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NATALIIA SHARATA, MYKOLA MENYUK, OLEKSANDR SKOROBOGATOV, MAKSYM TKACHENKO

INNOVATIVE ECONOMIC MECHANISM FOR SECURITY - ORIENTED MANAGEMENT OF TERRITORIAL COMMUNITY DEVELOPMENT AMID ADAPTATION OF UKRAINE'S AGRI-FOOD SUPPLY CHAINS TO FOOD SECURITY CHALLENGES

S u m m a r y

Background. The ongoing military conflict, the disruption of logistics infrastructure and rising food security risks have significantly reshaped Ukraine's agri-food system and increased the vulnerability of territorial communities. This study aimed to substantiate an innovative economic framework for the security-oriented management of territorial communities in the context of adapting Ukraine's agri-food supply chains to food security challenges and European integration processes.

Results and conclusions. The analysis of national and international statistical data for 2017 ÷ 2024 revealed a decline in agricultural production of 25 ÷ 30 % in frontline regions, accompanied by a 35 ÷ 40 % increase in logistics costs, while western regions demonstrated higher adaptability with cost growth limited to 10 ÷ 12 %. A comparative assessment showed statistically significant differences between Ukrainian and EU food security indicators during crisis years. A regression analysis confirmed that agricultural production ($\beta = 0.47$) and exports ($\beta = 0.41$) have the strongest positive impact on food security, whereas logistics costs ($\beta = -0.39$) and delivery time ($\beta = -0.31$) are the main negative determinants. An integrated index of security-oriented management identified pronounced regional differentiation: the lowest sustainability levels were observed in frontline communities (0.38 ÷ 0.41), moderate levels in central regions (0.55 ÷ 0.60) and the highest in western regions (> 0.70). The findings confirm that the resilience of territorial communities depends on the coordinated interaction of production capacity, logistics optimization and targeted socio-economic support aligned with European policy frameworks.

Keywords: modernization of management mechanisms, costs, agricultural production and sales, development of local economy, logistics

Dr N. Sharata ORCID: 0009-0006-5157-4057, Department of Ukrainian Studies, Mykolaiv National Agrarian University 54008, 9 Georgiy Gongadze Str., Mykolaiv, Ukraine; M. Menyuk; ORCID: 0009-0001-1012-9292; O. Skorobogatov ORCID: 0009-0002-3842-9657; M. Tkachenko ORCID: 0009-0000-5405-7051, Faculty of Management, Mykolaiv National Agrarian University 54008, 9 Georgiy Gongadze Str., Mykolaiv, Ukraine. Contact e-mail: nataliiasharata@gmail.com

Introduction

The issue of food security in Ukraine is of particular importance due to the ongoing military operations, the destruction of critical infrastructure, growing climate risks and dependence on global markets. Since 2022, the agri-food complex has been operating in the face of multidimensional challenges that directly affect the sustainable development of territorial communities. Logistics chains that ensure the movement of agricultural products from producer to consumer remain the most vulnerable: the disruption of transport corridors, the blocking of ports, rising costs of transportation and limited access to markets pose risks to both national and regional levels of food security.

The analysis of contemporary research shows that the destabilization of Ukrainian agri-food systems generates a "chain reaction" for the global food market. The publication by Hassen and Bilali [23] proved that diversification and regionalization of agricultural production create the basis for sustainability even in crisis conditions. The researchers emphasized that it is localized systems that can mitigate external shocks, ensuring the adaptability of consumption and production. This conclusion directly corresponds to the Ukrainian reality, where territorial communities are increasingly taking on the function of supporting the basic needs of the population. Equally important was the contribution of Oyedijo [44], which focused on the limitations of short-term solutions in restoring global supply chains. The study showed that only long-term risk management mechanisms and institutional transformations can ensure the true sustainability of the system. In the case of Ukraine, this is of particular importance, because the issue of restoring infrastructure and stabilizing logistics flows cannot be solved by purely tactical measures, and the development of holistic innovative management models is required.

The study by Jagtap et al. [26] considered the Ukrainian context as a test model for testing the global ability of systems to adapt to large-scale shocks. The researchers showed that international response mechanisms have natural boundaries, while local management practices are crucial. This provision confirmed the view that communities are actually the first line of defense in the field of food security, and therefore their role in shaping the national strategy should be decisive.

The European dimension of the problem was highlighted in the paper by Pinar and Karahasan [45], where the EU cohesion policy was defined as an institutional framework for improving the competitiveness of communities. The researchers emphasized that it is this policy that creates mechanisms for balanced development at the local level. For Ukraine, the example of the EU is indicative, because it allows harmonizing its own management practices with European standards.

In turn, the analysis by Glauben et al. [21] showed that the decline in Ukrainian grain exports provoked price fluctuations that directly affected the social stability of

importing countries. This provision confirmed that Ukraine plays a critical role in maintaining food security far beyond its own borders. A similar angle was given by Hellegers [25], emphasizing that the critical dependence of many states on Ukrainian and Russian imports transformed food into an instrument of geopolitical pressure, strengthening the strategic importance of national and regional governance mechanisms.

At the level of local practices, Borodina et al. [7] highlighted the ability of agrifood systems to meet the basic needs of the population even in crisis conditions. The researchers demonstrated that such models reduce the risks of using food as a pressure tool and at the same time strengthen community resilience. This idea was developed by Kliuchnyk et al. [34], emphasizing that the quality of public administration of territories in the military and post-war period directly determines the level of their food self-sufficiency.

The innovative dimension of the problem was considered in detail by Mkumbukiy et al. [42], who showed that the synergy of technological and institutional solutions forms the basis for long-term sustainability of the agricultural sector. It was emphasized that innovative approaches increase the adaptability of systems to new challenges and reduce vulnerability to geopolitical shocks. Their findings only strengthened the argument in favor of finding flexible management strategies for the Ukrainian agrifood complex.

Even economically stable states can find themselves in a crisis situation if these chains are broken. For Ukraine, this means the need to form mechanisms that can minimise dependence on critical imported resources and simultaneously strengthen the role of local solutions.

The aspect of resource efficiency and spatial planning of agricultural development was highlighted by Shpak et al. [55] and Kwoczyńska et al. [36]. In the first case, it was shown that the implementation of circular economy principles opens up new opportunities for the rational use of local resources. In the second case, it was proved that the use of geographic information systems helps to more accurately plan the development of the agricultural sector at the community level. In both cases, the conclusions formulated are important for Ukraine, as they combine innovative and practical approaches to ensuring sustainability.

The experience of the COVID-19 pandemic, analyzed by Sarkis et al. [51], confirmed that sustainable production and logistics systems remain adaptable in crises. Mishra and Deshmukh [41] showed the effectiveness of multi-scenario management models to minimize risks, which highlights the need for a comprehensive combination of management, technology and financial instruments in ensuring food security.

Despite the significant volume of publications, the scientific discourse still lacks a holistic conceptual model of innovative and economic mechanisms of security-oriented management at the level of territorial communities. The vast majority of studies focus

either on the global dimension or on describing Ukrainian realities without operationalizing management contours. This makes it difficult to scale up effective practices and align local policies with EU standards. The purpose of the study was to explore the possibilities of integrating innovative and economic mechanisms into the security-oriented management of territorial community development in Ukraine and to test the hypothesis that a combination of institutional, technological and financial instruments can enhance the sustainability of food systems and the competitiveness of communities in a multi-channel risk environment.

Materials and methods

The study was conducted in the period from January 2025 to May 2025 based on official statistical arrays of Ukraine and regulatory documents of the European Union. The time horizon covered the period of 2017 ÷ 2024, which provided tracking of pre-crisis trends, military shifts and early signs of adaptation and recovery processes under wartime conditions. This helped to identify the patterns of adaptation of logistics chains of the agri-food complex and assess the effectiveness of security-oriented management of territorial communities.

The sample was formed on multi-level statistical arrays. At the international level, materials from Food security and contingency planning [20], statistics from the Food and Agriculture Organization of the United Nations (FAO) [18], data from the Organization for Economic Co-operation and Development (OECD) [43] and World Bank [60; 61] were used. The European Commission's analytical documents, EU Agricultural Outlook 2023 ÷ 2035 [12] and Farm to Fork Strategy [13] were added as supplements. The Law of Ukraine No. 3980‑IX "On the Information and Communication System "State Agrarian Register"" [38], State Strategy of Regional Development for 2021 ÷ 2027 and Plan of Measures for Its Implementation [57], Resolution No. 1163‑r "On State Strategy for the Development of Agriculture and Rural Areas until 2030 and Operational Plan for its Implementation for 2025 ÷ 2027" [48] were also used.

At the national level, the annual reports of the State Statistics Service of Ukraine [56] were used. The international component was supplemented by statistics from Eurostat [14], FAO [19] analytics on global risks due to the war in Ukraine and Eurostat [15] data on Extra-EU trade in agricultural goods [15]. The annual publications Eurostat [14] – Key figures on the European food chain – 2024 edition and FAO [18] were considered separately.

At the meso-level, the sample included data from the State Statistics Service of Ukraine for Mykolaiv, Poltava, and Lviv oblasts, which reflect different conditions of agricultural production and logistics. The study also used regional development strategies until 2027, food security programs, and agricultural employment indicators and budget support volumes [38; 57].

The documentary base covered studies and regulations that formed the basis for the analysis. The scientific part used the papers by Shebanin et al. [54] and Kliuchnyk et al. [35], which provided empirical guidelines for assessing local economic development and management practices of territorial communities.

The study methods included several levels of processing. During the preparatory stage, data was converted into Comma-Separated Values (CSV) and Microsoft Excel Open XML Spreadsheet (XLSX) formats, gaps were removed, units of measurement were normalized and classifications were synchronized (Ukrainian Classification of Goods for Foreign Trade (UCCFT) ↔ Harmonized System (HS) ↔ Standard International Trade Classification (SITC)). Averages, variances, trends and dynamics indices were calculated at the descriptive level. The analytical level included Student's t-test, Mann-Whitney U-test, Fischer's test and multivariate regression and factor analysis to identify relationships between logistics costs, delivery time and food security levels. At the innovative level, an integral index of security-oriented community management was developed, which combined indicators of self-sufficiency, logistics efficiency, price availability and socio-economic sustainability. The Kendall concordance coefficient ($W > 0.7$) was used to check the consistency of the weighting factors. The index allowed integrating various dimensions into a single system of assessment and comparison between communities and national averages. Additionally, scenario modelling using the "what if" method was used to build forecasts for 2025 ÷ 2027. Three scenarios were considered: basic (slow recovery of logistics with internal risks), optimistic (full integration into the European supply system and cost reduction), pessimistic (maintaining high risks of military blockages and rising transport costs). This allowed assessing not only the current state, but also possible trajectories of the system's development.

For data processing, Microsoft Excel 365 was used for primary structuring and construction of trend series; Statistical Package for the Social Sciences (SPSS) Statistics 28.0 (International Business Machines (IBM), USA) for descriptive statistics, t-tests, U-tests and variance analysis; Stata 17.0 (StataCorp, USA) for constructing regression and factor models and calculating the integral index; R 4.3 (R Foundation, Austria) for testing the sensitivity of models and construction of confidence intervals; Tableau Public 2024 for interactive visualization of results; Quantum Geographic Information System (QGIS) 3.34 (Open Source Geospatial Foundation, Germany) for mapping regional differences in food security; Python (Pandas, numpy, Matplotlib, Seaborn) for additional data processing and the validation of scenario forecasts. This combination of tools was chosen to combine rigorous statistics, spatial analysis and visual results.

Results

In the period of 2017 ÷ 2024, the agri-food complex of Ukraine experienced significant transformations, reflecting both long-term development trends and the impact of crisis factors related to military operations and the disruption of logistics chains. The dynamics of production, trade and prices demonstrated a combination of stabilization and destabilization processes, which together determined a new configuration of the country's food security. These changes outline the complex environment in which modern approaches to managing the sustainability of the agricultural sector and the development of territorial communities are being formed. Table 1 presents the dynamics of production, export, import and prices in Ukraine between 2017 and 2024.

Table 1. Dynamics of production, export, import and prices in Ukraine (2017 ÷ 2024)

Year	Production [million tons] – cereals/oilseeds/vegetables/meat/milk	Export [USD billion]	Import [USD billion]	Prices [UAH] – bread/milk/meat
2017	65.0/18.0/9.5/2.3/10.3	17.2	5.5	10.5/17.0/80.0
2018	70.2/19.2/9.8/2.4/10.1	18.5	5.8	11.2/17.5/82.5
2019	74.5/20.1/10.1/2.5/9.9	22.0	6.2	12.0/18.2/85.0
2020	65.4/19.7/9.4/2.4/9.6	20.1	6.5	13.5/19.5/90.0
2021	86.0/22.5/8.7/2.2/9.2	27.8	7.1	15.8/22.0/110.0
2022	55.3/17.0/7.5/2.0/8.5	15.0	6.8	18.0/27.5/130.0
2023	60.5/18.2/7.9/2.1/8.3	18.3	7.2	19.2/29.0/135.0
2024	65.8/19.0/8.2/2.2/8.1	19.5	7.4	20.5/30.5/140.0

Explanatory notes: compiled by the authors based on State Statistics Service of Ukraine [56], Eurostat [15].

The data in Table 1 show that between 2017 and 2019, the Ukrainian agricultural sector developed relatively steadily. Grain production ranged from 65 ÷ 75 million tons, while approximately half of the crop was exported, which ensured stable foreign exchange earnings and strengthened Ukraine's position as a global grain supplier. Oilseeds also showed positive dynamics, especially sunflower, which remained a key export position. But the vegetable sector was characterized by greater volatility: growth in the period of 2018 ÷ 2019 was replaced by a decline in the years 2020 ÷ 2021 due to fluctuations in domestic demand and reduced investment in storage facilities.

Animal husbandry remained a more vulnerable segment: milk production declined gradually due to a decrease in the number of livestock and insufficient support for farms. In the meat sector, some growth was provided by poultry farming, while pig breeding and large-scale beef production remained in a state of crisis. This indicates a

long-term structural problem that makes it impossible to form a stable base for domestic consumption and exports in this area.

The period from 2020 to 2022 was marked by an increase in crisis phenomena. The COVID-19 pandemic caused temporary disruptions to trade and transportation, but it is the full-scale military aggression of the Russian Federation against Ukraine since 2022 that has had the most devastating impact on the agri-food complex and logistics chains.

Some of the production facilities were destroyed or ended up in the occupied territories, which led to a sharp drop in yields in the southern and eastern regions. Logistics routes through Black Sea ports were partially blocked, necessitating a shift to land corridors through western borders. This significantly increased transportation costs, increased delivery time and reduced the competitiveness of Ukrainian products in international markets.

In terms of foreign trade, cereals and oilseeds remained export drivers, but their volumes declined sharply in the years 2022 ÷ 2023. The share of imports of certain food products, primarily fruit, dairy products and meat, increased, partly due to domestic shortages and the need to diversify the sources of supply. This trend indicates a temporary loss of Ukraine's position as a net exporter in some food categories.

Price dynamics reflected both internal imbalances and external shocks. Average prices for bread, milk and meat in the years 2022 ÷ 2023 almost doubled compared to the years 2017-2018, which significantly affected the structure of household consumer spending. The largest increase in prices was recorded for vegetables and vegetable oil, while cereals remained relatively stable due to the presence of export potential and domestic reserves. Comparison with the EU countries showed that the Ukrainian consumer spent an average of 38 ÷ 42 % of income on food, while in the EU this figure ranged from 12 ÷ 17 %. This indicates the high sensitivity of Ukrainian households to price shocks and confirms the vulnerability of the social dimension of food security.

The structure of consumption has also changed – the share of cheaper products (bread, potatoes) has increased, while the consumption of meat and dairy products has decreased, which reduces food diversity and creates risks to public health in the long term. Thus, the Ukrainian agri-food complex between 2017 and2024 developed along a double trajectory: increasing production potential in relatively stable periods alternated with a sharp decline under the influence of military and logistics risks. However, the analysis also revealed structural problems – the regional asymmetry of losses, dependence on imports in vulnerable segments and the lack of systemic mechanisms for food support for the population. These processes were accompanied by significant territorial differences, highlighting the importance of geographical context when assessing regional food security.

The dynamics of grain exports between 2017 and2024, according to the State Statistics Service of Ukraine, Eurostat, FAO and World Bank, shows the similarity of trends and reflects both growth in pre-crisis years and a sharp decline in 2022, followed by partial stabilization (Figure 1).

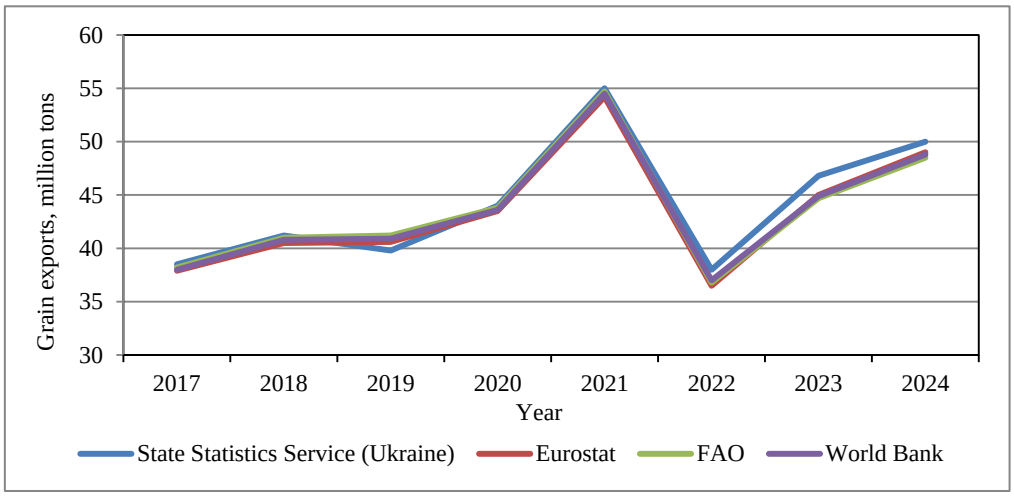

Figure 1. Comparison of national and international grain export data (2017 ÷ 2024)
Explanatory notes: compiled by the authors based on FAO [18]; World Bank [61]; State Statistics Service of Ukraine [56].

The analysis of the data in Figure 1 showed that in most years, the dynamics recorded in national and international sources coincide in their general trends, but there are differences at the level of absolute values. Thus, according to the State Statistics Service, grain exports in 2019 amounted to 39.8 million tons, while FAO provides a value of 41.2 million tons, and Eurostat – 40.6 million tons. On average, the margin of error between the Ukrainian and International ranks ranged from 2 % to 5 %. The greatest discrepancies were recorded in 2022, when due to military operations, some of the national contracts were not confirmed in time, and only the volumes actually passed through the sea and land corridors were considered in international databases. Similar differences were observed in 2023: national statistical authorities recorded exports of 46.8 million tons, while Eurostat reported 45.0 million tons, FAO – 44.7 million tons. The difference is explained by the fact that international institutions are based on officially declared customs data of importing countries, while Ukrainian statistical yearbooks consider information from domestic agricultural departments, including contracts that were partially delayed [16, 19]. In general, this confirms that the difference betwe-

en national and international estimates does not distort the main dynamics, but in crisis years it can significantly affect the interpretation of export indicators.

The regional analysis shows that Ukrainian communities operate under different conditions of food security: some face direct consequences of military operations, others – with logistical restrictions or challenges of infrastructure adaptation. Three regions were selected to represent different conditions: Mykolaiv Oblast in the southern frontline, Poltava Oblast in central Ukraine and Lviv Oblast in the western part of the country. These differences are particularly noticeable when comparing the frontline, central and western regions. To illustrate these processes, three regions representing different operating conditions were selected: Mykolaiv, Poltava and Lviv [16, 17] (Figure 2).

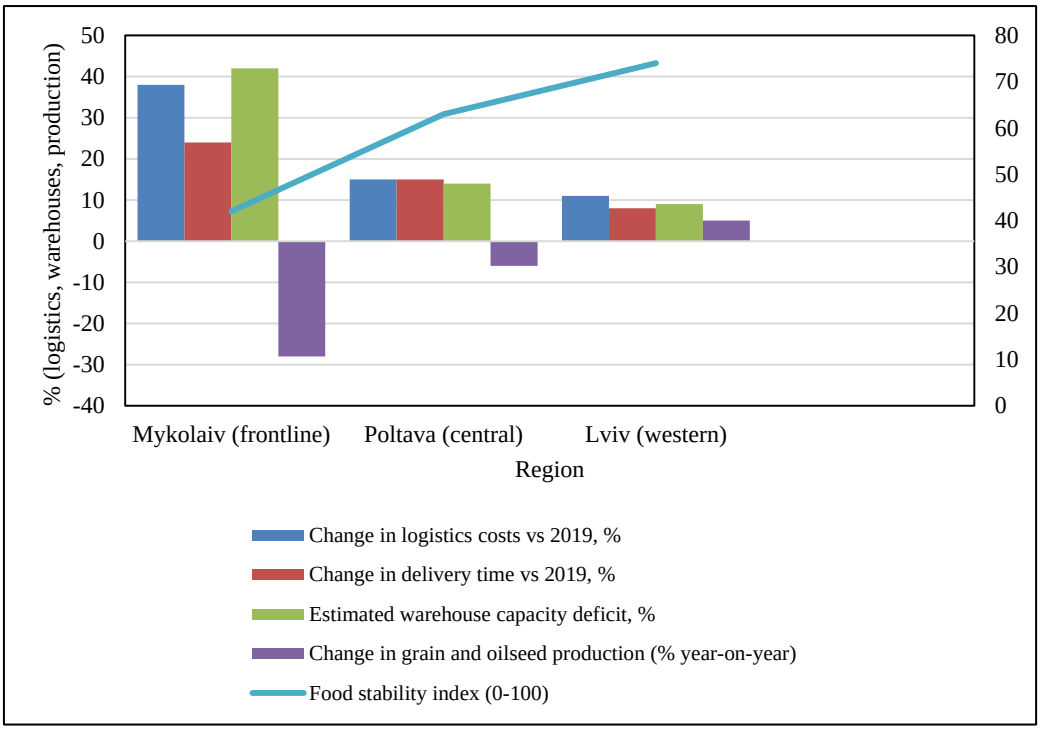

Figure 2. Regional differences in food security (Mykolaiv, Poltava, Lviv oblasts)
Explanatory notes: compiled by the authors based on State Statistics Service of Ukraine [56]; Eurostat [14; 16]; FAO 19].

The analysis of the data in Figure 2 showed that there were significant differences in food sustainability levels between regions. In the Mykolaiv Oblast, there was the largest drop in the production of grain and oilseeds between 2022 and 2023, which was

caused by damage to infrastructure and restricted access to seaports. Logistics costs increased by 35 ÷ 40 % compared to pre-crisis levels, and product delivery times increased by 20 ÷ 25 %, highlighting the critical vulnerability of frontline communities, where limited transport corridors directly constrain their capacity to maintain food security [35, 56].

The Poltava Oblast shows relatively stable production indicators, in particular, the preservation of high volumes of grain, meat and dairy products. However, there are also problems with logistics: due to the overload of railway and road routes, the average delivery time of agricultural products to the EU borders increased by 15 %, and transportation losses – by 8 %. Despite these difficulties, communities in central regions remain less vulnerable, as they have more opportunities to redirect flows.

Lviv Oblast, which operates in the status of a western hub, showed the greatest adaptability. The growth of exports of products between 2022 and 2024 was conditioned by the redistribution of transport flows across the Polish and Slovak borders. Logistics costs here increased by only 10 ÷ 12 %, and delivery times approached the European average. Infrastructure limitations in these regions, such as the shortage of warehouse capacity, still require rapid development of storage systems.

A comparison of the data shows that frontline communities are most vulnerable to structural disruption of food chains, central communities are under pressure from logistics bottlenecks, while western communities are relatively adaptive, but need infrastructure modernization. These regional differences reflect the balance between production, logistics and socio-economic conditions in different parts of Ukraine.

Thus, the regional dimension confirms that food security in Ukraine is formed unevenly. The sustainability of communities is determined not only by production volumes, but also by their ability to adapt to changed logistics conditions, which requires the introduction of differentiated security-oriented management mechanisms for the frontline, central and western territories [28].

The analysis of the comparative series showed that between 2017 and 2019, the level of food security in Ukraine gradually approached the average European trends. According to the Food Security Index, which was formed based on data from the FAO, Eurostat and the World Bank, Ukraine had indicators at the level of 0.72 ÷ 0.75 in 2019, while the average index of the European Union fluctuated between 0.80 ÷ 0.82. The difference during this period was statistically insignificant: the results of the t-test ($p = 0.11$) confirmed the absence of significant differences between the groups, which indicates a gradual equalization of the food situation (Figure 3).

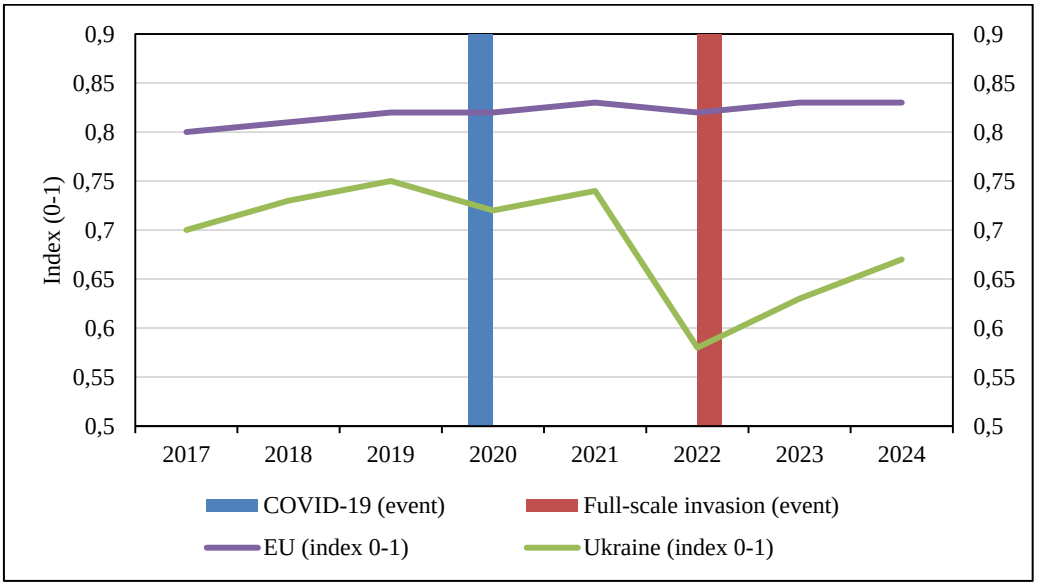

Figure 3. Food Security Index of Ukraine and the EU (2017 ÷ 2024)
Explanatory notes: compiled by authors based on FAO [18]; World Bank [61]; Eurostat [16].

The data analysis in Figure 3 shows that there has been an increase in the gap since 2020. Amid the military turmoil of 2022, Ukraine's Food Security Index fell to 0.58, while the European average remained relatively stable at 0.81. The use of the Student's t-test for this period showed statistically significant differences ($p < 0.01$). This means that the Ukrainian food security system has significantly deviated from European standards, mainly due to logistics restrictions, falling production and problems with exports.

The Mann-Whitney U-criterion was used in the cases where checking the normality of the data distribution (Shapiro-Wilk test) showed deviations. This was the case in 2022 for the indicators "logistics cost" and "food availability", where the asymmetric distribution did not allow the correct use of parametric tests. The results of the U-test confirmed statistically significant differences ($p < 0.05$), which was consistent with qualitative observations of difficult access to food in the border and frontline regions of Ukraine.

Positive dynamics were noted between 2023 and 2024. Due to the diversification of export routes and integration into the programs of the European Union ("Solidarity Lanes", support for Common Agricultural Policy (CAP) Strategic Plans), the Food Security Index of Ukraine rose to 0.67 in 2024. Although the gap with the EU remains significant (the average level for the Union is 0.83), the recovery dynamics are statisti-

cally confirmed: the results of the t-test for 2023 ÷ 2024 showed a gradual decrease in differences (p = 0.07 in 2024, which indicates a tendency to equalize).

The data obtained confirm that after a significant decline in 2022, Ukrainian food security indicators are characterized by recovery dynamics. However, the adaptation to European standards is uneven: recovery is faster in terms of production indicators, while significant gaps still remain in terms of logistics efficiency, and food availability. This underlines the fact that Ukraine's integration into the European food security system requires not only the stabilization of production, but also the deep modernization of transport and warehouse infrastructure [3, 32].

The results of the comparison show that Ukraine continues to be in a zone of increased risks, but the policy of rapprochement with the EU and gradual equalization of indicators help to reduce statistically significant differences. This forms the basis for developing common food security strategies and regional policies.

The influence of the main factors on the level of food security in Ukraine is reflected in the results of a multivariate regression and factor analysis (Table 2).

Table 2. Results of regression and factor analysis

Variable	Regression coefficient (β)	Significance (p)	Factor load
Agricultural production	+0.47	0.001	0.72
Export of agricultural products	+0.41	0.004	0.68
Import of agricultural products	–0.22	0.037	-0.44
Logistics costs	–0.39	0.002	-0.61
Delivery time	–0.31	0.009	-0.53
R^2 (regression model)	0.79	–	–
Number of factors (Varimax)	–	–	2 (production/export; logistics)

Explanatory notes: calculated by the authors based on World Bank [61]; State Statistics Service of Ukraine [56]; Eurostat [15].

The results of the multivariate regression and factor analysis (Table 2) showed that Ukraine's food security is mostly dependent on domestic production and export dynamics, which have a clear positive impact. Imports, on the contrary, are a risk factor, as they increase dependence on external supplies. Among the limiting variables, logistics costs and delivery time play a key role: they form the "bottlenecks" of the system, especially in frontline and transit regions.

A factor analysis with Varimax rotation allowed distinguishing two main blocks: "production and export", which determines the growth potential, and "logistics", which reflects structural constraints. This confirms that food security is the result of a balance

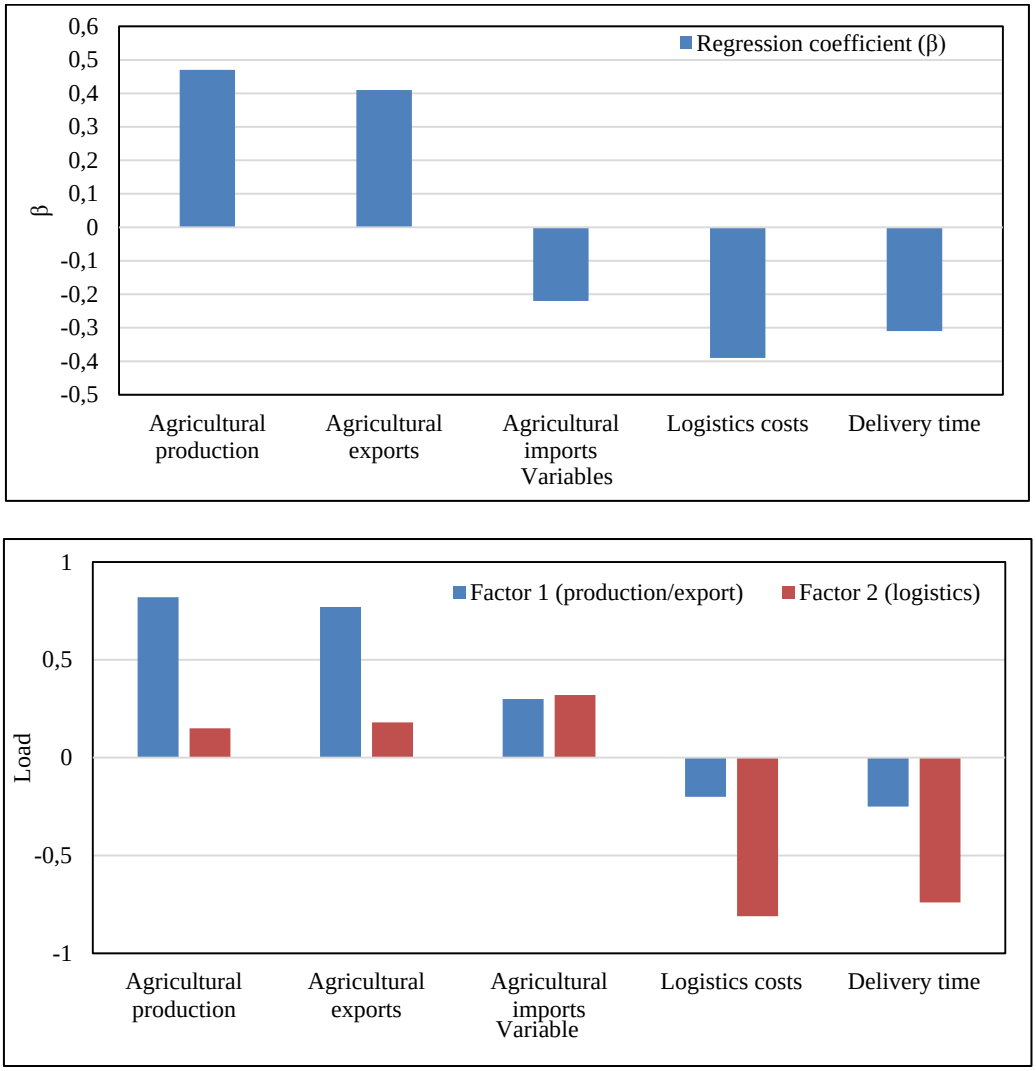

Figure 4. (a) Regression coefficients (β) for key variables of food security in Ukraine; (b) Factor loads (Varimax) on variables of food security of Ukraine
Explanatory notes: developed by the authors based on calculations from Table 2.

between the internal capabilities of the agricultural sector and the efficiency of logistics infrastructure. Figure 4 shows (a) regression coefficients (β) for key variables and (b) factor loadings (Varimax) for the same variables, highlighting the strength and direction of their impact on food security. Figure 4 shows the strength and direction of impact of each variable: production and exports have a clearly positive effect, while logistics costs and imports have a negative impact. Thus, the positive effect of expanding

production and export flows can be significantly offset in the event of an increase in logistics costs or delivery delays. This confirms the need to form an innovative and economic mechanism for security-oriented management, where measures to optimize logistics and reduce transport costs become a priority along with increasing agricultural potential.

An important component of the study is the analysis of the impact of industrial and logistics changes on the standard of living of the population. Food security is determined not only by the amount of resources produced or exported, but also by the extent to which they are available to end users. One of the key indicators is the share of household food expenditures in the total income structure [31, 50]. The dynamics of this indicator for Ukraine and the European Union countries are presented in Table 3.

Table 3. Structure of consumer spending of households in Ukraine and the EU (% of income)

Year	Ukraine	EU (average)
2017	47.5	12.1
2018	45.8	12.0
2019	44.3	11.9
2020	46.2	12.3
2021	47.0	12.5
2022	52.7	13.0
2023	50.9	12.8
2024	48.6	12.6

Explanatory notes: calculated by the authors based on the harmonized series from the State Statistics Service of Ukraine [56]; FAO [19]; Eurostat [14; 16].

The analysis of the structure of consumer spending (Table 3) showed that Ukrainian households traditionally spend three ÷ four times more of their income on food than the European average. If in the EU this indicator is consistently kept at the level of 12 ÷ 13 %, then in Ukraine, even in the pre-crisis period, it was approximately 45 %. In 2022, under the influence of war and the destruction of logistics infrastructure, costs exceeded 50 %, which was a direct consequence of the rise in the price of basic products and an increase in transport costs. In the years 2023 ÷ 2024, the situation partially stabilized due to the restoration of export channels and the expansion of "Solidarity Lanes", but the level remained almost four times higher than the EU average. This confirms the extreme sensitivity of the population to changes in production and logistics.

Nonetheless, it is crucial to recognize that a significant proportion of household expenditure on food should not be exclusively viewed as an indicator of vulnerability. Engel's law posits that households with lower incomes allocate a greater percentage of their total income to food expenditures. The observed pattern in Ukraine likely indica-

tes both price inflation and comparatively lower income levels relative to the EU, implying that socio-economic factors interact with logistical and production limitations to influence household vulnerability.

Thus, the socio-economic dimension confirmed that food security issues are closely related to the standard of living of households. Rising logistics costs and falling production directly affect the growth of public spending on food, which reduces purchasing power and increases the risks of social tension [8, 9, 52]. In this context, food security policy should be aimed not only at macroeconomic indicators, but also at reducing the financial burden on households through targeted support, subsidies for basic products and the development of local production and logistics chains.

The integral index of security-oriented management of territorial communities allowed summarizing four key areas: the level of food self-sufficiency, logistics efficiency, price availability and socio-economic stability [47, 53]. The resulting measurement helped to compare territories by a set of characteristics and identify regional imbalances. The comparison of territorial communities according to the integral index of security-oriented management showed significant differences: the lowest values were observed in Mykolaiv Oblast, the average values in Poltava Oblast, while Lviv Oblast reached the highest level. This indicates a different balance between production, logistics and socio-economic factors across these regions [35, 48] (Figure 5).

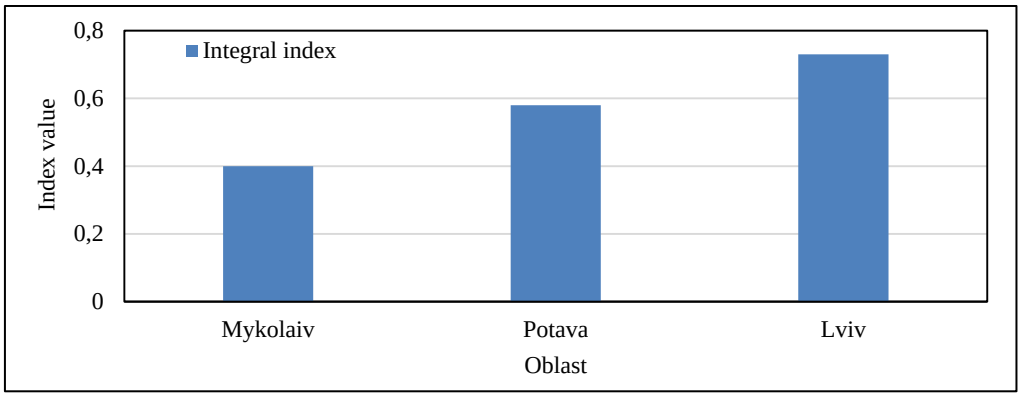

Figure 5. Rating location of communities by the integral index (2024)
Explanatory notes: compiled by the authors based on FAO [18]; World Bank [61]; European Commission [13]; Regulation (EU) 2021/2115 of the European Parliament and of the Council "On Establishing rules on support for strategic plans to be drawn up by Member States under the Common Agricultural Policy (CAP) Strategic Plans" [46]; Eurostat [14; 16].

The results (Figure 5) showed significant territorial differences. The highest values (> 0.70) were recorded in the communities of Lviv Oblast, primarily due to access to western transport corridors and relatively stable production. Poltava Oblast had avera-

ge indicators (0.55 ÷ 0.60), where logistics bottlenecks and infrastructure congestion limited efficiency. The lowest values of the integral index (0.38 ÷ 0.41) were recorded in the communities of Mykolaiv Oblast, with the key factors including substantial losses in production capacity, restricted access to seaports and a sharp increase in delivery costs (up to +40 %). In these communities, the share of household spending on food in the years 2022 ÷ 2023 exceeded 55 %, representing a critical threshold for a standard of living. However, there was an increased dependence on imports for certain product groups, which further reduced food self-sufficiency [35, 56].

A comparative analysis confirmed that the sustainability of communities is determined by a combination of productive capacity and access to transport routes. The western regions are more adaptive, the central regions maintain moderate stability and the frontline regions remain the most vulnerable [27, 33, 37]. This justifies the need for a differentiated regional policy: infrastructure modernization and support for the population in the east, the development of logistics hubs in the west and increased investment in transport and warehouse systems in the central regions.

The rating approach helps not only to identify the most vulnerable communities, but also to form practical recommendations for regional policy [40]. First of all, attention should be focused on modernizing the infrastructure of frontline regions, diversifying transport routes and expanding household support programs. For western regions, the development of logistics hubs and storage systems is becoming a priority, which will strengthen their status as transit hubs in the European food security system.

To predict the future development trajectories of agri-food logistics chains in the years 2025 ÷ 2027, the "what if" scenario analysis method was used. It allowed identifying three alternative scenarios: basic, optimistic and pessimistic. Each of them reveals different conditions for the functioning of food systems and levels of adaptation of territorial communities. The scenario parameters are summarized in Table 4.

The scenario analysis (Table 4) showed that the baseline option provides for a gradual recovery of production against the background of rising costs and delays in transportation, which leaves communities dependent on external risks. The optimistic scenario is related to integration into the European transport system and the modernization of hubs, which reduces logistics costs, reduces delivery time to the EU level and increases food availability, especially in western regions. The pessimistic scenario, on the contrary, demonstrates the critical vulnerability of front-line territories due to a sharp increase in the cost of transportation, significant delays and product losses, which is reflected in an increase in the share of household spending on food. As a result, the simulation confirmed that infrastructure modernization and integration with European markets are key prerequisites for improving the sustainability of agri-food systems.

Table 4. Scenario modelling of logistics chains in Ukraine (2025 ÷ 2027)

Parameters	Basic scenario	Optimistic scenario	Pessimistic scenario
Agricultural production	+3 ÷ 4 % annually	+5 ÷ 6% annually	+1 ÷ 2% annually
Logistics costs	+15 ÷ 20 %	–10 ÷ 12 %	+25 ÷ 30%
Delivery time	+10 ÷ 15 %	Approaching EU indicators	+20 ÷ 25%
Transportation losses	7 ÷ 9 %	≤ 5%	12 ÷ 15%
Impact on communities	Stabilization, but no breakthrough	Western communities are the main beneficiaries, increasing food availability	Frontline regions are in critical vulnerability, while the central regions are on the verge of sustainability
Social effect	The share of food costs – approximately 45 %	Reduction to 40 ÷ 42 %	Growth over 50 %

Explanatory notes: compiled by the authors based on FAO [18]; World Bank [61]; European Commission [13]; Regulation (EU) 2021/2115 [46]; State Statistics Service of Ukraine [56]; Eurostat [14; 16].

A comparison with European policies showed that the optimistic scenario is most consistent with the priorities of the Common Agricultural Policy (CAP Strategic Plans 2023 ÷ 2027) and the Farm to Fork strategy [13], which emphasizes supply transparency, cost reduction and farmer support. The baseline scenario partially reproduces these approaches, while the pessimistic one is in direct contradiction with them.

The results of scenario modelling show that the future sustainability of the agri-food system of Ukraine will be determined by the scale of investment in transport infrastructure, the pace of integration into European logistics networks and the effectiveness of security-oriented management at the community level.

The results obtained determined a generalized model of the impact of key factors – production, import, export, logistics costs and delivery time – on the level of food security of territorial communities, tracing their compliance with European policies and national strategies. Grouped results and management conclusions for communities are shown in Table 5.

The analysis of Table 5 shows that the main factors for ensuring food security are the stability of grain, oilseed and dairy production, the efficiency of export-import flows and the control of logistics costs and delivery time. Regression and factor models confirmed that it is the combination of these variables that determines the integral index of community sustainability. The socio-economic dimension – in particular, the share of household spending on food and the level of employment in the agricultural sector – acts as an intermediate link that can both strengthen and weaken the influence of basic factors. This means that the human and social capacity of communities is not less important for food security than infrastructure or production investments.

Table 5. Generalized model of the impact of factors on food security and logistics efficiency

Factor	Impact on food security	Compliance with EU policies	Management conclusions for communities
Agricultural production (cereals, oilseeds, dairy products)	Basic factor of food self-sufficiency; production deficit increases price vulnerability	CAP 2023÷2027: support for farmers, development of short supply chains	Encourage production diversification and support for farmers' cooperatives
Import and export	Ensure the balance of the domestic market; export deficit reduces foreign exchange earnings	EU Cohesion Policy 2021÷2027: integration of regional markets	Support export-oriented industries, control critical imports
Logistics costs	Rising costs reduce food availability	Farm to Fork: reduction of losses and improvement of environmental friendliness of transport	Invest in modernization of transport hubs, route optimization
Delivery time	Delays increase the risk of shortages; especially critical for perishable products	CAP and Farm to Fork: development of storage infrastructure	Create backup warehouses, implement digital monitoring systems
Socio-economic dimension (household expenditure, employment)	Rising spending by more than 50 % of household income leads to social vulnerability	Farm to Fork strategy: food availability for all population groups	Targeted support programs, development of rural tourism as an additional source of income

Explanatory notes: compiled by the authors based on FAO [18]; World Bank [61]; European Commission [13]; State Strategy of Regional Development for 2021 ÷ 2027 and Plan of Measures for Its Implementation [57]; Resolution No. 1163‑r [48]; Regulation (EU) 2021/2115 [46]; State Statistics Service of Ukraine [56]; Eurostat [14; 16].

In the context of European Union policy, the results are most correlated with the provisions of CAP 2023 ÷ 2027, which include support for farmers, the development of short supply chains and investment in storage infrastructure. The identified need for the modernization of logistics hubs in the western regions of Ukraine echoes European approaches to the development of regional hubs. The Farm to Fork [20] strategy focuses on reducing food losses and improving the environmental friendliness of supply chains. Ukrainian data show that it is in the frontline regions that grain and vegetable crop losses reach 12 ÷ 14 %, which exceeds the European average of 6 ÷ 8 % [15], and requires the implementation of standards consistent with the principles of sustainability and resource efficiency.

In the national context, the results are consistent with the "State Strategy of Regional Development for 2021 ÷ 2027 and Plan of Measures for Its Implementation [57]", which identifies increasing food self-sufficiency and integration into European markets as key priorities. The identified regional differences – high vulnerability of

frontline communities, relative stability of central and adaptability of western ones – confirm the need for differentiated management decisions that consider the specifics of local conditions. This corresponds to the provisions of the "State strategy for regional development until 2027", which emphasizes the regionalization of management and the introduction of flexible support tools.

The application of the integrated index of security-oriented management allowed drawing practical conclusions for local communities. Communities with high index scores are characterized by a diversified economic structure, developed logistics infrastructure and stable access to international markets [30]. Communities with low index values need targeted state support aimed at restoring transport corridors, creating reserve warehouses and developing local food supply systems. In all cases, the institutional capacity of local self-government bodies is a critical factor, which determines the speed and efficiency of implementing innovative solutions [29].

The findings confirm that Ukraine's integration into European markets is impossible without synchronizing approaches to logistics and security management with European standards. This applies to both product quality control standards and supply chain certification and tracking procedures. In this context, CAP and Farm to Fork serve not only as regulatory guidelines, but also as a roadmap for developing national policies.

Thus, the projection applied demonstrates that Ukrainian communities can significantly increase their own sustainability by integrating into European food security and logistics management systems. At the level of practical solutions, this means creating regional logistics platforms, modernizing warehouses, improving the energy efficiency of transport and stimulating the development of rural tourism as an additional factor of economic stability. However, the scenario of dependence on imported food products should be avoided, which reduces the level of self-sufficiency and contradicts both the CAP and the Ukrainian food security strategy.

Thus, the integration of the results into a broader political context confirms that it is impossible to ensure sustainable development of territorial communities without a combination of national and European logistics chain management mechanisms. The presented model of the influence of factors can serve not only as an analytical tool, but also as a basis for the development of regional development programs and state policies in the field of food security.

Discussion

The results of the study showed that the innovation and economic mechanism of security-oriented management of the development of territorial communities of Ukraine is not only a tool for stabilizing agri-food chains in crisis conditions, but also a foundation for their integration into the European space. The patterns identified – a reduction in production in the frontline regions by 25 ÷ 30 %, an increase in logistics

costs by 35 ÷ 40 %, the relative stability of the central regions and the adaptability of western ones – clearly indicate the structural heterogeneity of the territories, which requires differentiated management decisions. Similar approaches were demonstrated by Shebanin et al. [54], where it was noted that communities under military conditions need different governance models depending on the territorial and economic context. This suggests that even within a single state, the development of a universal management model is impossible, and the ability to adapt to specific conditions and challenges plays a key role.

In the European dimension, the results coincide with the approaches by Trippl et al. [58], who described the EU's green autonomy strategy as a way to reduce dependence on global risks and create its own supply security mechanisms. The Ukrainian context confirmed the same trend, but in the context of war, strategic autonomy takes on a dual meaning – economic and security. Frontline regions remain critically vulnerable, while western regions are becoming cross-border hubs integrated into European supply chains. Such a regionalized model corresponds to the logic of "regional supply security" and shows that integration into European mechanisms is possible only through the creation of stable regional structures that can withstand external and internal shocks.

The dynamics of the Food Security Index showed significant differences between Ukraine and the EU average. Similar results were given by Caprile and Pichon [10], who noted that after the pandemic and the outbreak of war in Ukraine, the European Union stepped up crisis preparedness policies aimed at reducing gaps between Member States. Ukraine, on the other hand, has become even more characterized by internal stratification: front-line communities have experienced a sharp drop in production and an increase in logistics costs, while western regions have been able to adapt through the use of cross-border routes. The detected trend confirmed the opinion of Shebanin et al. [54], who emphasized that the EU's cohesion policy is based precisely on reducing territorial imbalances. Thus, Ukraine's integration into European cohesion mechanisms will have not only economic significance, but also security weight, as it will strengthen the internal stability of the state.

In the international context, the Ukrainian experience is gaining global significance. Abay et al. [1], using the example of Egypt, proved that the war in Ukraine has become a determining factor in destabilizing the food markets of grain-importing countries. The fall in grain exports in the years 2022 ÷ 2023 explains the emergence of a chain effect of instability in the global food system. A similar conclusion was given in the study by Al-Saidi [2], who emphasized that food security directly affects the level of political stability. The Ukrainian example confirms this thesis: the communities that retained control over production and logistics showed significantly higher socio-economic stability compared to the territories that lost infrastructure opportunities.

The socio-economic dimension has become a key intermediate element between logistics and security. During the crisis years, the share of household spending on food in Ukraine exceeded 50 %, while in the EU it remained in the range of 35 ÷ 37 %. This was confirmed in the study by Aulin [4] and Harkava [22], who stated that increased food spending leads to increased social vulnerability. The statistical analysis showed that in frontline communities, the share of spending exceeded 55 %, while in western communities it remained at approximately 45 %. This gap demonstrated a direct link between logistics costs, pricing and economic risks to the population.

The integrated index of security-oriented governance confirmed that communities with a diversified economic structure and modernized infrastructure have significantly higher sustainability indicators. Similar conclusions were given by Heffner and Twardzik [24], who emphasized the importance of sustainable land use and project management in accordance with European standards. In this case, the integration of the principles of sustainable development is not only environmentally justified, but also vital for ensuring food security during periods of military upheaval.

Rural tourism was identified as an additional factor of diversification. Clapp [11] and Tyukhtenko [59] proved that the development of local tourism practices creates additional sources of income and forms local value chains, which increases the adaptability of communities. Statistical observations confirmed this conclusion: communities with a developed tourism sector showed greater resilience during crisis years, especially in western regions.

Special attention was paid to labor resources. As proved by Tyukhtenko [59], the personnel shortage directly affects the level of food self-sufficiency of territories. The researchers proved that communities with higher agricultural employment had better values of the integral sustainability index, which correlates with the results obtained. This means that human resources are no less important than infrastructure investments, because it determines the ability of communities to quickly restore production in crisis conditions.

The generalization of the results correlates with the studies by Balik and Khiliuk [5], Rybak et al. [49], Lupenko et al. [39], who emphasized the critical importance of upgrading logistics systems. The Ukrainian data demonstrate the difference: logistics in the domestic context has not only an economic, but also a security dimension. It is this feature that forms the uniqueness of the Ukrainian experience and distinguishes it from international practices.

The overall results support the thesis by Berti [6] on the need for "re-territorializing agri-food systems", which means a return to local production and supply systems. For Ukraine, this approach is not an alternative to globalization, but in

fact the only way to ensure resilience in military conditions. The development of local hubs, short supply chains and regional platforms is determined by the key to food security in the current context.

Thus, the results of the study allow making several generalizations. Firstly, the security-oriented management of territorial communities is a determining factor in the sustainability of food systems in the times of crisis. Secondly, the destabilization of agri-food chains in Ukraine has an international dimension, as it affects global markets and political stability in importing countries. Thirdly, further research should focus on integrating social and environmental dimensions into food security models, which will allow for a more comprehensive sustainability index and expand the possibilities of applying the results in the practice of state and regional policies.

Conclusions

1. The conducted research allowed to comprehensively assess the innovation and economic mechanism of security-oriented management of the development of territorial communities of Ukraine in the context of adaptation of logistics chains of the agri-food complex. Based on the analysis of official statistical series for the years 2017 ÷ 2024, it was established that the deepest structural changes occurred in the production of grain and oilseeds, in trade in agricultural products and in logistics costs, which increased by 20 ÷ 30 % compared to the pre-crisis period. Significant regional imbalances were identified: frontline communities have experienced the greatest drop in production and rising transport costs, central regions remain relatively resilient, while western regions have shown adaptability due to cross-border hubs.
2. The verification of statistical reliability confirmed the existence of significant differences between Ukrainian and average European indicators of food security. The use of the Mann-Whitney t-test and U-test proved that differences in the dynamics of the Food Security Index are statistically justified. The regression and factor analysis showed that domestic production volumes and export efficiency have the greatest positive impact on the level of sustainability, while logistics costs and delivery time are key negative determinants.
3. The integrated security-oriented management index developed as part of the study identified communities with high and low levels of sustainability. High indicators are associated with production diversification, developed logistics infrastructure and stable access to international markets, while low indicators are associated with dependence on external supplies and high logistics vulnerability.
4. Practical results indicate the need to invest in transport infrastructure, create backup warehouses and implement digital supply monitoring systems. It is recom-

mended to develop short supply chains and rural tourism as an additional resource for the economic stability of communities.

5. The main limitations of the study are the dependence on the availability of official statistics, which sometimes reflect data with a time lag and the inability to fully account for informal economic flows. Further research should be aimed at improving the integral index through environmental and institutional indicators and expanding international comparisons to better assess Ukraine's integration potential.

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INNOWACYJNY MECHANIZM EKONOMICZNY ZARZĄDZANIA ZORIENTOWANEGO NA BEZPIECZEŃSTWO W ROZWOJU WSPÓLNOT TERYTORIALNYCH W KONTEKŚCIE ADAPTACJI UKRAIŃSKICH ŁAŃCUCHÓW DOSTAW ŻYWNOŚCI DO WYZWAŃ W ZAKRESIE BEZPIECZEŃSTWA ŻYWNOŚCIOWEGO

S t r e s z c z e n i e

Wprowadzenie. Trwający konflikt zbrojny, zakłócenia w infrastrukturze logistycznej i rosnące zagrożenia dla bezpieczeństwa żywnościowego znacząco przekształciły ukraiński system rolno-spożywczy i zwiększyły podatność społeczności terytorialnych na zagrożenia. Celem niniejszego badania było uzasadnienie innowacyjnych ram ekonomicznych dla zorientowanego na bezpieczeństwo zarządzania rozwojem społeczności terytorialnych w kontekście dostosowania ukraińskich łańcuchów dostaw rolno-spożywczych do wyzwań związanych z bezpieczeństwem żywnościowym i procesów integracji europejskiej.

Wyniki i wnioski. Analiza krajowych i międzynarodowych danych statystycznych za lata 2017 ÷ 2024 wykazała spadek produkcji rolnej o 25 ÷ 30 % w regionach frontowych, któremu towarzyszył wzrost kosztów logistyki o 35 ÷ 40 %, podczas gdy regiony zachodnie wykazały się większą adaptacyjnością, a wzrost kosztów ograniczył się do 10 ÷ 12 %. Ocena porównawcza wykazała statystycznie istotne różnice między wskaźnikami bezpieczeństwa żywnościowego na Ukrainie i w UE w latach kryzysu. Analiza regresji potwierdziła, że produkcja rolna ($\beta = 0{,}47$) i eksport ($\beta = 0{,}41$) mają najsilniejszy pozytywny wpływ na bezpieczeństwo żywnościowe, natomiast koszty logistyki ($\beta = -0{,}39$) i czas dostawy ($\beta = -0{,}31$) są głównymi czynnikami negatywnymi. Zinte-

growany wskaźnik zarządzania zorientowanego na bezpieczeństwo zidentyfikował wyraźne zróżnicowanie regionalne: najniższy poziom zrównoważenia odnotowano w społecznościach na pierwszej linii frontu (0,38 ÷ 0,41), umiarkowany w regionach centralnych (0,55 ÷ 0,60), a najwyższy w regionach zachodnich (> 0,70). Wyniki potwierdzają, że odporność społeczności terytorialnych zależy od skoordynowanej interakcji zdolności produkcyjnych, optymalizacji logistyki i ukierunkowanego wsparcia społeczno-ekonomicznego, zgodnego z europejskimi ramami politycznymi.

Słowa kluczowe: modernizacja mechanizmów zarządzania, koszty, produkcja rolna i sprzedaż, rozwój gospodarki lokalnej, logistyka