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

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

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

▶ Introduction

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

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

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

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

▸ Materials and methods

Methodological principles for assessing and forecasting food security indicators in Ukraine. In the study, an officially approved methodology for assessing the main food security indicators (Resolution of the Cabinet of Ministers of Ukraine No. 1379, 2007) was used; however, its provisions were adapted for the purposes of forecasting analysis. At the first stage, based on available data up to 2021 from the State Statistics Service of Ukraine (n.d.), time series of key food system indicators were constructed. For each indicator, separate calculations were carried out in accordance with standard formulas, in particular: Indicator 1 – the daily dietary energy value per person (reflecting the overall level of food provision of the population) – not less than 2,500 kcal per day. Indicator 2 – the adequacy of consumption of basic food products – the index should be no less than 1.0 (compliance of actual consumption with rational norms). This indicator was calculated using the formula:

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

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

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

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

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

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

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

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

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

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

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

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

1) the observation equation:

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

2) level update:

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

3) trend update:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The minimum AIC value indicated the most balanced model. After determining the best model for each indicator, forecasting for 2025-2026 was carried out. As these values were formed without accounting for the shock of the war (due to the absence of data after 2021), they reflected a hypothetical trajectory assuming the continuation of pre-war trends. For all indicators, forecasting was performed in the R environment using the forecast and stats packages. Given the wartime nature of the shock in 2022-2026 and the destabilisation of logistics, state reserves, and foreign trade, the baseline forecast was adjusted in accordance with a "partial recovery" scenario. The scenario assumed: 1) 2022 – a decline of most indicators by approximately 15%; 2) 2023 – partial recovery (10% of the peacetime forecast); 3) 2024 – convergence towards pre-war dynamics (5%); 4) 2025 – return to the forecast trajectory. The scenario was developed based on an analysis of Ukraine's macroeconomic dynamics in 2022-2024 and forecast assessments by international financial institutions, including the International Monetary Fund (2023), the World Bank *et al.* (2023), and the National Bank of Ukraine (n.d.). Additionally, analytical assessments by international institutions regarding the global food situation and economic recovery were taken into account (FAO, 2023; OECD, 2023). Adjustment coefficients were determined by aligning the scale of decline in key macroeconomic indicators with the sensitivity of food security indicators to economic shocks.

Results and Discussion

Forecasting and analysis of trends in key food security indicators

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

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

Figure 7. Forecast values for Indicator 1

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

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

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

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

Table 1, Continued

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

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

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

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

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

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

Figure 8. Forecast values for Indicator 2

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

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

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

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

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

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

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

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

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

Figure 9. Forecast values for Indicator 3

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

According to the modelling results, the ARIMA model was identified as the most accurate for forecasting the volume of food grain in reserves and domestic consumption of bread and bread products in grain equivalent, as it produced the lowest error during the test period. This indicated that the dynamics of grain consumption in Ukraine exhibited pronounced inertia and a gradual, smooth decline, which the ARIMA model reproduced most accurately. In 2025-2026, the volume of grain continued to decrease, which was fully consistent with the long-term trend of declining bread consumption in Ukraine. Table 3 presents the actual values for 2009-2021 and the forecast indicators for 2025-2026 obtained using the ARIMA model. This made it possible to trace changes over the long term and to assess the impact of wartime events on the adequacy of state food grain reserves.

Table 3. Volume of state food grain reserves

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

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

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

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

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

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

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

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

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

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

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

Figure 11. Forecast values for Indicator 5

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

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

Table 5. Economic accessibility of food products

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

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

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

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

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

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

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

Figure 12. Forecast values for Indicator 6

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

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

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

Table 6. Assessment of domestic market capacity, thousand tonnes

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

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

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

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

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

Figure 13. Forecast values for Indicator 6

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

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

Table 7. Imports of food products, thousand tonnes

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

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

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

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

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

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

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

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

Table 8, Continued

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

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

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

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

Conclusions

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

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

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Conflict of interest

None.

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

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

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