dependence on logistics, seasonality, and export orientation. This leads to differences in the formation of profitability and financial results of enterprises, depending on their production specialisation. The financial condition of agricultural

enterprises is also determined by the influence of factors of resource provision and the labour market. The loss of about 5 million hectares of agricultural land, the shortage of labour resources caused by migration processes, in addition to changes in the territorial structure of production, led to a decrease in production potential and complication of capital reproduction processes. Therewith, large enterprises showed a higher level of adaptation to environmental changes compared to small farms, which is reflected in the difference in financial results. Assessment of resource efficiency confirms the differentiation of financial condition depending on the scale of activity. Production per 1 ha in large enterprises amounted to UAH 54.4 thousand, in medium-sized enterprises – UAH 34 thousand, in small – UAH 26 thousand, highlighting the advantages of resource concentration and access to financial instruments. The market structure is characterised by a high level of concentration: large-scale enterprises, whose share is only 3.6%, form 53.9% of total production, and their productivity exceeds the indicators of small enterprises by ten times (Sikachyna & Gagalyuk, 2025).

The comparison showed that both studies were aimed at analysing the stability of the agricultural sector under the influence of external shocks, but differed in the level and methods of research. H. Yu & Y. Liang (2025) analysed a multidimensional model and spatial econometric methods at the macro level, while this study considered the financial indicators of agricultural enterprises in Ukraine at the micro level. It was common to account for the impact of complex shocks and the role of resource support and state support in building sustainability. However, the differences were in methodology and time horizon: the Chinese study covered long-term dynamics and regional imbalances, while this study covered short-term changes during the war period. H. Yu & Y. Liang recorded an increase in agricultural sustainability and the formation of spatial clusters, while in the present study, fluctuations in financial indicators and instability under the influence of war were observed.

Further comparison with a study by Y. Lu & Y. Chen (2021) deepened this understanding, as both approaches were based on the use of financial indicators, but differed in the context of their interpretation. The Chinese study reviewed financial ratios in relation to institutional characteristics, such as corporate governance and government support mechanisms, which reflected the functioning of enterprises in a relatively stable environment. In this study, these same indicators took on a different meaning – they recorded changes in liquidity, profitability, and access to financing under military restrictions, which led to their high variability. A similar difference was observed when comparing with the approach of Y. Liu *et al.* (2021), where performance evaluation was conducted on the basis of Integral indicators and factor analysis at the macro level. In this case, the study focused on identifying patterns of sustainable development and the impact of resources and technologies on productivity. In turn, in this paper, these same factors were considered through the prism of the financial condition of enterprises operating in conditions of increased uncertainty, where the results did not have stable dynamics. In this context, a paper of X. Zhong & J. Wang (2024) added to the overall picture, as it focused on structural changes and productivity in the agricultural sector of China using quantitative models. It reflected the processes of improving efficiency in conditions of relative macroeconomic stability. In this study, similar factors – resource provision, technology, and external conditions – were manifested due to fluctuations in the financial results of enterprises, which was due to the impact of military risks.

A comparison with the research of Q. Ma & X. Li (2025) summarised differences in approaches to performance evaluation. In this paper, econometric models were used to analyse the impact of fiscal and financial support on overall factor performance, which allowed us to identify the positive effect of each instrument. In this study, the role of financing was also traced, but its impact was manifested through changes in liquidity, access to credit and financial stability of enterprises during the war period. This led to a difference in the results: in the Chinese study, productivity growth was recorded, while in this study, the variability of financial indicators and dependence on external restrictions were recorded.

The financial condition of agricultural enterprises in 2021-2024 was characterised by a significant variability of indicators, which is due to the influence of military factors, changes in the structure of production and resource constraints. The decline in the share of the agricultural sector in GDP and the unstable dynamics of production volumes indicate a decrease in its contribution to the economy and the absence of a stable recovery trend. The growth of revenues and profits in 2024 and the activation of lending confirm the adaptation of enterprises to the new operating conditions. The totality of the results obtained indicates the need to improve approaches to managing financial resources, considering the impact of external risks, cost structure, and availability of financing.

Assessment of the financial condition of agricultural enterprises in the Zhytomyr region

Cygnet Agrocompany (n.d.) is a group of agricultural enterprises with foreign capital, the activities of which cover the cultivation of grain and oilseeds, sugar production, the development of dairy farming, along with the provision of grain storage services. Thus, the activity of Cygnet Agrocompany is characterised by a combination of crop production, animal husbandry, processing, and logistics, which forms a comprehensive model of the functioning of an agricultural enterprise and creates prerequisites for the formation of financial results. The dynamics of the company's financial indicators in 2021-2024 are presented in Table 1.

Table 1. Dynamics of Cygnet Agrocompany's financial condition in 2021-2024

Indicator	2021	2022	2023	2024	2024 in % to 2021
Income, th. UAH	1,134,258	1,423,517	1,641,195	1,896,874	167.23
Cost price, th. UAH	(876,412)	(1,390,284)	(1,306,575)	(1,567,215)	178.82

Table 1, Continued

Indicator	2021	2022	2023	2024	2024 in % to 2021
Gross profit, th. UAH	257,846	33,233	334,620	329,659	127.85
Operating profit, th. UAH	198,745	(215,634)	346,220	352,418	177.32
Net profit, th. UAH	111,245	(272,183)	192,686	241,132	216.76
Assets total, th. UAH	2,487,615	2,986,104	3,361,012	3,742,588	150.45
Current liquidity	1.3	1.05	1.56	1.61	123.85
Coefficient of autonomy	0.53	0.22	0.47	0.49	92.45
Return on sales, %	9.8	-19.1	11.7	12.7	129.59

Source: compiled by the author based on KyivAudit (2021; 2022; 2023; 2024)

The dynamics of financial indicators calculated using formulas 1-3 Cygnet Agrocompany in 2021-2024 reflect the impact of military factors on the company's performance and further adaptation to the changed business conditions. In 2022, there was a sharp deterioration in the financial condition, which was manifested in the formation of a loss of UAH 272 million, a decrease in gross profit to UAH 33.2 million and a drop in profitability to -19.1%. A reduction in the share of equity to 0.22 was observed, pointing to an increase in dependence on borrowed sources of financing. In 2023, the company showed a recovery in financial results, which was manifested in an increase in revenue to UAH 1.64 billion and the formation of net profit at the level of UAH 192.7 million. Liquidity and financial stability indicators also improved: the current liquidity ratio rose to 1.56, and the autonomy ratio – to 0.47, which indicates a partial restoration of financial equilibrium and the ability of the enterprise to meet its obligations. In 2024, the trend towards stabilisation continued, which is confirmed by a further increase in revenue to UAH 1.9 billion and net profit to UAH 241.1 million. Profitability increased to 12.7%, reflecting improved resource efficiency. The increase in current assets and equity was accompanied by an increase in liquidity to 1.61 and a strengthening of financial independence to 0.49. A summary of the results shows that after the crisis downturn of 2022, the company was able to adapt to the new operating conditions, restore profitability, and improve key financial indicators. The trends in the indicators suggest that the financial position remains sensitive to external factors, in particular, changes in market conditions, resource availability, and macroeconomic conditions.

The company's activity is characterised by a focus on crop production without developing a livestock direction. Assessment of the financial condition of Agricultural Company "Nadiya VP" LLC is conducted on the basis of indicators of income, profit, assets, liabilities, and calculated coefficients of financial stability and efficiency for 2021-2024 (Table 2).

Table 2. Financial indicators of Agricultural Company "Nadiya VP" LLC

Indicator	2021	2022	2023	2024	2024 in % to 2021
Income, th. UAH	85,187	78,855	69,579	100,469	117.94
Net profit, th. UAH	19,115	-40,398	-36,831	-14.536	-76.04
Profitability level, %	22.44	-51.23	-52.93	-21.15	-94.25
Assets, th. UAH	3,282,901	259,687	284,017	298,018	9.08
Obligations, th. UAH	233,610	212501	277,091	290,215	124.23
Equity, th. UAH	94,680	47,185	6,925	7,804	8.24
Coefficient of autonomy	0.29	0.18	0.02	0.03	10.34
Financial dependency ratio	0.71	0.82	0.98	0.97	136.62
Return on assets (ROA)level, %	5.82	-15.56	-12.97	-4.88	-83.85
Number of employees, persons	47	41	38	40	85.11
Income per 1 employee, thousand UAH	1,813	1,923	1,831	1,718	97.76

Source: compiled by the author on the basis of Agricultural Company "Nadiya VP" LLC (n.d.)

As can be seen from Table 2, the figures in which were calculated using formulas 2-4, the financial position of Agricultural Company "Nadiya VP" LLC in 2021-2024 was characterised by fluctuations and a deterioration in key indicators after 2021. In 2021, the company made a profit of UAH 19.1 million with a profitability level of 22.44%, in 2022 the activity became unprofitable (UAH -40.4 million), and in 2023 the unprofitability remained (UAH -36.8 million). In 2024, there is a decrease in the loss to UAH -14.5 million, which indicates a partial improvement in financial results. The capital structure has changed. Equity decreased from UAH 94.7 million in 2021 to UAH 6.9-7.8 million in 2023-2024, which led to a decrease in the autonomy coefficient to a critically low level (0.02-0.03). The coefficient of financial dependence increased to 0.97-0.98, which indicates the dominance of borrowed sources of financing. Asset efficiency also declined: the return on assets indicator changed from 5.82% in 2021 to negative values in subsequent years. Despite the increase in revenue in 2024 to UAH 100.5 million, this did not lead to a recovery in profitability, which reflects an increase in costs or a decrease in operational efficiency. The dynamics of income per employee also indicate a decrease in productivity in 2024. Thus, the financial condition of the enterprise in the study period is characterised by a transition from profitable to unprofitable activities, a decrease in financial

stability and an increase in dependence on attracted funds, which indicates the need to review approaches to managing financial resources and capital structure.

Comparative analysis shows differences in the financial condition of the enterprises under study. Following a loss-making 2022, Cygnet Agrocompany demonstrated a return to profitability and revenue growth to UAH 1.9 billion in 2024, whereas Agricultural Company "Nadiya VP" LLC remained loss-making in 2022-2024, despite an increase in revenue to UAH 100.5 million in 2024. The level of financial stability also varies: Cygnet-Center's autonomy ratio in 2024 stood at 0.49, whereas that of Agricultural Company "Nadiya VP" LLC was just 0.03, indicating differing levels of reliance on borrowed capital. Performance indicators confirm this trend: Cygnet Agrocompany's return on sales reached 12.7%, while Agricultural Company "Nadiya VP" LLC maintained a negative return (-21.15%). Thus, the results of the analysis reflect the higher adaptive capacity and financial stability of a large diversified enterprise compared to an enterprise whose activities are characterised by a limited scale and higher dependence on external factors.

A comparison with a study by L. Vilani *et al.* (2024) allowed moving from analysing the actual financial condition to a broader understanding of the role of risk in economic decision-making. While in this study, financial indicators were used to record the consequences of the influence of military factors on the activities of enterprises, L. Vilani *et al.* integrated risk directly into the process of evaluating investment projects through a combination of discounted cash flows, Monte Carlo modelling, and real options analysis. This approach focused on forecasting and scenario variability, while in this study, risks were manifested after the fact due to fluctuations in liquidity, profitability, and access to financial resources. Accordingly, the differences were determined not only by methodological tools but also by the time logic of the analysis: long-term modelling was contrasted with short-term assessment in conditions of limited managerial flexibility.

This difference in approaches was logically deepened when compared with the publication of F.U. Khan *et al.* (2024), where financial constraints were considered at a generalised level. Their publication formed a systematic view of funding barriers – from collateral to information asymmetry – which allowed outlining the institutional prerequisites for access to resources. Instead, in this study, these limitations took on a specific dimension due to changes in the financial performance of enterprises in military conditions. Thus, while F.U. Khan *et al.* developed a conceptual framework, this study reflected its practical implementation in conditions of increased uncertainty. Further comparison with I. Prigoreanu *et al.* (2025) shifted the focus from individual businesses to the sector level. The use of integrated indicators based on the Farm Accountancy Data Network in the European context allowed the authors to assess economic sustainability through the structural characteristics of agricultural production. In this study, similar categories – liquidity, profitability, and cash flows – were analysed at the micro level and reflected the impact of military factors on financial results. The difference in the scale of the study also led to a difference in the results: in the European context, relative stabilisation was observed, while in this case, the variability of indicators dominated.

In this context, F.J. Castillo-Díaz *et al.* (2025) expanded the analysis in the direction of combining finance and technological transformation. The authors focused on the investment challenges of implementing sustainable technologies in European policy, which formed the long-term logic of development. In contrast, in this study, financial resources were considered as a limitation of current activities, which was manifested due to the instability of indicators and changes in the cost structure. The European approach reflected investment reorientation, whereas this study recorded the adaptation of enterprises to the crisis environment. A similar logical difference was also observed when compared with a paper of R. Pérez-Vas *et al.* (2024), where risk was an element of assessing the value of an investment project. The use of the real options method allowed considering the flexibility of management decisions and the variability of the environment. In the present study, these factors were not modelled, but reflected in the actual dynamics of financial results, which highlighted the difference between the predictive and diagnostic functions of the analysis.

A comparison with a study by Y. Sorroche-del-Rey *et al.* (2025) clarified a shift in focus from financial results to environmental aspects of the agri-food sector. This study analysed the determinants of emissions and the role of international trade, which formed a different dimension of performance evaluation. However, in this study, financial indicators remained central, reflecting the impact of military restrictions. Common to both approaches was the consideration of external factors, but their interpretation was different: in the first case – due to the environmental consequences of economic activity, in the second – due to the financial stability of enterprises in times of crisis. A comparison of enterprises demonstrates differences in the ability to adapt to changes in the external environment. A diversified business structure and the availability of processing and storage infrastructure ensure more stable financial results for a single enterprise. Another company is characterised by a higher dependence on external factors and instability of financial indicators. This reflects the impact of the scale of operations, resource structure, and level of diversification on the formation of the financial condition.

Directions for strengthening the financial condition of agricultural enterprises

The use of state and market mechanisms of financial support for agricultural enterprises in 2022-2025 was formed in the context of military risks, limited access to financial resources, disruption of logistics chains, and increased production costs. Under such conditions, providing liquidity, maintaining the production cycle, and financing seasonal work became possible due to a combination of budget support tools and market mechanisms for raising capital. State policy during this period was focused on expanding access to financial resources for micro-, small, and medium-sized agricultural enterprises, in addition to supporting production in frontline and de-occupied regions.

The key instrument of state financial support was the "Affordable loans 5-7-9%" programme, which provided

concessional lending to agricultural enterprises with partial interest rate compensation. In 2024, 8,750 agricultural enterprises were financed under this programme for a total amount of UAH 46.9 billion, which accounted for a significant share of the total volume of lending to the sector. The requirements for borrowers were adapted to wartime conditions and provided for simplified assessment procedures, the possibility of obtaining loans without collateral for small amounts and the use of state guarantees for large amounts of financing (Ukrainian farmers received..., 2025).

Along with credit instruments, grant programmes were used, in particular, "eWork" and "Own business" (Ministry of Economy of Ukraine, 2025), which enabled the provision of financial assistance in the amount of UAH 50 thousand to UAH 500 thousand to create jobs and develop business activities. The budget of these programmes reached UAH 16 billion, covering a substantial number of business entities, including the agricultural sector. In addition, subsidy and compensation mechanisms were implemented to support animal husbandry, land cultivation, and restore production potential in the affected regions. Specifically, a compensation of 25% of the cost of agricultural machinery and financing of land demining (about UAH 1 billion) contributed to reducing investment costs and restoring production (Committee on Agricultural and Land Policy, 2024).

A major role in providing financial resources was played by bank lending, which, despite military risks, showed growth. In 2024, the total volume of lending to the agricultural sector amounted to UAH 104.5 billion, and in 2025, the loan portfolio reached UAH 142 billion. The share of the agricultural sector in total corporate lending was about 14%, which indicates its importance for the banking system. Soft loans accounted for up to 40-50% of the loan portfolio of agricultural enterprises during peak periods, which reflects a high level of dependence on state support. Of the total loan portfolio of UAH 142 billion, approximately UAH 83 billion was provided by leading banking institutions, particularly Oschadbank, PrivatBank, and Raiffeisen Bank. The rest of the financing was provided by PUMB and ProCredit Bank. This means that about 58% of the market is concentrated among the leading financial institutions that determine key lending parameters, in particular the level of interest rates, collateral requirements, and approaches to assessing credit risks. PUMB is one of the largest banks in Ukraine in terms of assets: as of the beginning of 2026, their size amounted to UAH 231 billion, and net profit – UAH 8.05 billion. The concentration of lending to the agricultural sector in large universal banks indicates the integration of agricultural finance into the mass banking segment and increased competition between banks for solvent borrowers (InVenture, 2026).

Directions for improving the efficiency of using financial resources of agricultural enterprises in the context of military risks are associated with optimising the financing structure, diversifying capital sources, and implementing financial risk management tools. The results of the analysis show that enterprises with different scales of activity have excellent opportunities for access to financial resources, which determines the need for a differentiated approach to the formation of financial management mechanisms. For enterprises like Cygnet Agrocompany (n.d.), the activities of which are characterised by a diversified production structure, availability of storage, and processing infrastructure, along with a stabilisation of financial results after the crisis period, it is advisable to expand the use of market financing instruments. In particular, increasing the share of forward contracts in the structure of product sales allows ensuring the predictability of cash flows and reducing dependence on short-term lending. In conditions where the share of sales under forward contracts can reach 40-50%, the formation of a portfolio of such contracts with different delivery dates creates opportunities for balancing the risks of price volatility. It is advisable to expand the use of factoring operations that accelerate capital turnover and reduce accounts receivable.

Optimisation of the capital structure involves reducing dependence on short-term borrowed funds and increasing the share of equity financing. For large businesses, this can be achieved by reinvesting profits and using long-term financing tools, including investment loans and leasing programmes. In the case of Cygnet Agrocompany, this will allow maintaining the level of financial stability and ensuring further updating of the material and technical base without increasing financial risks. For businesses with limited financial resources, such as Agricultural Company "Nadiya VP" LLC (n.d.), the priority area is to increase access to state financial support programmes and optimise the use of available resources. Given the high level of financial dependence and negative profitability, it is advisable to actively use concessional lending under the "5-7-9%" programme, which reduces the cost of attracting resources and stabilises cash flows. Thereby, it is important to make use of grant schemes to fund specific areas of activity that do not require repayment and can be directed towards upgrading equipment or implementing technological solutions.

A separate area is the introduction of cost management tools, which provides for optimising the structure of production costs and improving the efficiency of resource use. Given the high share of material costs in the cost of production, it is advisable to use elements of operational planning that allow predicting the need for resources and minimising the impact of price fluctuations. For smaller businesses, this may also include working with other manufacturers to reduce the cost of purchasing material and technical resources.

Wartime conditions also necessitate the development of a financial risk management system. The use of insurance instruments, agricultural receipts, and diversification of product sales channels can reduce the impact of external factors on financial results. For large enterprises, it is advisable to form a comprehensive risk management system, while for small enterprises, it is advisable to use affordable tools that provide a basic level of financial security. The generalisation shows that improving the efficiency of financial management of agricultural enterprises in the context of military risks should be based on a combination of state and market financing instruments, optimising the capital structure, and implementing risk management mechanisms. The level of effectiveness of these measures is determined by the scale of enterprises' activities, their resource potential and ability to adapt to changes in the external environment.

A comparison with a study by N. Hani *et al.* (2025) allowed drawing general attention to the financial constraints of the agricultural sector, but approaches to their interpretation differed. Within the framework of this study, the financial condition of enterprises was assessed through a system of quantitative indicators of liquidity, profitability, and access to lending under military restrictions, providing for recording actual changes in financial results. N. Hani *et al.* considered financial barriers in a broader analytical field, forming a generalised model of restrictions that covered credit and institutional factors. While in the work of researchers, financial constraints acted as a conceptual category; in the current study, they were manifested due to fluctuations in specific financial indicators of enterprises. This difference in generalisation levels was even more pronounced when compared with the approach described by R.M. Yusoff *et al.* (2025), where attention was shifted from restrictions to conditions for the development of agricultural entrepreneurship. In their study, financial resources, the institutional environment, and management competencies were considered as factors for growth and efficiency gains. In turn, in the presented study, the same factors took on a different meaning – they reflected the limitations of the functioning of enterprises, which were manifested due to the instability of liquidity, profitability, and cash flows during the war period. Accordingly, in a paper of R.M. Yusoff *et al.*, the long-term developmental perspective dominated, while the current analysis focused on short-term adaptive changes.

A similar logic was observed when comparing with the findings of Z. Othman *et al.* (2024), where the emphasis was placed on the entrepreneurial and organisational prerequisites for the efficiency of the agricultural sector. In this case, resource provision and access to finance were interpreted as the basis for development, while in this study, these same factors were the reasons for the variability of financial indicators. Thus, the difference was not only in the methods but also in the functional interpretation of the same economic categories. Further comparison with a study by C.D. Osei & J. Zhuang (2024) expanded the understanding of differences through level analysis. Financial mechanisms were considered by the authors at the macro level as an element of institutional policy and long-term development, while the assessment was conducted at the micro level in this study, where these mechanisms were manifested through changes in the financial condition of specific enterprises. As a result, financial resources were in one case a tool for development, and in the other – a factor sensitive to external constraints.

This contrast was supplemented by the results of I. Nassim & B. Benraïss (2024), who investigated the impact of capital structures and government subsidies on the financial performance of enterprises using econometric models. Financial parameters were analysed by the researchers as factors of profitability formation, while in this study, they reflected the consequences of military risks and restrictions on access to resources. While I. Nassim & B. Benraïss established causal relationships between the structure of funding and performance, this paper recorded the dynamics of indicators in an unstable environment. A comparison with a study by S. Shariff *et al.* (2025) summarised the identified differences. In this case, the analysis was performed based on a systematic review of the literature, identifying typical problems of the agricultural sector, such as labour shortages, ageing farmers, and limited adoption of technologies. In this study, similar factors were not generalised, but reflected through their impact on the financial results of enterprises. Therefore, S. Shariff *et al.* outlined a generalised picture of structural changes, and in this study, these processes were manifested at the level of financial indicators in military conditions.

The functioning of agricultural enterprises in 2022-2025 was determined by a combination of state and market financing mechanisms under military restrictions. Ensuring liquidity and continuity of production was made possible by expanding access to financial resources and adapting support tools to crisis conditions. Nonetheless, dependence on external sources of financing and the impact of risks led to the variability of financial results of enterprises. Improving the efficiency of financial management is associated with diversifying sources of financing, optimising the capital structure, and implementing risk management tools.

▸ Conclusions

The study generalised the features of the formation of the financial condition of agricultural enterprises in Ukraine in wartime conditions and determined the relationship between macroeconomic changes, resource support, and the results of enterprises' activities. The analysis showed that in 2021-2024, the share of the agricultural sector in GDP decreased from 10.89% to 7.11%, that is, by 3.78 percentage points, which reflects a reduction in the industry's contribution to the economy. The volume of agricultural production decreased from UAH 1.344 trillion in 2021 to UAH 1.004 trillion in 2022 (-25.3%), followed by a partial recovery to UAH 1.115 trillion in 2023 and a repeated decline to UAH 1.078 trillion in 2024, indicating instability in financial results.

The sector's financial performance shows significant variability. In 2022, the income of agricultural enterprises amounted to UAH 796 billion with a profit of UAH 88.6 billion, in 2023 the income increased to UAH 920.9 billion, but the profit decreased to UAH 6.8 billion, while in 2024, there was a sharp increase in income to UAH 2.4 trillion and profit to UAH 327 billion, with an average profitability of about 13.6%. This reflects changes in the cost-income ratio and the adaptation of enterprises to new conditions. In the same period, production costs remain high: up to 30-32 thousand UAH per 1 ha, and the total need for financing spring field work in 2025 is estimated at UAH 210-220 billion. The results of the study confirm the significant role of lending: in 2024, 13,088 enterprises attracted UAH 104.5 billion, while in 2025, more than 9,282 enterprises received more than UAH 60 billion in loans. A significant share of financing is provided by state programmes, which affects the capital structure of enterprises. Nonetheless, losses in the agricultural sector exceeded USD 80 billion, of which USD 10.3 billion were direct losses of assets, and the reduction in production reached about 40%, which determines the decline in financial stability.

Micro-level analysis demonstrated a differentiation of the financial condition of enterprises. Cygnet

Agrocompany, after a loss in 2022 (UAH -272 million), restored profitability to UAH 241.1 million in 2024, while revenue grew to UAH 1.9 billion and profitability increased to 12.7%. Instead, Agricultural Company "Nadiya VP" LLC remained unprofitable in 2022-2024 (UAH -14.5 million in 2024), with a decrease in the coefficient of autonomy to 0.02-0.03, which indicates a critical dependence on borrowed capital. The financial condition of agricultural enterprises is determined by a combination of military losses, resource dependence, access to credit, and the scale of activity. Large diversified enterprises show a higher ability to adapt, while small farms are characterised by greater financial instability. This confirms the need to combine state and market financing instruments, optimise the capital structure, and develop risk management mechanisms as conditions for stabilising the sector's activities.

The limitation of the study was the use of mainly open statistical and financial data, which limited the possibility of considering the full detail of internal financial processes of enterprises in wartime conditions. Prospects for further research include expanding the empirical base through microdata of enterprises and applying economic and mathematical modelling to assess scenarios for strengthening the financial stability of the agricultural sector.

Acknowledgements
None.

Funding
None.

Conflict of interest
None.

References
[1] Agricultural Company "Nadiya VP" LLC. (n.d.). Retrieved from https://opendatabot.ua/c/13576121.
[2] Castillo-Díaz, F.J., Belmonte-Ureña, L.J., Gálvez-Sánchez, F.J., & Camacho-Ferre, F. (2025). Sustainable technological innovations in agriculture: Financial challenges and investment priorities under the European Green Deal. *Journal of Environmental Management*, 389, article number 126150. doi: 10.1016/j.jenvman.2025.126150.
[3] Committee on Agricultural and Land Policy. (2024). *Recommendations of the committee hearings on the topic: "State support for the agricultural sector 2024. State and non-state funds and mechanisms"*. Retrieved from https://komagropolit.rada.gov.ua/documents/sluhannja/75427.html.
[4] Cygnet Agrocompany. (n.d.). Retrieved from https://latifundist.com/kompanii/292-signet-holding.
[5] Dardona, Z., Amane, M., & Boussaa, S. (2025). Assessing the effects of 2023-2024 conflict on food security, dietary habits, and nutritional well-being among the population of Gaza. *Discover Public Health*, 22, article number 373. doi: 10.1186/s12982-025-00761-w.
[6] Dyvnych, O., & Martynyuk, M. (2023). Management of land use of agricultural enterprises in wartime conditions: Innovative trends. *Journal of Innovations and Sustainability*, 7(4), article number 10. doi: 10.51599/is.2023.07.04.10.
[7] Global Economy. (n.d.). *Ukraine: GDP share of agriculture*. Retrieved from https://www.theglobaleconomy.com/Ukraine/share_of_agriculture/.
[8] Hani, N.M., Romli, N., Yusof, M.F., Zainuddin, N.H., Bhari, A., & Hussin, M.Y. (2025). Successful factors of agricultural entrepreneurship in Malaysia. *International Journal of Research and Innovation in Social Science*, 9(2), 1337-1351. doi: 10.47772/IJRISS.2025.9020108.
[9] Hassoun, A., Al-Muhannadi, K., Hassan, H.F., Hamad, A., Khwaldia, K., Buheji, M., & Al Jawaldeh, A. (2024). From acute food insecurity to famine: How the 2023/2024 war on Gaza has dramatically set back sustainable development goal 2 to end hunger. *Frontiers in Sustainable Food Systems*, 8, article number 1402150. doi: 10.3389/fsufs.2024.1402150.
[10] Institute of Agricultural Economics. (2025). *Sowing 2025. How many resources are needed – Interview with Oleksandr Zakharchuk for the Internet resource "AgroPerspektiva"*. Retrieved from http://www.iae.org.ua/presscentre/massmedia/4060-posivna-2025-skilky-treba-resursiv-intervyu-oleksandra-zakharchuka-ahro-perspektyvi.html.
[11] InVenture. (2026). *Banks increased lending to the agricultural sector of Ukraine to UAH 142 billion*. Retrieved from https://surl.li/qbxxmf.
[12] Khan, F.U., Nouman, M., Negrut, L., Abban, J., Cismas, L.M., & Siddiqi, M.F. (2024). Constraints to agricultural finance in underdeveloped and developing countries: A systematic literature review. *International Journal of Agricultural Sustainability*, 22(1), article number 2329388. doi: 10.1080/14735903.2024.2329388.
[13] Kostyrko, L., Solomatina, T., Kostyrko, R., Zaitseva, L., & Chernodubova, E. (2024). Comprehensive risk analysis as a tool for choosing the financial strategy of agricultural enterprises in conditions of uncertainty: Methods, assessment, audit. *Financial and Credit Activity: Problems of Theory and Practice*, 5(58), 207-224. doi: 10.55643/fcaptp.5.58.2024.4586.
[14] KyivAudit. (2021). *Independent Auditor's Report on the Financial Statements of LIMITED LIABILITY COMPANY "SIGNET-CENTER" as of December 31, 2021*. Retrieved from https://cygnet.ua/wp-content/uploads/2023/04/zvit-nezalezhnogo-audytora-z-prymitkamy-signet2021.pdf.
[15] KyivAudit. (2022). *Independent Auditor's Report on the Financial Statements of LIMITED LIABILITY COMPANY "SIGNET-CENTER" as of December 31, 2022*. Retrieved from https://cygnet.ua/wp-content/uploads/2023/11/financial-report-of-cygnet-center-for-2022.pdf.
[16] KyivAudit. (2023). *Independent auditor's report on the financial statements of LIMITED LIABILITY COMPANY "SIGNET-CENTER" as of December 31, 2023*. Retrieved from https://cygnet.ua/wp-content/uploads/2024/07/finansovyj-zvit-tov-signet-czentr-2023.pdf.

[17] KyivAudit. (2024). *Independent auditor's report on the financial statements of LIMITED LIABILITY COMPANY "SIGNET-CENTER" as of December 31, 2024*. Retrieved from https://cygnet.ua/wp-content/uploads/2026/03/finansovyj-zvit-tov-signet-czentr-2024.pdf.
[18] Liu, Y., Ji, D., Zhang, L., An, J., & Sun, W. (2021). Rural financial development impacts on agricultural technology innovation: Evidence from China. *International Journal of Environmental Research and Public Health*, 18(3), article number 1110. doi: 10.3390/ijerph18031110.
[19] Lu, Y., & Chen, Y. (2021). Is China's agricultural enterprise growing steadily? Evidence from listed agricultural companies. *Chinese Journal of Population, Resources and Environment*, 19(2), 203-212. doi: 10.1016/j.cjpre.2021.12.022.
[20] Ma, Q., & Li, X. (2025). The impact of fiscal-financial synergistic support for agriculture on agricultural total factor productivity: Based on provincial panel data in China. *International Review of Economics & Finance*, 103, article number 104556. doi: 10.1016/j.iref.2025.104556.
[21] Ministry of Agricultural Policy and Food of Ukraine. (2025). *Available loans 5-7-9%: 26.8 billion UAH have already been attracted by farmers this year*. Retrieved from https://www.kmu.gov.ua/news/dostupni-kredyty-5-7-9-268-mlrd-hrn-uzhe-zalucheno-ahrariiamy-tsoho-roku.
[22] Ministry of Economy of Ukraine. (2025). *Vlasna sprava: More Ukrainians will be able to receive grants to start or develop a business in 2025*. Retrieved from https://surl.li/njicsy.
[23] Nassim, I., & Benraïss, B. (2024). Capital structure and financial performance of Moroccan agricultural small- and medium-sized enterprises: Moderating effects of government subsidies. *Journal of Risk and Financial Management*, 17(7), article number 256. doi: 10.3390/jrfm17070256.
[24] Negoda, Y., & Konyukhov, D. (2025). Assessment of financial security of investment activities of agricultural enterprises. *Economy and Society*, 78. doi: 10.32782/2524-0072/2025-78-1.
[25] Oliinyk, N., & Lyzhenkova, T. (2024). Profitability of enterprise in the conditions of wartime: Threats and opportunities. *Social Economics*, 68, 193-211. doi: 10.26565/2524-2547-2024-68-19.
[26] Osei, C.D., & Zhuang, J. (2024). The effects of institutional supports on farm entrepreneurial performance: Exploring the mediating role of entrepreneurial orientation. *SAGE Open*, 14(1). doi: 10.1177/21582440241227713.
[27] Othman, Z., Shahzad, A., & Ramalu, S.A. (2024). Environmental, technical, and resources challenges facing agroforestry: A case of sustainable land management in Malaysia. *Journal of Intercultural Communication*, 24(1), 64-76. doi: 10.36923/jicc.v24i1.633.
[28] Pérez-Vas, R., Hervés-Estévez, J., Garza-Gil, M.D., & Fernández-González, R. (2024). Valuation of an innovative investment project using real options approach: A case study of a viticulture company in Spain. *Agricultural Economics – Czech*, 70(2), 91-100. doi: 10.17221/299/2023-AGRICECON.
[29] Prigoreanu, I., Radu, G., Grigore-Sava, A., Costuleanu, C.L., Ungureanu, G., & Ignat, G. (2025). Assessing the economic sustainability of the EU and Romanian farming sectors. *Sustainability*, 17(10), article number 4440. doi: 10.3390/su17104440.
[30] Shariff, S., Baharudin, S.A., & Ismail, N.A. (2025). A systematic review of the challenges and opportunities of the agriculture economic sector in Malaysia. *Information Management and Business Review*, 17(1), 285-303. doi: 10.22610/imbr.v17i1(I).4350.
[31] Shovkun-Zablotska, L., Pysarenko, V., Sierova, L., & Tegipko, S. (2024). Management and marketing of the wartime agribusiness in Ukraine. *Economics, Entrepreneurship, Sustainability*, 8, 64-77. doi: 10.61954/2616-7107/2024.8.1-6.
[32] Sikachyna, O., & Gagalyuk, T. (2025). *Farm structure in Ukraine: Analytical review in the context of European integration. German-Ukrainian Agricultural Policy Dialogue*. Retrieved from https://surl.li/shygme.
[33] Sobchenko, M. (2025). Assessment of the internal potential of analytical and forecasting support for the management of financing in agricultural enterprise development. *Economics of Systems Development*, 7(2), 125-134. doi: 10.32782/2707-8019/2025-2-18.
[34] Sorroche-del-Rey, Y., Piedra-Muñoz, L., Galdeano-Gómez, E., & García-Granero, E.M. (2025). Determinants of pollutant emissions in the Spanish agrifood sector: The role of international trade. *Agricultural Economics – Czech*, 71(3), 130-141. doi: 10.17221/353/2024-AGRICECON.
[35] Ukraine's agricultural sector profits exceeded pre-war results. (2025). Retrieved from https://agroportal.ua/news/finansy/pributok-agrosektoru-ukrajini-perevershiv-dovoyenniy-rezultat.
[36] Ukrainian farmers received 46.9 billion available loans last year. (2025). Retrieved from https://surl.li/tiuzlv.
[37] Vilani, L., Zanin, A., Lizot, M., Trentin, M.G., Afonso, P., & de Lima, J.D. (2024). A framework for investment and risk assessment of agricultural projects. *Journal of Risk and Financial Management*, 17(9), article number 378. doi: 10.3390/jrfm17090378.
[38] Yu, H., & Liang, Y. (2025). Enhancing agricultural economic resilience in China: A spatio-temporal and multidimensional assessment under compound shocks. *Frontiers in Sustainable Food Systems*, 9, article number 1694106. doi: 10.3389/fsufs.2025.1694106.
[39] Yusoff, R.M., Syed Abdul Kader, S.Z., Arshad, A., Halim, A.H., Rosli, M.R., & Mohd Hafiz, S.M. (2025). A strategic proposal for enhancing Malaysia's economy through national food security initiatives. *Environment-Behaviour Proceedings Journal*, 10(28), 149-154. doi: 10.21834/e-bpj.v10iSI28.6965.
[40] Zhong, X., & Wang, J. (2024). Empowering agricultral economic resilience in China: Does green finance matter? *Advances in Agriculture*, 2024(1), article number 1350399. doi: 10.1155/aia/1350399.

Оцінка фінансового стану аграрних підприємств та шляхи його зміцнення в умовах воєнного часу

Валерій Микитюк
Доктор економічних наук, професор
Поліський національний університет
10008, бульв. Старий, 7, м. Житомир, Україна
https://orcid.org/0009-0009-3567-7795

► **Анотація.** Метою даного дослідження було визначення чинників формування фінансового стану аграрних підприємств України в умовах воєнних трансформацій. Методологія дослідження ґрунтувалася на застосуванні статистичного, порівняльного, структурного та системного аналізу, а також методу кейс-стаді, що дозволило дослідити макроекономічні тенденції, галузеві зміни та фінансові показники окремих підприємств. Результати дослідження показали, що частка аграрного сектору у внутрішньому валовому продукті України знизилася з 10,89 % у 2021 році до 7,11 % у 2024 році (-3,78 %). Обсяг сільськогосподарського виробництва скоротився з 1,344 трлн грн у 2021 році до 1,004 трлн грн у 2022 році (-25,3 %), із подальшими коливаннями на рівні 1,115 трлн грн у 2023 році та 1,078 трлн грн у 2024 році. Дохід аграрних підприємств зріс з 796 млрд грн у 2022 році до 2,4 трлн грн у 2024 році, тоді як прибуток збільшився з 88,6 млрд грн до 327 млрд грн, що відповідає рентабельності близько 13,6 %. Водночас виробничі витрати досягали 30-32 тис. грн на 1 га, а потреба у фінансуванні у 2025 році становила 210-220 млрд грн. Обсяг кредитування у 2024 році склав 104,5 млрд грн (13088 підприємств), тоді як у 2025 році – понад 60 млрд грн (9282 підприємства). Загальні втрати сектору перевищили 80 млрд дол. США, а скорочення виробництва досягло близько 40 %. Висновки дослідження свідчать, що фінансовий стан аграрних підприємств визначається поєднанням ресурсних обмежень, доступу до фінансування та масштабів діяльності, що обумовлює необхідність удосконалення механізмів фінансового забезпечення та управління ресурсами. Практичне значення дослідження полягає у можливості використання його результатів аграрними підприємствами, банками та органами державної влади для оптимізації фінансування і підтримки аграрного сектору України

► **Ключові слова:** ліквідність; рентабельність; грошові потоки; кредитування; капітал; виробництво

ЕКОНОМІКА АПК
Міжнародний науково-виробничий журнал

Том 33, № 1
2026

Відповідальний редактор:
О. Дендебера

Підписано до друку 12.02.2026
Формат 60*84/8
Ум. друк. арк. 8,2
Наклад 100 прим.

Видавництво: Національний науковий центр «Інститут аграрної економіки»
03127, вул. Героїв Оборони, 10, м. Київ, Україна
Тел.: (+38044)258-43-21
E-mail: info@eapk.com.ua
https://eapk.com.ua/uk

EKONOMIKA APK
Scientific and Production Journal

Volume 33, No. 1
2026

Managing editor:
O. Dendebera

Signed to the print 12.02.2026
Format 60*84/8
Conventional Printed Sheet 8.2
Circulation 100 copies

Publisher: National Scientific Centre “Institute of Agrarian Economics”
03127, 10 Heroiv Oborony Str., Kyiv, Ukraine
Tel.: (+38044)258-43-21
E-mail: info@eapk.com.ua
https://eapk.com.ua/en