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Scenario analysis of the degree of depreciation of cereals yield and milk yield in the context of Ukraine's economic security

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▸ **Abstract.** The purpose of this study was to model the dynamics of indicators of Ukraine's industrial and food security against the background of strategies for increasing organic land and scenarios of hostilities until 2030. The methodological basis consisted of both time series models that considered exogenous variables and multifactor linear regression models. It was established that a decline in the degree of fixed asset depreciation in agriculture by 0.15 p.p., resulting from a 1 p.p. growth in the share of organic land, wasn't pose a threat to Ukraine's industrial security, but it couldn't offset the destructive consequences of the russian-Ukrainian war. While setting a target of 10% organic area will brought cereal yields (64 c/ha) closer to the optimal state (45-55 c/ha) with a weighted average yield loss of 1.97 c/ha in 2030, corn yields, even with losses (2.60 c/ha), will remain in an unsatisfactory state, reaching 75 c/ha. Although the average annual milk yield will predict to accomplish a satisfactory state in 2028 (5,521.2 kg>5,000 kg) under the baseline forecast, the yield losses (amounting to 119.89 kg) associated with a more than 10% organic livestock will prevent this achievement by 2030. Therefore, accelerated development of organic dairy production couldn't be recommended under any of the scenarios. However, achieving a 3% share of organic cows wasn't jeopardise industrial security (except for the pessimistic war until 2030). Given the critical condition of milk self-sufficiency (<80% starting from 2025), which was the consequence of a steady reduction in the number of cows, organic dairy production exacerbated the problem of food insecurity. The study results can be used by Ukraine's executive authorities in developing substantiated strategies for the transition to organic agriculture that will meet the goals of economic security

▸ **Keywords:** industrial security indicators; war scenarios; strategy; organic production development; milk self-sufficiency; food insecurity

▸ Introduction

Ukraine's agriculture was a critically vital sector of its economy, squarely or indirectly influencing the state of economic security indicators. The russian full-scale invasion dealt a substantial blow to Ukraine's agricultural sector, thus jeopardising both its industrial and food security. Under these conditions, forecasting the dynamics of individual indicators of economic security components proved crucial for economic planning and ensuring agricultural development during the 2026-2030 period. The agricultural sector of Ukraine and its relationship with the industrial and food components of economic security have become a subject of intense research, particularly in the context of full-scale hostilities.

V. Lagodiienko *et al.* (2022), determining modern food security level using a developed thorough system of indicators consisting of components (affordability, availability, quality and safety, sustainability, and adaptation), identified its bottlenecks in the context of the ongoing war with russia and global crises, such as the COVID-19 pandemic. A. Podsokha *et al.* (2023) examined the potential for improving food security, detailing levels of self-sufficiency in various food categories, and concluded that the production of milk and dairy products, fruits, berries, and grapes in Ukraine did not fully meet consumption in 2020-2021. However, their model was built on historical data up to 2021, and, therefore, did not consider the impact of a full-scale invasion and various scenarios of its completion. V. Hobela *et al.* (2022) called for a modernisation of the agro-industrial complex, given that Ukraine's food security was lower than the average world and European

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indicators in 2022. Although the authors forecast its level until 2027, the effect of full-scale war was not integrated as an independent variable.

Researchers O. Petrenko (2025), focusing on the yield of major crops, determined their losses by comparing alternative yields in the absence of a military shock with actual indicators in 2022-2023 using Autoregressive Integrated Moving Average with Exogenous Variables (ARIMAX). S. Kaushik & N. Bhardwaj (2024) showed that the integration of exogenous variables in the ARIMAX model, i.e., climatic data, allowed for more accurate forecasts, surpassing the results obtained by ARIMA models. The study by A. Kulyk *et al.* (2025) indicated that the use of the seasonal ARIMAX model provided the best forecasting accuracy, contributing to more effective planning of business processes, optimisation of production, and competitiveness of the agricultural industry. Scientists M.A. Omar *et al.* (2024) carried out forecasting of future milk production volumes, using ARIMAX without considering any external factors, compared to the study of previous authors. But, the results of this researchers could not be applied to assess the state of the dairy industry of Ukraine in the context of industrial or food security.

N. Strochenko & O. Kovalova (2025) revealed a critical level of fixed assets depreciation in agricultural enterprises, proposing solutions through innovation and investment activities. However, uncertainty related to the full-scale war called into question the feasibility of implementing high-tech solutions. Therefore, for an objective planning of investment and innovation activities, the need arose to model the degree of fixed assets depreciation depending on the intensity of hostilities under several scenarios. I. Kryukova & M. Ihnatenko (2025) found that the influence of hostilities restrained and limited the potential for the renewal of agricultural machinery, and therefore should be considered, when analysing the degree of fixed assets depreciation. According to the authors, their modernisation should consider the need for economic, environmental, and social sustainability, and organic farming was a component of one of these sustainable development dimensions. R. Lobai (2024) emphasised that the renewal should meet modern market requirements, and therefore focused on the production of crops with high added value and food grown according to the organic model to gain competitive advantages. S. Amons (2021) mentioned that the development of organic agriculture in Ukraine in the future will allow to promote innovative development, that was, had been a catalyst for modernisation and technological renewal of agricultural enterprises. R. Lohosha (2025) emphasised that the development of organic production was necessary not only to increase the competitiveness of Ukraine's agricultural sector, but also was a prerequisite for Ukraine's integration into the European space. The study aimed to forecast the dynamics of key agricultural indicators of Ukraine's industrial and food security and assess the potential effects of organic agriculture development strategies under various war-ending scenarios by 2030.

▸ Materials and methods

To forecast the degree of fixed assets depreciation in agriculture until 2030, the ARIMAX model was used, which was built based on historical indicators from 2012 to 2021 (Sladkovska, 2023). In turn, based on the data for 2010-2024, forecasts were created for the yield of the main cereal and legume crops in general and the yield of corn in particular, using the ARMA model, and for the average annual milk yield from one cow, using ARIMAX (Sladkovska, 2023; State Statistics Service of Ukraine, n.d.). Checking the time series for stationarity using the Augmented Dickey-Fuller test (ADF) allowed for specifying the required number of differentiations (*d*) and the presence of a constant or deterministic trend in the model. The validity, reliability, and suitability of time series models for further interpretation were assessed based on stationary $R^2 > 0.5$, indicating moderate to high explanatory power, and Mean Absolute Percentage Error (*MAPE*) $\leq 10\%$, which served as an estimate of forecast accuracy. In addition, the residuals from the models had to demonstrate no statistically significant autocorrelation according to the Ljung-Box (LB) statistic, i.e., $Q_{LB}\ (k) < \chi^2_{crit}$ at a significance level of $\alpha = 0.05$ and $df = 1$ for k lags, the number of which was defined based on the parameters of the Autoregressive () and Moving Average () models to provide at least one degree of freedom required for the LB test. Also, in this study, the Akaike Information Criterion (AIC) was employed to select the optimal model specification.

A stationary ($d = 1$) exogenous dummy variable reflected the impact of a full-scale invasion (*warDummy*) and its completion under three different scenarios. It was used in modeling the degree of fixed assets depreciation, average annual milk yield, and the level of milk self-sufficiency. Since active hostilities began in 2022 and continued in 2025, *warDummy = 1* was from 2022 to 2025. In 2014-2022, *warDummy* was estimated as the normalised number of civilian casualties according to the United Nations Human Rights Office of the High Commisioner (2025), characterising the intensity of the effect of russian hybrid aggression compared to 2022. Considering the considerable level of uncertainty, for 2026-2030, their forecast was carried out according to three options for the development of the security situation. The baseline scenario was defined as a linear fading of the intensity of hostilities, starting from 2026, that was, *warDummy* decreased from 1 in 2025 to 0 in 2030 in a descending arithmetic progression with a difference of 0.2. The optimistic scenario assumed the end of hostilities in 2025, which meant *warDummy = 0* in 2026-2030. In the most unfavourable scenario, the intensity of hostilities would have continued until 2030, and therefore, *warDummy = 1* in the same periods.

The forecasts of industrial security indicators were adjusted contingent on two strategies for the development of organic agriculture, O1 and O2, which could be implemented in Ukraine from 2026 to 2030. Due to limited data, it was assumed that the share of organic areas in 2025 remained unchanged from 2022 at 0.64% amid active hostilities (FiBL Statistics, n.d.). The O1 strategy projected a gradual rise in organic land share from 0.64% in 2025 by 0.47 p.p. annually to 3% in 2030, aligning with the Resolution of the Cabinet of Ministers of Ukraine No. 179 (2021). The O2 strategy assumed a faster linear growth of 1.98 p.p. per year, targeting 10.54% organic land by 2030 – the EU-27 average in 2022 (FiBL Statistics, n.d.). To assess the effect of expanding organic areas on fixed asset depreciation in agriculture, two cross-country regression models were developed using Eurostat (n.d.) data for EU-27 countries in 2019 and 2021. Model 1 examined the influence of capital formation in agriculture, forestry, and fisheries on fixed asset depreciation:

$$Fixed\ asset\ depreciation_i = \beta_0 + \beta_1\ Organic\ area\ share_i + \\ + \beta_2\ Capital\ formation_i + \beta_3\ D\_Country_i + \varepsilon_i, \quad (1)$$

where Organic area share – the share of organic land in the structure of the total agricultural area of country *i*; D_Country – a dummy variable, with the help of which specific anomalies for a separate country *i* were taken into account, equal to 1 if an unexplained outlier was observed (which in this study applied to Cyprus, Malta, and Slovakia); β_0 – constant; β_1, β_2, β_3 – coefficients of the cross-country regression model; ε_i – residuals.

Model 2 had the following mathematical form:

$$Fixed\ asset\ depreciation_i = \beta_0 + \beta_1\ Organic\ area\ share_i + \\ + \beta_2\ Rural\ develop\ expend_i + \beta_3\ D\_Country_i + \varepsilon_i, \quad (2)$$

where *Rural develop expend* – expenditure on development of rural areas in country *i*.

The coefficients were considered reliable if the models had moderate or high explanatory power (Adjusted $R^2 > 50\%$), demonstrated both overall *F*-significance and the significance of all its parameters that had no multicollinearity (Variance Inflation Factor (*VIF*) <5)). Although the Durbin-Watson statistic, fluctuating around 2, indicated the absence of first-order autocorrelation ($k = 1$), ε_i were additionally tested using the LB test to ensure the absence of potential higher-order autocorrelation ($k = 7$). According to the European Commission (2023), organic crop yields were 5-30% lower than conventional ones. Therefore, a stress test was conducted under the O2 strategy (2026-2030), assuming a maximum 30% yield loss to assess the impact of accelerated organic expansion on industrial security. With the total agricultural area in 2030 held constant at the 2022 level, potential cereal and corn losses were estimated. For dairy farms shifting to organic production, milk yields are typically 8-33% lower. Hence, a 33% maximum loss was assumed, with the share of organic cows increasing proportionally to organic land. Based on 3% (O1) and 10.54% (O2) organic shares in 2030, weighted average milk yield losses were calculated, assuming livestock numbers remained at 2023 levels. To assess food security, the study modeled Ukraine's self-sufficiency in milk and dairy products under war conditions and organic growth scenarios O1 and O2. Using ARIMAX models, cow numbers (2010-2023) were forecasted with a *warDummy* variable, and milk production was derived from predicted yields. Accuracy was verified by *MAPE* comparison with actual data (2011-2021). Milk consumption forecasts (2010-2030) were similarly based on cow numbers to reflect the effects of war and supply. Self-sufficiency levels were then projected through 2030 under the gradual end of hostilities and compared with historical values. The feasibility of implementing O1 and O2 was evaluated considering Ukraine's industrial and food security thresholds (Order of the Ministry of Economic Development and Trade of Ukraine No. 1277, 2013).

Results

Forecasting agricultural fixed asset depreciation by 2030

To forecast the degree of fixed assets depreciation in agriculture by 2030, considering different scenarios of the intensity of hostilities, the ARIMAX (2,1,0) model was used, considering the influence of the stationary ($d=1$) exogenous variable *warDummy*. After single differentiation, the time series of the dependent variable was also determined to be stationary by type 0, since the *p*-value of the ADF test (0.04) was less than the significance level of 0.05, allowing for the rejection of the null hypothesis of a unit root presence. Since stationary $R^2 = 0.63$, the model had high explanatory power, and $MAPE = 2.17\%$ indicated high accuracy of its forecasts. Additionally, the results of checking the autocorrelation of residuals using the LB test confirmed the model adequacy. Given the number of observations in 2012-2021 ($N = 10$) and the need to involve at least one degree of freedom ($df = 1$) at $AR = 2$, $k = 3$ lags were chosen for testing autocorrelation. Since the $Q_{LB}(3) = 1.94$ was quite less than the critical value $\chi^2 = 3.84$ at the significance level $\alpha = 0.05$ and $df = 1$, and $p = 0.16 > 0.05$, the hypothesis of the absence of autocorrelation in the residuals could not be rejected. Thus, residuals that did not exceed the confidence limits were considered white noise. For these reasons, the forecast values of the degree of fixed assets depreciation in agriculture were determined to be reliable for interpretation in the context of Ukraine's economic security (Kuzyk *et al.*, 2025). The obtained values of the degree of wear and tear under the baseline scenario (gradual fading of the intensity of hostilities by 2030) demonstrated that the studied indicator of industrial security was predicted to be in an unsatisfactory state, exceeding the 45% threshold value in 2022-2026. Moreover, despite its transition to a satisfactory state due to the relative stabilisation of the security situation, the degree of fixed assets depreciation in 2030 (39.6%) still exceeded its average historical value observed in the period 2017-2021 (38.1%) (Sladkovska, 2023). In addition, the analysis of the upper confidence interval limit indicated that the indicator's path to a dangerous state in the context of industrial security was not excluded under the baseline scenario, especially in 2025-2026 (Fig. 1). Thus, the easing of the intensity of hostilities in 2026 led to the start of the restoration of the agricultural sector, the implementation of new investments and repair for damaged premises, equipment and machinery, which contributed to a reduction in the degree of wear and tear of fixed assets in agriculture

Considering the estimation of the model parameters (Table 1), the degree of depreciation in the current period (t) had a strong (0.77) statistically substantial (*p*-value = *0.04*) relationship with its value in the previous period (*t-1*). In addition, the significance of the war effect was borderline and, being on the verge of the accepted threshold (*p*-value = *0.05*), it showed that the degree of fixed assets depreciation in agriculture increased due to the beginning of hostilities by approximately 6.82 p.p. in 2022. Thus, the inclusion of *warDummy* in the ARIMAX (2,1,0) model reliably reflected the period of intensification of hostilities: the sharp increase in the degree of depreciation in 2014-2015, which was associated with the beginning of russian hybrid aggression, reproduced a similar jump, but on a much larger scale, in 2022, coinciding with the beginning of the invasion.

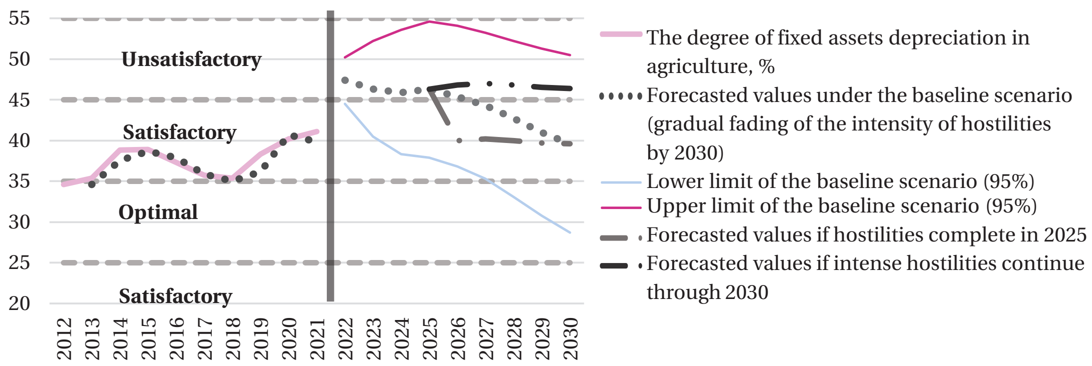

Figure 1. Agricultural fixed asset depreciation forecasts to 2030 and industrial security in 2022-2025 in Ukraine
Source: based on Ministry of Economy, Environment and Agriculture of Ukraine (n.d.)

Table 1. Parameter estimates for the ARIMAX (2,1,0) model

Variable	Estimate	Standard error	*t*-statistic	*p*-value
AR (Lag 1)	0.77	0.30	2.59	0.04
AR (Lag 2)	-0.65	0.32	-2.07	0.08
warDummy (Lag 0)	6.82	2.84	2.40	0.05

Source: developed by the author

Under the most unfavourable scenario – the intensity of military aggression that remained will until 2030 – the degree of wear and tear was in an unsatisfactory condition throughout the 2010-2024 period, reaching 47% in 2027. Thus, the long-term destruction of production capacities and the lack of financial resources for the renewal of fixed assets led to the degradation of both the material and technical equipping of the agricultural sector, which posed a threat to the country's economic security. Under the most optimistic forecast, if the hostilities ended in 2025, after peak values in 2022-2023, the degree of depreciation will begin to decrease gradually, fluctuating in 2026-2030 around the average value of 39.9%, which was higher than the average in 2012-2021 (37.57%). Among the three forecasts, this scenario was closest to the optimal indicator threshold values, indicating a massive renewal of capital in the agricultural sector, notable potential for reconstruction programmes, and the expected attraction of international investments and financial assistance in the post-war recovery period, provided that the hostilities end as soon as possible.

To quantify the impact of the share of organic land in combination with other factors on the degree of fixed assets depreciation in agriculture in the case of Ukraine implementing strategies O1 or O2, a cross-country regression model was built using data for EU-27 member states in 2019 and 2021 (Table 2). Given the summarised results, the constructed Models 1-2 were statistically significant ($p=0.00$), explaining from 51% to 65% of the variation in the dependent variable. The adequacy of the models was also confirmed by the absence of multicollinearity between the predictors ($VIF<5$) and the rejection of the hypothesis of significant autocorrelation in the residuals according to the LB test >0.05) at $k=7$ lags, the maximum number of which was determined considering $N=27$ observations. Since no problems with the correlation of factors x_i and latent time dependencies were identified, the obtained unstandardised estimates of β_j were considered reliable.

Table 2. Organic land share and agricultural asset depreciation in the EU

Model characteristic indicator/Variable	Model 1		Model 2	
Year	2019	2021	2019	2021
Key predictors (x_i)	1 – *Organic area share* (%)			
	2 – *Capital formation* (EUR 1 million) 3 – *D_Country*		2 – *Rural develop expend* (EUR 1 million) 3 – *D_Country*	
Adjusted R^2	0.57	0.51	0.65	0.62
F-statistics (*p*-value)	12.24 (0.00)	9.96 (0.00)	17.10 (0.00)	15.09 (0.00)
Durbin-Watson	2.40	1.91	2.51	2.15
Min *p* for residuals in LB test (at lag *k*)	0.07 (k=2)	0.15 (k=6)	0.09 (k=1)	0.24 (k=2)
Unstandardised β_j (*p*-value)				
β_0	7.23 (0.00)	7.13 (0.00)	6.71 (0.00)	6.49 (0.00)
β_1	-0.16 (0.00)	-0.14 (0.01)	-0.15 (0.00)	-0.12 (0.01)
β_2	0.000261 (0.01)	0.000271 (0.01)	0.002079 (0.00)	0.002247 (0.00)
β_3	-4.15 (0.00)	-4.18 (0.00)	-3.78 (0.00)	-3.68 (0.00)
Max *VIF* (for Variable)	1.13 (*D_Country*)	1.16 (*D_Country*)	1.17 (*D_Country*)	1.21 (*D_Country*)

Source: based on Eurostat (n.d.)

The impact of the *Organic area share* on *Fixed asset depreciation* in the EU-27 in 2019 and 2021 was statistically significant, negative, and relatively stable: an increase in their share by 1 p.p. was associated with an average decrease in the degree of fixed assets depreciation by 0.15 p.p., other things being equal. It could be due to investments in new means of production, more sustainable technologies, better soil care, or a lower need for intensive use of equipment and machinery. The effect of the *Capital formation* and *Rural develop* expend turned out to be positive and substantial. The statistical significance of *D_Country* for Cyprus, Malta and Slovakia indicated that *Fixed asset depreciation* in these countries was 3.7–4.2 p.p. lower compared to other EU member states, which could be due to their specific structural features or institutional programmes, in particular Malta and Cyprus are island countries with slightly different scales and conditions of agriculture, which received some of the largest payments per ha of cultivated area under the Common Agricultural Policy. According to the European Commission (2023), while the EU average for 2018-2021 was EUR 144.22 per ha, payments to Cyprus amounted to EUR 429.80 per ha and to Malta EUR 394.15 per ha, significantly exceeding the next ranked countries, such as Croatia (EUR 304.50 per ha) and Greece (EUR 290.31 per ha). Given the reliability of the parameter estimates of the regression models, the average value $\beta_1 = -0.15$ was used to adjust the primary forecast of the degree of fixed assets depreciation in Ukraine in 2026-2030 depending on the scenarios of organic area share increasing (Table 3), based on the assumption that similar relationships will be observed in Ukrainian realities against the background of European integration processes.

Table 3. Forecast adjustment of agricultural asset depreciation considering war and organics

War scenario	The target share of organic land in 2030 according to the strategy	Forecasted degree of depreciation in 2027, %	Deviation from the degree of depreciation under the baseline scenario (44.3%)
Baseline	O1: up to 3%	44.23	-0.07
	O2: up to 10.54%	44.01	-0.29
Optimistic	O1: up to 3%	40.13	-4.17
	O2: up to 10.54%	39.91	-4.39
Pessimistic	O1: up to3%	46.93	2.63
	O2: up to 10.54%	46.71	2.41

Source: developed by the author

The more ambitious development of organic production (O2) resulted in a more noticeable (compared to strategy O1), but relatively small decrease in the degree of depreciation in agriculture (-0.29 p.p.) in 2027 under the baseline scenario. It meant that although the active enlargement in the share of organic lands partially compensated for the degree of depreciation that increased as a result of the full-scale invasion, this strategy could not become the only solution to the problem of the suboptimal state of the industrial security indicator, since its negative trend was determined by both general economic factors and exogenous factors, in particular the consequences of the ongoing hostilities that began in 2014. For these reasons, in the case of the development of the safety situation under the optimistic scenario and strategy O2, the degree of fixed assets depreciation in agriculture declined the most, by 4.39 p.p. compared to the baseline forecast. It showed that the reduction of war pressure activates investments and renewal of fixed assets, bringing their degree of wear and tear closer to the upper limit of the optimal state of industrial security at 35%. In the case of the performance of the most pessimistic scenario, even moderate development of organic production under the O2 strategy did not offset the negative effect of ongoing military operations, since the degree of depreciation compared to the baseline was 2.41 p.p. higher, i.e., against the background of resource shortages, constant destruction of production capacities and agricultural infrastructure, organic agriculture development strategies were unable to counteract the large-scale degradation of the state of fixed assets in conditions of a long war.

Thus, in the context of reducing the level of fixed assets depreciation in agriculture, organic production could become one of the directions of a broader strategy for the post-war restoration of Ukraine's agricultural sector, positively affecting the state of economic security and bringing the indicator value closer to the optimal condition. However, given the small value of β_1, the development of organic agriculture did not provide a comprehensive solution for the excessive level of fixed assets depreciation and could not be recommended under the pessimistic scenario of the completion of hostilities. Moreover, it may divert limited budgetary resources necessary to support producers, who agree to implement strategies O1 and O2 from ensuring the priority needs related to national security and defence.

Forecasting crop yields to 2030 under organic strategies

The ARMA (4,0) model was used to forecast an equally important indicator of industrial security related to agriculture – the yield of the main cereal and legume crops until 2030. Unlike the degree of depreciation, when the direct impact of hostilities (*warDummy*) was considered in the ARIMAX (2,1,0) model, the dynamics of yield depend to a greater extent on natural and climatic conditions, agricultural technologies, and other factors. In addition, although the time series did not require differentiation, given the p-value $= 0.01 < 0.05$ for type 2, which were determined, when minimising the AIC, its modelling required the inclusion of the constant and trend. The constructed model, in which the values of the 2010-2024 period (t) had a marginally significant relationship with the fourth previous period (t-4), explained 72.6% of the variation of the stationary part with a *MAPE* of 9.67%, which became a satisfactory characteristic of the model quality. Since the residuals were statistically insignificant according to the LB test ($Q_{LB}(5) = 2.15$, which was less than the critical value $\chi^2 = 3.84$ at $df = 1$, and $p = 0.14 > 0.05$), the model successfully took into account all the dependencies in the time series and was used to build a reliable forecast of cereal and legume yields and its interpretation in the context of Ukraine's economic security. The deterministic trend (*p*-value = *0.00*) turned out to be a key component, as the yield of cereals, starting from a base level of 30.88 c/ha (p-value for the constant was 0.00), systematically increased by an average of 1.63 c/ha each year (Table 4). According to the forecast, the yield of cereal and leguminous crops was characterised by an upward trend – from 45.8 c/ha in 2022 to over 60 c/ha in 2028-2030. It was evidence of raised productivity of crops, soils, or improved cultivation technologies as opposed to extensive farming methods consisting of simply extending the sown areas.

Table 4. Parameter estimates for the ARMA (4,0) model

Variable	Estimate	Standard error	*t*-statistic	*p*-value
Constant	30.88	2.08	14.87	0.00
AR (Lag 1)	-0.34	0.36	-0.94	0.38
AR (Lag 2)	0.07	0.37	0.18	0.86
AR (Lag 3)	-0.11	0.43	-0.27	0.80
AR (Lag 4)	-0.62	0.31	-2.02	0.08
Trend	1.63	0.28	5.78	0.00

Notes: *Trend* variable was included in the model because the ADF test indicated that the time series was stationary around both a constant and a trend (Type 2 stationarity)
Source: developed by the author

Even though the forecast intervals expanded with distance from the last observation, which was typical for time series forecasts in the long term, the average yield level (47.4 c/ha) in 2020-2022 became the lower limit of its prognosis in 2030, indicating the potential for intensive development of the agricultural sector in the foreseeable future. However, in the context of the threshold levels of the economic security indicator presented in Order of the Ministry of Economic Development and Trade of Ukraine No. 1277 (2013), an increase in yield above 45-55 c/ha was a deterrent factor to the economic security level and, starting in 2026, the indicator finally moved from an optimal condition to a satisfactory one, ranging from 57 c/ha in 2027 to 64 c/ha in 2029. Given the upper limit of the confidence interval, which exceeded the threshold level of 75 c/ha, the forecast did not exclude the indicator being in an unsatisfactory state of industrial security starting in 2028.

According to the European Commission (2023), the yield of organic crops was 5-30% lower due to the limited use or complete ban on fertilizers, pesticides, and plant protection products. Thus, the transition to organic agriculture had a direct influence on the indicator of industrial security. To assess its impact on the state of industrial security, a stress test of the yield dynamics of cereal and leguminous crops in 2026-2030 was conducted, within the framework of which maximum yield losses were set at 30% on all organic lands under the most ambitious O2 strategy. In keeping with the results, if in 2026 the share of organic lands increased by 1.98 p.p. and amounted to 2.62%, the weighted average yield losses amounted to only 0.50 c/ha. However, in 2030, yield losses reached 1.97 c/ha if an organic production model was implemented on 10.54% of cereal and legume lands. Assuming that in 2030 the total area allocated for cereal and legume crops remained as in 2022 (12,171 thousand ha), the total harvest volume decreased by approximately 252.72 thousand tons, accounting for about 0.47% of the production volume of cereal and legume crops in 2022 (53,864 thousand tons). Since the level of grain supply in Ukraine has traditionally been high, the adjusted yield forecast also did not endanger the state of food security. Therefore, despite the potential losses, neither moderate (strategy O1) nor accelerated organic production of cereal and leguminous crops under strategy O2 created critical threats to industrial and food security. Moreover, increasing the share of organic areas to 10.54% (the O2 strategy) and maximum yield losses, on the contrary, contributed to the indicator approaching the optimal condition in the context of Ukraine's economic security, while simultaneously meeting the strategic sustainable development goals (Fig. 2).

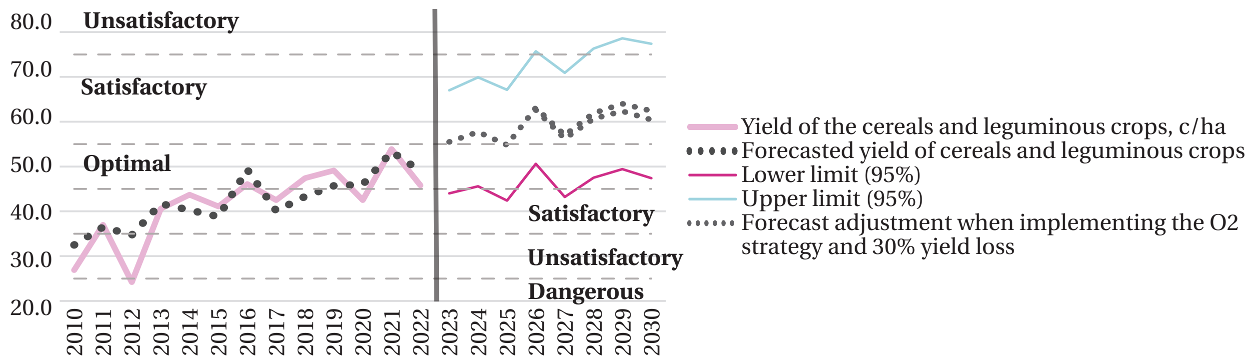

Figure 2. Crop yield forecast and stress-test adjustment to 2030
Source: based on Ministry of Economy, Environment and Agriculture of Ukraine (n.d.)

Though the dynamics of the yield of the cereal and legume crops by 2030 was not in an unsatisfactory, dangerous, or critical state, it was essential to analyse the potential risks of its component, corn yield, to the threshold values of industrial security. Moreover, the study by R. Ivanov & Yu. Hurtovyi (2023) found that its significant production volumes were not optimal, also in the context of foreign economic security. The ARMA (1,0) model was used to forecast corn yields by 2030. In this model the original time series did not have a unit root (p-value < 0.01 according to the ADF test, and the lag order according to the AIC was equal to 3, but it required considering a constant and a deterministic trend during modelling. The constructed model was characterised by the Stationary $R^2 = 0.58$, which indicated its acceptable explanatory power, and $MAPE = 8.35\%$ demonstrated even more satisfactory accuracy compared to the forecast of cereal and legume yields. Considering that the model had one autoregressive term ($AR = 1$), $k = 2$ lags were chosen for the analysis of autocorrelation of residuals so that $df = 1$. Since $Q_{LB}(2) = 1.54 < \chi^2_{crit}$ at a significance level of $\alpha = 0.05$, and $p = 0.22 > 0.05$, the model residuals did not contain any statistically substantial latent patterns, which led to the conclusion about the reliability of the forecasts and further scenario adjustments. Having estimated the parameters of the model, for corn yield the average base level was 52.80 c/ha (p-value $= 0.00$). At the same time, given the statistical significance ($p = 0.02$) of the autoregressive component, the yield up to 2030 period (t) was negatively associated, since the coefficient was (-0.67) and reflected oscillating dynamics (Table 5). In addition, corn was characterised by a stable tendency to increase yield by an average of 1.41 c/ha ($p = 0.00$), which could be associated with the positive effect of agrotechnical factors.

Table 5. Parameter estimates for the ARMA (1,0) model

Variable	Estimate	Standard error	*t*-statistic	*p*-value
Constant	52.80	2.63	20.08	0.00
AR (Lag 1)	-0.67	0.24	-2.80	0.02
Trend	1.41	0.34	4.19	0.00

Notes: *Trend* variable as included in the model because the ADF test indicated that the time series was stationary around both a constant and a trend (Type 2 stationarity)
Source: developed by the author

For corn, the yield of which in 2018-2019 and 2021 was on the verge of satisfactory and unsatisfactory state, there was a characteristic trend of increasing yield throughout the entire forecast horizon: if in 2022 it was 63.5 c/ha, by 2030 the yield grew to 82.1 c/ha, being within the range between 61.7 and 102.6 c/ha with a probability of 95%. Despite the presence of short-term cycles in its dynamics, which caused small fluctuations, the anticipated values were considerably higher compared to cereal and legume crops (on average by 18.3 c/ha in 2023-2030), since corn has historically been a higher-yielding crop (for 2010-2022, the excess was also about 20 c/ha on average). For these reasons, unlike cereal and legume crops, in the context of industrial security, corn yield, according to the forecast, was steadily in an unsatisfactory condition (>75 c/ha) starting from 2025, gradually moving towards a dangerous one. Additionally, based on the upper and lower forecast limits, it was considered reliable that, based on the threshold values, its yield was not optimal starting from 2025, and the forecast did not exclude the indicator reaching the critical level in 2029-2030 (Fig. 3).

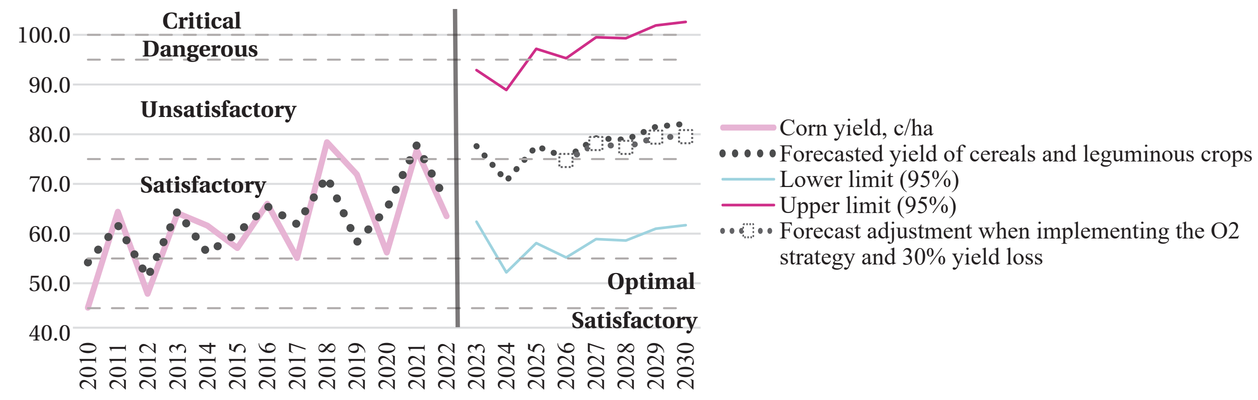

Figure 3. Forecasted corn yield and stress-test adjustment to 2030
Source: based on State Statistics Service of Ukraine (n.d.)

When assessing the consequence of the gradual transition from conventional to organic corn production on the state of industrial security, similar stress test conditions were used as for the cereal and legume crops. Simulating the maximum yield losses in 2026-2030 under the strategy of accelerated growth in the share of organic land

(O2), the results of the adjusted forecast showed that although the indicator was still in an unsatisfactory condition, it was observed to approach a satisfactory threshold value. While in 2026 the yield losses of corn amounted to only 0.59 c/ha, since about 98% of the land was still occupied by conventional agricultural production, in 2030, with organic corn cultivation on 10.54% of the areas, the losses amounted to 2.60 c/ha. If the area allocated for corn cultivation in 2030 was the same as in 2022 (4,325 thousand ha), the total harvest volume (calculated according to the O2 strategy yield forecast) declined by 118.52 thousand tons, accounting for about 0.45% of the corn production volume in 2022 (26,186.9 thousand tons) (State Statistics Service of Ukraine, n.d.). Thus, the development of organic corn production under the ambitious O2 strategy not only did not create threats to industrial security, but contributed to a lower level of its forecasted unsatisfactory condition in 2026-2030. Even though the interpretation of the results, as in the case of the yield of cereal and leguminous crops, was carried out within the framework of the Order of the Ministry of Economic Development and Trade of Ukraine No. 1277 (2013), increasing the threshold values of the indicator in the updated economic security system will most likely led to its shift to a satisfactory state, and expanding the share of organic areas for corn cultivation in the structure of agricultural land will bring its yield closer to optimal condition.

Average milk yield and industrial security, 2030

To predict the average annual milk yield per cow, which was also an indicator of the modern industrial security system, the ARIMAX (1,1,0) model was used. First-order differentiation allowed for the achievement of stationarity, since the results of the repeated ADF test (p-value < *0.01*) became the basis for rejecting the hypothesis of a unit root presence, although provided that a constant and a deterministic trend were present. Though milk yield was an indicator of cow productivity, which largely depended on genetics, housing conditions, completeness of feeding, and veterinary coverage, unlike other values in the time series, a negative increase in the indicator was recorded in 2022. It decreased from 5,155 kg in 2021 (Ministry of Economy, Environment and Agriculture of Ukraine, n.d.) to 5,119 kg in 2022 (State Statistics Service of Ukraine, n.d.). To assess and simulate the impact of this anomalous deviation associated with a full-scale invasion from the established trend, a stationary *warDummy* was added. Considering the dependence of the 2025 milk yield (t) on the indicators of the previous period (t-*1*), the model, built on data from 2010 to 2022, was characterised by high explanatory power, since stationary $R^2 = 0.78$. At the same time, the *MAPE* (0.46%) indicated a high accuracy of the milk yield forecast. Since, according to the LB test, the hypothesis of the absence of autocorrelation in the residuals could not be rejected ($Q_{LB}(2) = 1.00$ did not exceed $\chi^2_{crit.}$ under the condition of $df = 1$ at the significance level $\alpha = 0.05$, $p = 0.32 > 0.05$), the model was statistically adequate and reliable for forecasting the state of the indicator by 2030 in the context of Ukraine's economic security.

The forecast values of the average annual milk yield showed a gradual rise from 5,155.3 kg in 2023 to 5,649.3 kg in 2030 according to the baseline scenario. In agreement with the parameters of the ARIMAX model, while the average annual increase, being statistically significant (p-value = *0.00*), was 135.25 kg, indicating a long-term growth trend, the full-scale invasion led to an immediate and substantial reduction of 148.92 kg ($p = 0.00$) per cow (Table 6). In addition, the value of the autoregressive component (-0.75) meant that high milk yield in the current period was accompanied by lower ones in the next, and vice versa ($p = 0.02$). The statistical significance of the deterministic trend ($p = 0.03$) confirmed an additional inverse linear effect, which reduced milk yield by an average of 4.89 kg.

Table 6. Parameter estimates for the ARIMAX (1,1,0) model

Variable	Estimate	Standard error	*t*-statistic	*p*-value
Constant	135.25	14.20	9.53	0.00
AR (Lag 1)	-0.75	0.26	-2.85	0.02
Trend	-4.89	1.84	-2.66	0.03
warDummy (Lag 0)	-148.92	37.61	-3.96	0.00

Notes: *Trend* variable was included in the model because the ADF test indicated that the time series was stationary around both a constant and a trend (Type 2 stationarity)
Source: developed by the author

This forecast reflected an increase in productivity in dairy cattle breeding, coinciding with global trends in the intensive development of milk production, which are based on innovations and modern technologies to ensure feeding and keeping cattle, milking, and improving the genetic potential of the cattle breeding stock. However, despite the positive dynamics, the expected growth turned out to be insufficient for the indicator to achieve the optimal condition in the context of the current industrial security system: having crossed the threshold of an unsatisfactory state (5,000 kg) in 2020, the average annual milk yield was able to leave this state only after 8 years, given that the indicator crossed the satisfactory threshold value in 2028 (5,521.2 kg > 5,500 kg). At the same time, the current results negated the likelihood of achieving optimal yield values, since the upper forecast limit in 2030 was 5,780 kg, which was less than the optimal threshold of the current Methodological recommendations at the 6,000 kg level (Fig. 4).

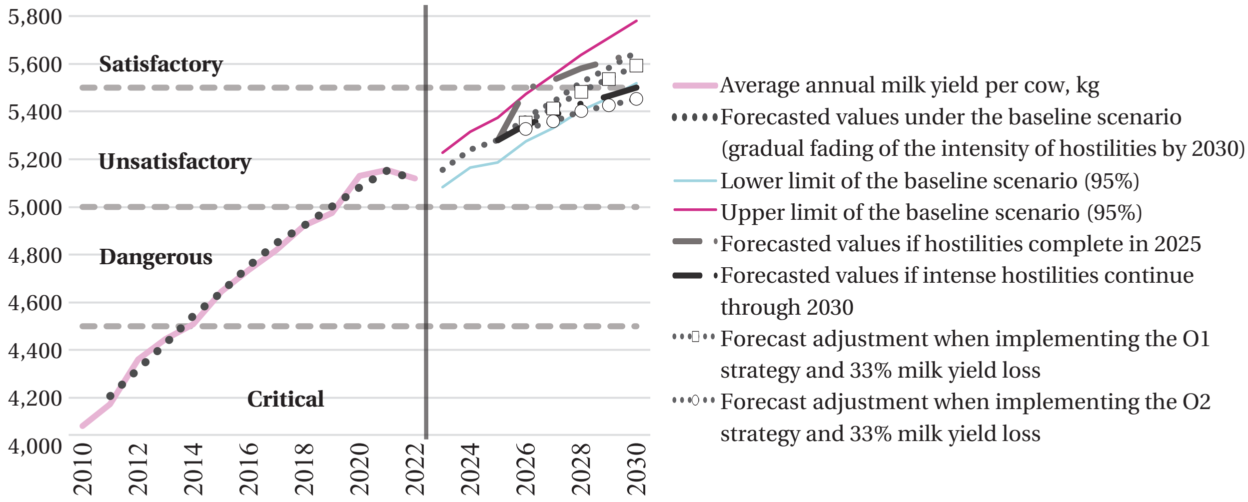

Figure 4. Milk yield forecast per cow under stress-test, 2030
Source: based on Ministry of Economy, Environment and Agriculture of Ukraine (n.d.)

According to the optimistic scenario, the average annual milk yield will increase of 4.05% in 2026, amounting to 5,493.6 kg compared to 5,279.9 kg in 2025 due to the levelling of the influence of hostilities. Moreover, under this scenario, the indicator will reach a satisfactory condition a year earlier (in 2027), in contrast to the baseline unfolding of occurrences. The pessimistic scenario revealed a gap in cow productivity, as the average milk yield will cross the threshold of a satisfactory state only in 2030, amounting to 5,500.4kg, which was 148.9 kg less than other possible alternatives. Thus, the continuation of russian aggression until 2030 will be the reason for the slowdown in the development of the agricultural sector, the average annual yield in particular, for 2-3 years in the context of Ukraine's industrial security.

As the average annual milk yield of farms that converted to organic farming was 8-33% lower than that of non-organic dairy farms (European Commission, 2023), a stress test was also conducted to assess the robustness of the industrial security indicator. By simulating the worst-case loss of milk yield of 33% on certified land used for keeping and grazing cows, increasing to 3% and 10.54% under strategies O1 and O2, respectively, the stress test results demonstrated a threat to economic security, which was a significant difference compared to cereals and corn. Given the adjusted predictions presented in Figure 4, the active implementation of organic production had a negative effect on the average annual milk yield per cow in the context of industrial security, moving the indicator away from achieving a satisfactory state. It emphasised the need for balanced development of both spheres of agriculture, because while the crop production has historically been at a high level, occupying considerable agricultural areas and dominating the export structure, husbandry, in particular dairy farming, has confirmed vulnerability to transformation processes, maintaining a long-term trend towards reducing livestock, material and resource base, and dairy production volumes.

In the case of updating the methodological thresholds of Ukraine's economic security indicator, which would be based on the experience of countries with a high level of agricultural development, where productivity was much more elevated, its predicted values in 2023-2030, which were defined as unsatisfactory and satisfactory in the context of industrial safety, may shift to the category of dangerous and unsatisfactory condition, respectively. Although the implementation of the O1 strategy postponed the achievement of a satisfactory state by a year compared to the baseline scenario, the indicator was kept within the limits of a favourable state in 2029-2030. Because of this, the O1 strategy, which had a small negative impact on the indicator (with calculated losses of weighted average productivity ranging from 19.72 kg in 2026 to 55.93 kg in 2030, when compared to the baseline forecast), could be justified by the need to achieve sustainable development goals or the orientation of the dairy production system to meet the needs of consumers on the foreign market. In contrast, the O2 strategy, which resulted in a larger gap between the average annual milk yield, caused the transition of the indicator to an unsatisfactory condition, demonstrating the adverse consequences of its performance. For these reasons, O2 could not be recommended until the milk productivity of cows raised under the conventional agricultural production system was significantly increased to compensate for the loss of milk yield resulting from compliance with organic standards.

Additionally, since in 2030 the average weighted loss of productivity per cow under the O2 strategy was 196.49 kg, which was equal to the average milk consumption per capita in Ukraine at 196 kg as of 2023 according to the Ministry of Agrarian Policy and Food of Ukraine (n.d.), it caused serious concern not only in case of industrial security condition. If the number of cows in 2030 remained as in 2023 (1,307.9 thousand heads), and the weighted average difference in productivity, when implementing the O2 strategy and a 33% loss in milk yield was 196.49 kg, the total milk losses due to the contrast in milk yield amounted to 256.994 thousand tons. Since the estimated milk losses in 2030, when implementing the O2 strategy, were equivalent to the annual milk consumption fund for 1,311.196 million Ukrainians, the transition to organic production, accompanied by a 33% reduction in cow milk productivity according to the stress test, could also pose a threat to the food security level.

Food security and dairy self-sufficiency to 2030

Due to the potential reduction in milk and dairy production volumes caused by the lower average milk yields, the likelihood of unfavourable food security conditions increased, particularly for the ratio of production and consumption for a defined food category. Given the need to consider losses in milk productivity, the modelling of this food security indicator was carried out by sequentially forecasting and aggregating its components. To calculate realistic milk production volumes by 2030, the average annual milk yield obtained in the previously ARIMAX model (1,1,0) was multiplied by the forecast values of the cow population. The prediction for the number of cows for 2024-2030 was carried out on based on historical data for 2010-2023 (State Statistics Service of Ukraine, n.d.), using the ARIMAX model (2,1,0) taking into account the exogenous variable *warDummy* ($d = 1$), which allowed for setting several scenarios of the end of hostilities by 2030, which directly affected the logistics, safety and conditions of keeping animals, their feed base and forced relocation or slaughter. Stationarity of the time series was achieved using first-order differentiation, which allowed for the rejection of the hypothesis of a unit root existence (p-value $= 0.03 < 0.05$ according to the ADF test). However, type 1 indicated the presence of a constant. Although double differentiation also confirmed stationarity, it was not advisable since it worsened the quality of the model, as evidenced by the increase in AIC by 0.29 units. Thus, the constructed model had high explanatory power (stationary $R^2 = 0.66$) and accuracy ($MAPE = 0.94\%$). In addition, the presence of autocorrelation in the residuals was checked using the LB test at $k = 3$ lags, given $N = 14$ observations and the need for $df = 1$ at $AR + MA = 2$. Since $Q_{LB}(3) = 2.11 < 3.84$ (χ^2_{crit}) at the significance level $\alpha = 0.05$, and $p = 0.15 > 0.05$, the residuals in the model did not have any unaccounted statistically substantial regularities that could cast doubt on the correctness of further calculations of milk production volumes.

Based on the model parameters estimates, the presence of a long-term trend towards a drop in the number of cows by an average of 98.23 thousand heads per year was significant (p-value $= 0.00$). Since the coefficient of the autoregressive component at lag 1 was statistically substantial ($p = 0.03$), there was a positive (0.65) relationship between the livestock of the 2010-2024 period (t) and the previous one (t-1) (Table 7). In addition, a strong negative autocorrelation with a lag of two periods was observed, given the value of $AR(2) = -0.75$, i.e., fluctuations in dynamics were observed in the time series. The beginning of a full-scale invasion (p-value was 0.03) led to a decrease in the number of cows by 73.80 thousand heads in 2022. At the same time, the dynamics of the indicator were characterised by a recovery effect, since after the initial shock associated with *warDummy*, which caused a sharp reduction in the number of cows instantly, in the following period the rate of decline slowed down, given the positive and statistically significant ($p = 0.05$) value of the numerator at lag 1.

Table 7. Parameter estimates for the ARIMAX (2,1,0) model

Variable	Estimate	Standard error	t-statistic	p-value
Constant	-98.23	7.92	-12.41	0.00
AR (Lag 1)	0.65	0.25	2.63	0.03
AR (Lag 2)	-0.75	0.22	-3.39	0.01
warDummy (Lag 0)	73.80	27.65	-2.67	0.03
warDummy (Lag 1)	79.27	33.88	2.34	0.05

Source: developed by the author

The forecast of the number of cows in Ukraine demonstrated that the weakening of the intensity of hostilities in 2026 under the baseline scenario will be an encouraging signal for households and enterprises to partially resume production activities: while in 2022-2023 the historical absolute increases were negative and amounted to (-189.0) and (-143.3) thousand heads, respectively (State Statistics Service of Ukraine, n.d.), model forecast showed it will be equal to (-69.0) and (-51.3) thousand cows in 2027-2028. However, despite the cessation of hostilities in 2030, under the baseline scenario forecast and the gradual restoration of production, the number of cows (753.5 thousand heads) remained far (-53.16%) from their number as of 2021 (1,608.5 thousand heads) (State Statistics Service of Ukraine, n.d.). Analysis of the model's upper limit of the 95% confidence interval, which was 931.61 thousand heads, gave grounds to argue that in 2030, the number of cows will be no less than 42.08% lower compared to the 2021, before the russian full-scale invasion. According to the optimistic forecast scenario, the number of cows in 2027 will exceed the corresponding indicator of the baseline scenario by 107.7 thousand heads, in 2029 – by 46.47 thousand heads. In turn, the longer events developed under the pessimistic scenario, the gap in the indicator increased because the number of cows will be lower by 45.37 thousand heads in 2027, by 106.6 thousand in 2029, compared to the baseline scenario.

By calculating the volume of milk produced as the outcome of the forecasted number of cows according to the ARIMAX model (2,1,0) and the average annual milk yield according to the ARIMAX model (1,1,0), indicators for 2011-2030 were obtained, since both time series were differentiated ($d = 1$) to achieve stationarity. Integrating both the influence of internal factors of livestock farming, which determine milk yields, and external ones, the war scenario in particular, which determined the dynamics of the livestock, the *MAPE* for historical data on milk production volumes in 2011-2022 was only 2.99%, which confirmed the adequacy of the estimated values. To forecast the volume of milk consumed in 2022-2030, an ARIMAX (1,1,1) model was built on actual data (2010-2021), which explained 58.6% of the variation in the time series with $MAPE = 1.69\%$. At the same time, moderate explanatory power and high accuracy were achieved by considering the exogenous variable, the historical (2010-2023) and predicted (2024-2030) number of cows under three scenarios, which were obtained at the previous stage. This exogenous variable enabled the indirect incorporation of both the completion of hostilities scenario, which was considered, when forecasting the number of cows by 2030, and the dependency of consumption on supply, which was directly related to the number of cows. Based on fundamental microeconomic theory, the reduction in livestock led to a decline in supply, which provoked an increase in prices, negatively affecting the volume of milk consumption. Given *AR=1*, *MA=1*, the autocorrelation test was performed at $k=3$ lags to satisfy the minimum required condition ($df=1$) for the LB test. Since $Q_{LB}(3)=0.55$, which was significantly less than $\chi^2_{кр}$, and $p=0.46>0.05$, the predictive values were reliable and could be used to interpret the indicator in the context of food security.

According to the forecast, milk and dairy product consumption began to show a gradual recovery in response to the slow decline in the intensity of hostilities, a likely increase in supply, and a slowdown in the growth of dairy prices starting in 2027, as its volumes increased by 53.8 thousand tons compared to the previous period and amounted to 7,221 thousand tons (Fig. 5). Even though the average growth rate of milk consumption in 2026-2030 at the level of 0.26% was consistent with the possible return of some Ukrainians, who left with the start of the russian full-scale invasion, as a result of the consistent improvement of the security situation, its volume in 2030, which was forecast to be 7,535.5 thousand tons, did not exceed the actual volumes of the period before the full-scale invasion (8,337.3 thousand tons), that was, the constructed model also demonstrated a general reduction in the Ukraine's population, which accordingly affected the fund of milk and dairy product consumption in the direction of its decline.

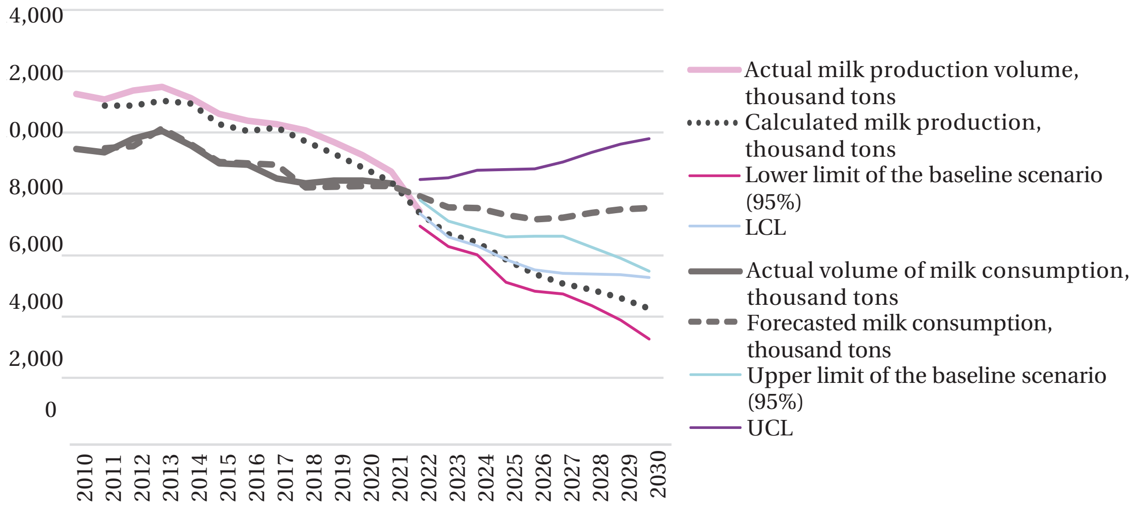

Figure 5. Forecasting of milk and dairy products production and consumption in Ukraine for 2022–2030 under the baseline war scenario

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

The analysis of milk production and consumption in 2022-2030 did not exclude the possibility of meeting the population's needs with the milk produced volumes. However, it could be achieved, when production volumes were close to the upper limit, and consumption to the lower one, on the contrary. Despite the significant width of the 95% confidence intervals, in the long term, there was a weakening in food security even under such favourable conditions. While consumption volumes showed recovery, the reduction in milk production volumes was a consequence of a steady trend towards a decrease in the number of cows. Given this, the upper limit of the range for milk self-sufficiency, being 103.89% in 2030, was less than 105%. It already meant that the optimal state in the context of food security had not been achieved. Having the milk production volumes determined based on the ARIMAX (2,1,0) for the number of cows and ARIMAX (1,1,0) for the average annual milk yield, as well as the volumes of its consumption, established using the ARIMAX (1,1,1) model, it became possible to directly calculate the level of milk and dairy product self-sufficiency and its adjustment depending on the two strategies for the organic agriculture development. Keeping integrated various exogenous influences into the forecasts of the indicator components, the *MAPE* for the ratio of milk and dairy product production and consumption volumes per capita in 2011-2021 was 3.03%, which confirmed the conformity of the models to historical data and their adequacy. An analysis of the level of milk and dairy products self-sufficiency showed a noteworthy deterioration in food security as a result of the full-scale invasion: having reached a maximum in 2017 (118.2%), the indicator began to decline and in four years lost 16.5 p.p. compared to the indicated peak value, thus moving from an optimal condition to an unsatisfactory one even before the full-scale invasion, amounting to 104.5% in 2021. According to the forecast, in 2022, its level in the context of food security dropped by an additional 11.4 p.p. compared to the period before the full-scale invasion, which determined its state as unsatisfactory, which in 2023-2024 was already less than 90%, already being dangerous. In 2025 the level of milk and dairy product self-sufficiency reached a critical state in the context of food security, which only amplified, as by 2030 the indicator will reach a value of 56.49% (Fig. 6).

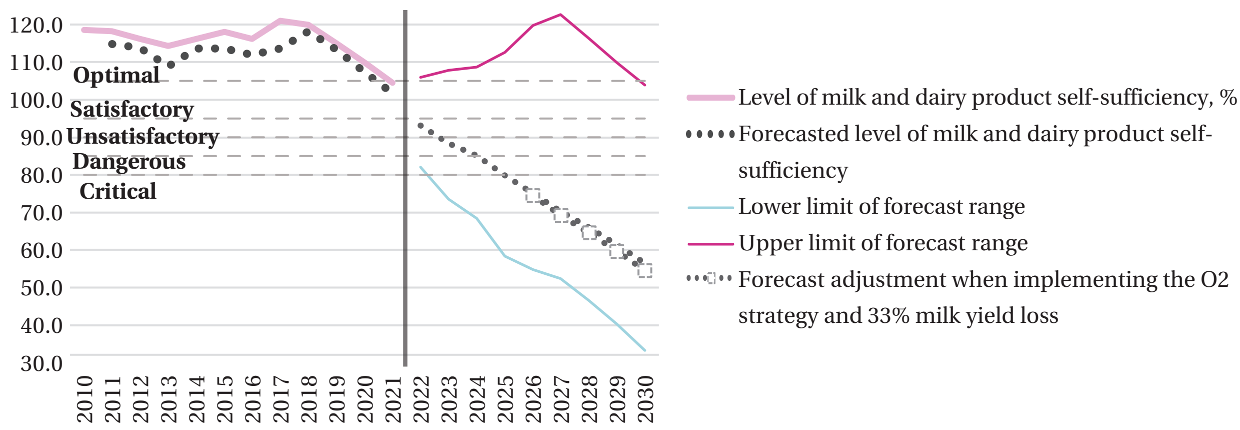

Figure 2. Forecasted dairy self-sufficiency under stress-test, 2030
Source: based on Ministry of Economy, Environment and Agriculture of Ukraine (n.d.)

Though the forecast limits were not classic 95% confidence intervals, calculated based on the upper and lower limits of the ARIMAX models for the components of the self-sufficiency level, it became the basis for evaluating possible fluctuations of the indicator. According to them, the level of milk and dairy products self-sufficiency in 2030 could be in all conditions, except for the optimal one (<105%). The obtained calculations of the level of milk and dairy products self-sufficiency were reliable if the anticipated dynamics of the reduction of the livestock population by 2030, which was based on historical data for 2010-2023, was not reversed by external factors, such as the implementation of effective state support programmes for dairy production, which will contribute to the restoration and increase of the number of cows in Ukraine. Moreover, in the ARIMAX (1,1,1) model, this exogenous variable demonstrated a statistically significant effect ($p = 0.03$) on milk consumption. A decline in the number of cows by 1 thousand heads was associated with a decrease in consumption of 5.62 tons (Table 8). That was, the model coefficient was economically justified, consistent with the average annual milk yield per cow exceeded 5,000 kg starting in 2020.

Table 8. Parameter estimates for the ARIMAX (1,1,1) model

Variable	Estimate	Standard error	*t*-statistic	*p*-value
Constant	441.36	224.42	1.97	0.09
AR (Lag 1)	-0.07	0.91	-0.08	0.94
AM (Lag 1)	-0.49	0.81	-0.60	0.57
Number of cows (Lag 0)	5.62	2.06	2.73	0.03

Source: developed by the author

The implementation of strategies, which led to an increase in the share of organic cows, has made substantial adjustments in the dynamics of the food security indicator due to lower milk productivity by 33% according to the stress test. In the case of the development of organic agriculture under the O1 strategy in 2026, the total loss of milk yield will be 19.8 thousand tons, since while the productivity of 991 thousand cows was 5,374.5 kg, which was the forecast value of the ARIMAX model (1,1,0), the productivity for 11.1 thousand organic heads (1.11% of the total livestock in 2026) will be determined at 3,600.9 kg. Along with the gradual increase in the share of organic cows to 3% by 2030, milk yield losses also will grow, reaching a maximum value of 42.14 thousand tons in 2030. It will lead to a slight increase of 0.56 p.p. in the criticality of the level of milk and dairy products self-sufficiency in 2030. Assumed that consumption per person in 2030 will recover to its average level in 2017-2021, which was 200.32 kg, with milk losses of 42.14 thousand tons, meeting food needs may become more strenuous for 210.363 thousand Ukrainians.

The implementation of the O2 strategy will lead to even more significant negative consequences, as total milk losses will range from 46.6 thousand tons in 2026 to 148.1 thousand tons in 2030 due to the enlargement in the number of organic livestock from 26.3 thousand cows (2.62%) to 79.4 thousand cows (10.54%) in the respective periods. According to the previous assumption, the milk losses in 2030 will lead to an increase in food insecurity for 739.317 thousand people, who could have consumed the produced products if the dairy farming model had remained conventional. Given the incomplete in milk and dairy products self-sufficiency throughout the entire period of 2022-2030 under the baseline scenario of the cessation of hostilities and the loss of the indicator from 1.43 p.p. in 2028 to 1.96 p.p. in 2030 compared to the baseline forecast, the transition to organic production under the O2 scenario could not be recommended, as it would worsen the state of Ukraine's food security. Since the shortage of milk and dairy products on the internal market could provoke a probable increase in imported products and prices, limiting access to milk for a considerable part of the population, the transition to organic milk production was not desirable under any of the scenarios in the context of food security. Only in the case of accelerating the productivity growth of both conventional and organic livestock and reducing the gap between them from 33% to a lower percentage of losses or breaking the negative trend towards a reduction in the number of cows, the strategy O1 for developing organic production could be justified and not move the indicator away from more favourable conditions in the context of Ukraine's food security.

Discussion

The study findings made it possible to forecast the impact of various war scenarios on key agricultural indicators of industrial security and to assess potential threats associated with the implementation of organic strategies in Ukraine against the backdrop of active hostilities. S. Gbaka & V.U. Ijirshar (2024), studying the impact of the russian invasion in Ukraine on food prices in 12 low- and middle-income countries, determined it as statistically significant, which weakened global food security in the long term. The authors estimated this effect as a dummy variable, which took the value 0 for the pre-war period (from January 2021 to February 2022) and was equal to 1 from March 2022 to April 2023. This study used a similar approach using *warDummy*, which was equal to 1 in 2022-2023. However, given that the russian hybrid aggression that began in 2014 was already causing socio-economic tension, a normalised civilian casualty rate was calculated to obtain a continuous measure of the war's impact over its entire duration, including the hybrid phase. The study by I. Rumyk (2021), modelling agricultural production per capita as the central indicator of food security, found a significant impact from the consumption of bread products and meat, but not milk. This difference could be explained by different analysis periods; specifically, the author's study might not have covered 2020-2021, when the problem of milk self-sufficiency became more evident. This study revealed a critical state of self-sufficiency in milk and dairy products, the level of which fell below the optimal state (104.5% < 105%) back in 2021 and dropped below the critical threshold (<80%) by 2025 (79.9%), indicating systemic problems in the industry exacerbated by the war. N. Shmygol *et al.* (2024) noted that for Ukraine to reach the planned 3% share of organic land, which was a strategic goal according to the National Economic Strategy until 2030, the annual growth rate must be at least +13.3%. Researchers emphasised that this share was a minimum threshold, given the progress achieved by EU countries.

The relationship between organic production and other indicators of production security was clearer. R. Ostapenko *et al.* (2020) emphasised that although lower crop yields were characteristic of organic farms with a lower economic efficiency level, wheat yields, even for organic enterprises with a higher level of development, were lower compared to conventional agriculture in 2017. Comparing organic and traditional dairy production in the EU, G. Grodkowski *et al.* (2023) found that organic milk yields were significantly lower due to energy-restricted diets and lower intake of concentrated feed. S. Portiannyk (2024), focusing on environmental safety and milk quality, recommended developing organic agriculture precisely in the post-war period, considering Ukraine's potential. This study supported this recommendation from the perspective of industrial security, demonstrating that increasing the organic cow population was possible during the post-war recovery period. Specifically, the average annual milk yield remained in a satisfactory state under both the optimistic scenario (5,531 kg in 2027) and even when implementing the O1 strategy under the baseline scenario (5,649.3 kg in 2030). The study by O. Popko (2020), which also identified opposing trends of increasing milk yields and decreasing cow numbers, predicted reaching the satisfactory level (>5,500 kg) as early as 2022 using the first-order Brown's method based on data for 1996-2018. This study accounting for the impact of external shocks (COVID-19, full-scale invasion), forecasts crossing this threshold only in 2028 (5,521 kg) using the ARIMAX (1,1,0) model ($MAPE = 0.46\%$). Furthermore, the confidence interval (upper limit 5,553.1 kg) indicated that this could not have occurred earlier than 2027, thus refining previous forecasts with more actual data.

A. Ohanisian *et al.* (2022) assessed the potential of organic dairy production, forecasting an overly optimistic number of organic livestock (3,713.63 thousand heads) by 2030 under a hypothetical scenario of significant growth in investment and livestock. However, this forecast contradicted the long-term trend of declining total livestock numbers and was based on data for all livestock, not just cows. Moreover, although Ukraine does have an export-oriented agriculture, the realisation of this potential was considered unconnected with the level of milk and dairy products self-sufficiency, which, according to the results, was characterised by suboptimal conditions in the context of food security. This study predicted a significantly lower number of organic cows (79.4 thousand heads) even under the ambitious O2 strategy, which was 97.86% less than the target set by the authors. It indicated more realistic scales for the development of organic production in the context of the systemic decline in livestock numbers. The research by R. Alvarez (2021) showed that organic farming yields were 25% lower than conventional yields, and for cereals, this difference reached 30%, intensifying the debate about the organic sector's ability to meet global food needs. It aligned with the maximum value in the range of cereal yield losses (30%) used in the stress test for the industrial security indicator in this study.

The study by Z. Sun & T. Fu (2022) showed that the average cereal yield in Western Europe (1991-2020) was 68.04 c/ha, significantly exceeding modern Ukrainian levels. This study, in contrast, forecasted Ukraine reaching only 62.77 c/ha by 2028-2030. A. Grzelak (2022) showed that an increase in organic land area by one standard deviation in 2004-2019 led to an increase in the total value of assets, including fixed assets, by 0.38 standard deviations, i.e., the growth in asset value required investment in new fixed assets or modernisation of existing ones. In turn, the correlation analysis by E.J. Szymańska *et al.* (2021) found that farms with a higher value of fixed assets made larger investments, likely to modernise or replace existing assets. Based on these cascading relationships, a larger agricultural area was associated with an increase in fixed asset investments, which was often accompanied by their renewal and, consequently, a decrease in the average degree of their physical depreciation. This study empirically confirmed this indirect relationship by establishing a direct correlation: an increase in the share of organic areas by 1 p.p. led to a reduction in the degree of fixed assets depreciation by 0.15 p.p., which indicated their active renewal in organic production.

Although W. Czubak & K.P. Pawłowski (2020), which focused on the interaction of pro-investment mechanisms of the Common Agricultural Policy and sustainable economic development of farms in Central and Eastern European countries, did not verify that the beneficiaries of investment support were those farms that had a higher level of their fixed assets depreciation, however, the mandatory criterion for them was the absence of any support in the year before the investment. Given this, the lack of prior EU assistance aimed at renovation and modernisation, on the contrary, increased the likelihood that these farms had a higher degree of fixed assets depreciation. It was most likely that substantial volumes of *Capital formation* or *Rural develop expend* demonstrated positive relationships with *Fixed asset depreciation* because it was a reaction to its considerable level. Specifically, an enlargement of EUR 1 billion in these factors was associated with an increase in *Fixed asset depreciation* by 0.27 p.p. and 2.16 p.p., respectively. That was, countries where fixed asset degradation was observed were the major recipients of these financial resources. V. Aggarwal (2025), analysing the transition to organic production, emphasised that the initial investment burden related to the modernisation of fixed assets required urgent state measures of financial and technical support. This research aligned with this conclusion, recommending against the implementation of either the O1 or O2 strategies under the pessimistic scenario for the completion of hostilities. This was because the degree of depreciation remained high (47% in 2027), and additional investments would create excessive pressure on the country's limited budgetary resources, given that the state budget deficit reached almost 20% of GDP in 2022-2025 (compared to 3.63% before the invasion).

▸ Conclusions

The study demonstrated that the state of fixed assets in Ukraine's agriculture was highly sensitive to wartime conditions. Under the baseline scenario, the depreciation level improved gradually – from an unsatisfactory 37.57% in 2012-2021 to forecast satisfactory 39.6% by 2030. The optimistic scenario showed a faster recovery, though depreciation still exceeded pre-war levels, indicating persistent post-shock effects. In contrast, the pessimistic scenario maintained an unsatisfactory depreciation rate (>45%) through 2030, signaling continued asset degradation. The expansion of organic farmland, as evidenced by EU experience, contributed to reduced asset depreciation (by 0.15 p.p.). For Ukraine, a 3% share of organic land improved the indicator by 0.07 p.p., while will reach 10.54% by 2030 led to a 0.29 p.p. improvement. Thus, organic production development could partially supported post-war recovery, though it cannot fully offset the destructive effects of prolonged hostilities.

The forecasted cereal yield exceeded the optimal range (45-55 c/ha) after 2026, will reach 79.50 c/ha by 2030. Even with losses under the O2 strategy (1.97 c/ha), the indicator approached optimal levels compared with the baseline forecast. Similarly, corn yield surpassed the unsatisfactory threshold (75 c/ha) after 2025, achieving 82.1 c/ha by 2030, and improved under O2 despite slightly higher losses (2.60 c/ha). However, milk self-sufficiency will decline under organic expansion – from 0.56 p.p. (O1) to 1.96 p.p. (O2) in 2030 – worsening an already critical condition (< 80%). Additionally, the lower average milk yield (196.49 kg less than the baseline) moved the indicator (5,493.6 kg) further from the satisfactory level (5,500 kg). Consequently, the O2 strategy cannot be recommended for maintaining food or industrial security if hostilities persist or subside only gradually. Future research should refine war impact assessment by integrating infrastructure destruction factors and modelling the potential of state support programmes to reverse negative trends, particularly the decline in livestock numbers, to strengthen Ukraine's food security.

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▸ Conflict of Interest

None.

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Сценарний аналіз ступеня зносу, врожайності зернових, надоїв молока у контексті економічної безпеки України

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▸ **Анотація.** Метою цього дослідження було моделювання динаміки показників промислової та продовольчої безпеки України в контексті стратегій розширення площ органічних земель і сценаріїв ведення бойових дій до 2030 року. Методологічну основу становили моделі часових рядів із урахуванням екзогенних змінних та багатофакторні моделі лінійної регресії. Встановлено, що зниження ступеня зносу основних засобів у сільському господарстві на 0,15 в.п. у результаті зростання частки органічних земель на 1 в.п. не становить загрози промисловій безпеці України, проте не може компенсувати руйнівні наслідки російсько-української війни. Визначення цільового показника у 10 % органічних площ наблизить урожайність зернових (64 ц/га) до оптимального діапазону (45-55 ц/га) за умов середньозважених втрат урожайності на рівні 1,97 ц/га у 2030 році. Урожайність кукурудзи, навіть за наявності втрат (2,60 ц/га), залишатиметься на незадовільному рівні – 75 ц/га. Хоча середньорічний надій молока, за базовим прогнозом, досягне задовільного рівня у 2028 році (5 521,2 кг > 5 000 кг), втрати урожайності (119,89 кг), пов'язані з часткою органічного поголів'я понад 10 %, унеможливлять досягнення цього рівня до 2030 року. Тому прискорений розвиток органічного молочного виробництва не може бути рекомендований за жодним із розглянутих сценаріїв. Водночас досягнення частки органічних корів у 3 % не створило загрози промисловій безпеці (за винятком песимістичного сценарію війни до 2030 року). Враховуючи критичний стан самозабезпечення молоком (<80 % починаючи з 2025 року), що стало наслідком сталого скорочення поголів'я корів, розвиток органічного молочного виробництва посилило проблему продовольчої небезпеки. Результати дослідження можуть бути використані органами виконавчої влади України для розроблення обґрунтованих стратегій переходу до органічного сільського господарства, які відповідатимуть цілям економічної безпеки

▸ **Ключові слова:** показники промислової безпеки; сценарії війни; стратегія; розвиток органічного виробництва; самозабезпечення молоком; продовольча небезпека