# Analysis the capacity of grain export potential in Ukraine, possible reasons for the decrease and development trends

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**Abstract**. The research presents an analysis of grain production and export capacity in Ukraine from 2010-2021. The major general factors that have recently affected the country's macroeconomic indicators and determined their potential for the decline have been destroyed and damaged infrastructure, a high level of military threat to crops, and massive internal and external migration of working-age people and businesses. Therefore, analysis of the availability and regularity of changes in the production reserve of these crops for domestic farm use and external consumers defines the relevance of the issue under study. The purpose of the study is to analyse the main indicators of grain crop production in Ukraine and to identify the factors that significantly influence their export potential. Using technical statistical methods, models have been developed to demonstrate possible fluctuations in the number of grain exports, considering the possible development of the country's economy. Using regression methods, the main factors influencing the export potential of grains were identified. These factors have been demonstrated to include, in particular, gross harvest volumes, availability and quantities of mineral and organic fertilisers, purchasing prices for produce, etc. A sustained long-term trend in grain exports over the past 10 years is demonstrated, but it has been established that Ukraine's significant export potential could change significantly. It could affect the economies of Ukraine's grain-importing countries. It is suggested that the adverse impact of the possible causes of Ukraine's declining export potential should be reduced through further development of technologies for growing, storing and transporting grain crops. The applied value of the results is to reduce uncertainty in the agricultural market for agro-industrial and foreign trade institutions by accounting for the impact of major grain production and export indicators

**Keywords**: exports of grain, economic analysis, grain yields, cultivated area, wheat cultivation

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## INTRODUCTION

The share of grain exports from Ukraine to other countries is very significant. With the beginning of the full-scale Russian invasion of Ukraine, the opportunity to export grain crops abroad has significantly decreased, but Ukrainian grain is still supplied. As of the end of November 2022, Ukraine exported 16,239 thousand tons of grain and legumes (Ministry of Agrarian Policy…, 2022). Compared the volume of grain exports with last year, it can be seen that with the beginning of the full-scale war, it decreased by more than 7 thousand tons. According to Ukrainian Grain Association statistics (UGA, 2022), corn (11,051,295 tons) was exported the most since March 2022, while wheat exports took the second place by volume (6,251,277 tons). The above statistics show the urgency of solving logistical and economic problems with the delivery of Ukrainian grain around the world, because otherwise importing countries may face a significant increase in prices or, in the worst case, starvation.

The search for a solution to the problem of exporting goods during crisis periods has been studied by scientists in the economic and agrarian spheres for a long time. For example, researchers C. Betrán and M. Huberman (2022) studied the influence of internal and external factors on the formation of political decisions in Spain in the interwar period. The study covers the period of the Great Depression (1929-1930), during which tariffs were the basis of the political approach to support the economy. The Spanish government was faced with the need for bilateral negotiations to open new markets for goods. As can be seen from the results of the articles, the saving step for the Spanish economy was cooperation with Great Britain and Italy, which agreed to accept Spanish goods in exchange for Spain's access to their market. The study shows that for difficult economic features, and it is necessary to have external partners, it is possible to prevent the recovery of the country's economy.

The role of grain exports in the events of the Great Famine in China was studied by H. Kasahara and B. Li (2020). In the course of the study, the scientists quantified the various causes that could have led to such mass mortality among the Chinese population from 1955 to 1963. Scientists have come to the conclusion that the increase in the volume of grain exports was directly proportional to the increase in the death rate of the Chinese. It is peculiar that death rates were higher in areas with fewer members of the Chinese Communist Party. Using the example of China, it can be seen that the lack of development of agricultural enterprises, an increase in the number of imported goods, and a parallel increase in the amount of exported grain can lead to a demographic catastrophe. Therefore, for Ukraine, reducing the export of grain in the post-war period can be quite a rational decision to avoid similar situations.

Other researchers such as Gutierrez *et al.* (2022), raised the issue of regulating the feed (cereal) market after the COVID-19 crisis. Cereal crops are consumed not only by humans but also by animals. This suggests an increase in the need for each of the states to import and export grain crops. The authors used a global vector auto regression model to estimate the shock to oil, exports, and stocks of wheat, corn, and barley for exporting countries. The results of the analysis indicate that grain prices remained stable in early 2020 thanks to the oil market. However, restrictions on grain exports, which could be observed at the beginning of 2020, may still lead to an increase in prices in importing countries. Given this forecast, reducing the volume of grain exported from Ukraine to other countries would be able to maintain a stable price policy in this food segment, but such actions may lead to the beginning of a shortage of grain crops at the national level. That is why the issue of export after the end of the war is so urgent.

Canada has a very large agricultural potential, but even such an economically stable state faced a crisis that was called the Great Canadian Grain Logistics Crisis. The events of the agricultural sector in 2013-2014 in Canada were studied by P.J.A.M. Rimmer and C. Comtois (2018). The researchers study the "politics" of Canada's grain supply chain, which includes producers, grain companies, rail companies, port operators and export buyers. P.J.A.M. Rimmer and C. Comtois (2018) suggest that Canadian grain exports have been in decline due to ineffective changes in the supply chain, particularly in the Asia-Pacific region. Researchers Brown *et al.* (2020) drew attention to the possibility of Canadian farms switching from low-value wheat to high-value canola. Such changes were associated with the abolition of export subsidies in the country in 1995. The authors of the study come to the conclusion that the adaptation of farms to new political and economic conditions can be carried out heterogeneously, but each farm must have an individual approach.

The purpose of the study is to identify factors that significantly affect the level of production and export potential of grain crops in Ukraine. It should consider the general economic situation in the country, investigate possible reasons for significant fluctuations in production, and identify potential scenarios for the development of Ukrainian grain exports. For this purpose, the following objectives have been set: to analyse statistical data from official sources on the main features of grain crop production and exports; to identify the main trends in grain production and to identify the main factors affecting this area of the economy; to establish a proper forecast of fluctuations in the capacity of Ukraine's grain export potential and to estimate the possible consequences.

## MATERIALS AND METHODS

To estimate the production capacity and export potential of grain crops, the use of official statistical methods to determine this integral indicator has been suggested.

During the preliminary analysis, the main groups of indicators that comprehensively describe the export potential of the country's agro-industrial complex were identified. The export potential of grain crops was estimated in the following sequence: to define a system of indicators to estimate the grain export potential; to determine the significance of individual indicators in the system for grain export volumes; to define the influence of the most influential indicators on the level of grain crops export potential; to calculate the forecast of grain export volumes for the medium term; to develop recommendations for agro-industrial and foreign trade institutions by considering their impact on the main indicators of grain crop production and exports according to the results of the forecast.

The main input data for the analysis of grain production indicators are derived from sources (State Statistics Service of Ukraine, 2022; Ukraine 2022, 2022) and for the years 2010-2021. To obtain an estimate of the prospects in the export potential, there is a necessity to forecast grain export volumes based on the series of dynamics of grain production volumes in Ukraine, the cultivated areas used for this purpose, the amount of mineral and organic fertilisers used, purchasing prices, etc. In the process of selecting a method for forecasting the capacity of grain export potential, it is considered that the forecast result must fulfil the requirements of applicability to the studied dynamic series and the objective significance of the obtained estimates (Hunk *et al.*, 2003). Considering this, it is suggested to use adaptive models of nonlinear type, which is described in (Ingle *et al.*, 2021; Silva *et al.*, 2019). These methods are seasonal and reflect modern approaches to forecasting complex time series, such as production and export volumes of grain crops. The trend adaptive model for forecasting the level of the indicator St will be called the analytical function of the type:

$$\begin{cases} S_t = f(t, \boldsymbol{G}) \\ F(G) = S_t - f(t-1, \boldsymbol{G}) \end{cases}, \quad (1)$$

where: $t$ – time unit given in the considered case, years; $G$ – vector of parameters significantly influencing the levels of the forecast indicator.

The function $F(G)$ allows the deviation of the actual and modelled values of $S_t$ over time to be estimated and the dependence of the parameters at which the model has the highest possible accuracy to be clarified. In general, the function $f(t, G)$ can be represented in analytical form, or by a complex neural network, etc. To establish these models, the least-squares method of error estimation is applied in most cases. The forecasting of grain export volumes has been suggested using the Holt-Winters exponential triple-smoothing (ETS) time-series forecasting method (Holt, 2004; Winters, 1960). Compared to simple and double exponential smoothing, the Holt-Winters triple exponential

smoothing model considers trend and seasonality factors (Holt, 2004; Winters, 1960). The selection of this model is based on the fact that it has performed extremely well for data with a pronounced seasonal component. It is assumed that the seasonal component of grain production and export levels is additive based on a predetermined annual period of constant periodic fluctuations from the mathematical expectation. With additive seasonality, the level of indicator St at time t is calculated as a recurrent relationship as:

$$S_t = \alpha(X_t - C_t - R) + (1-\alpha)(S_t - 1 + B_t - 1) \quad (2)$$

where: $X_t$ is the levels of the original time series in period t; $S_t$-1 is the seasonally deprived, smoothed value in the previous period $t$-1; $B_t$-1 is the trend component of the series; $C_t$ is the seasonal component of the series; $R$ is the season length in periods; $\alpha$ is the level smoothing factor, $\alpha \in (0, 1)$, which is selected based on the minimum accumulated error in expression (1).

Using the smoothing coefficient $\alpha$, the influence weight of the current value of $X_t$ and the smoothed previous value of $S_t$-1 of the level of grain exports is distributed. In calculating the smoothed value, the following feature is considered: if the corresponding smoothing coefficient is closer to 1, the values of the current and the nearest previous values of grain export levels are considered more. To identify the main trends in grain production and exports, regression methods have been proposed. The selection is based on the fact that, despite their relative simplicity, these methods provide effective results even when a large number of factors are involved. The multiple regression equation for capacity and export volumes of grain crops $S_t$ can be represented as:

$$S_t = f(\beta, W) + \varepsilon, \quad (3)$$

where: $W = W(W_1, W_2, ... W_i, ... W_m)$ – vector of factors influencing the one under study; $\beta$ – weight vector of coefficients to be determined; $\varepsilon$ – random error (or deviation).

In explicit form, the linear multiple regression equation has the form:

$$S_t = \beta_0 + \beta_1 W_1 + \beta_2 W_2 + ... + \beta_m W_m + \varepsilon, \quad (4)$$

where: $\beta_0$ – free regression term, determining the value of $S_t$, in the case when all factors $W_i$ and $\in [1...m]$, are 0; $\beta_1 ... \beta_m$ – regression coefficients.

The estimation of the regression coefficients $\beta_i$ is proposed to be performed using the least-squares method, as it is quite common and efficient as it provides a minimum of the mathematical expectation of the random deviation $\varepsilon_i$. To solve the problem of identifying the main factors influencing grain production and exports, it is suggested to estimate the value of the paired correlation coefficient:

$$R_m = \frac{\sum_i (W_i - \overline{W})(St_i - \overline{St})}{\sqrt{\sum_i (W_i - \overline{W})^2 \sum_i (St_i - \overline{St})^2}}, \quad (5)$$

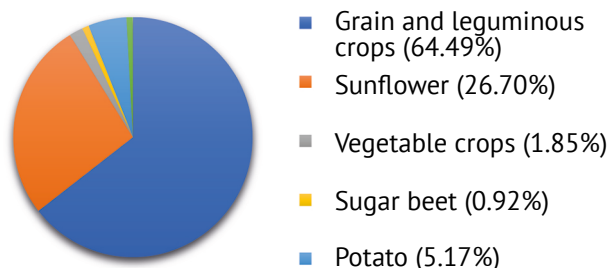where: $\overline{W} \, \overline{St}$ – is the mathematical expectation of the corresponding values $W_i$ and $St_i$ at time $i$.

The quality of the obtained regression model is suggested by identifying the hypothesis of equality of zero coefficient of determination of data by Fisher's F-criterion using well-known methods (Lomotko *et al.*, 2019; Silva *et al.*, 2019).
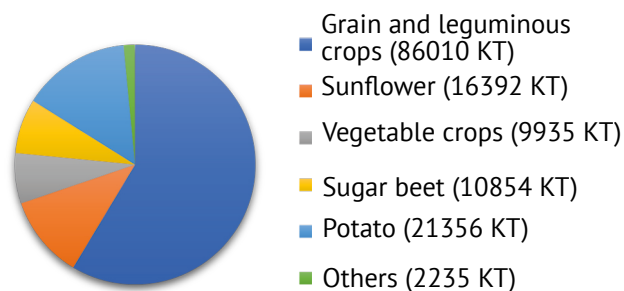
## RESULTS AND DISCUSSION

The production and export of grain and leguminous crops occupy a major place in the income structure of the national economy. Grain production is the activity of agricultural producers, which is specifically designed to grow grain to meet the domestic demands of Ukraine for seed, grain for food, fodder and technical purposes, to improve its quality, to maintain and develop the export potential of grain crops market, and is associated with the food security of Ukraine through the development of grain economy (Law of Ukraine No. 37-IV, 2002). The situation in the Ukrainian economy and agro-industrial complex is defined by the high level of military threat to agriculture and crops, massive damage to the infrastructure necessary for proper functioning and other adverse consequences. It presents new challenges to all economic subjects. Therefore, the analysis of the availability and patterns of changes in the reserve of grain crop production for domestic usage of the farm and external consumers determines the relevance of the question under study.

The agricultural industry occupies one of the main positions in terms of volume and financial performance among all economic activities in the country. A significant role in agricultural production is dedicated to the cultivation of grain crops. Grain and its products have multiple uses: food, fodder and technical. The leading crop for the national economy in terms of production and cultivated area belongs to grains (Fig. 1). As it can be seen, cereals and leguminous crops dominate in the structure of cultivated area – 64.49% of the total Ukrainian crop production, which according to (State Statistics Service of Ukraine, 2022) in 2021, amounted to 24804 thousand hectares. By production volumes (Figure 2) wheat and maize are in the lead, respectively 38.7% and 47.1%, followed by 11.4% of barley in the total production of grains and leguminous crops in 2021. It demonstrates the significance of studying the availability of these crops for domestic use in Ukraine and for external consumers who import grain from Ukraine.



■ Grain and leguminous crops (64.49%)

■ Sunflower (26.70%)

■ Vegetable crops (1.85%)

■ Sugar beet (0.92%)

■ Potato (5.17%)

***Figure 1****. Structure of cultivated area in Ukraine (2021), %*
***Source:*** *State Statistics Service of Ukraine (2022)*



■ Grain and leguminous crops (86010 KT)

■ Sunflower (16392 KT)

■ Vegetable crops (9935 KT)

■ Sugar beet (10854 KT)

■ Potato (21356 KT)

■ Others (2235 KT)

***Figure 2****. Production volumes of grains and leguminous crops in Ukraine (2021), KT*
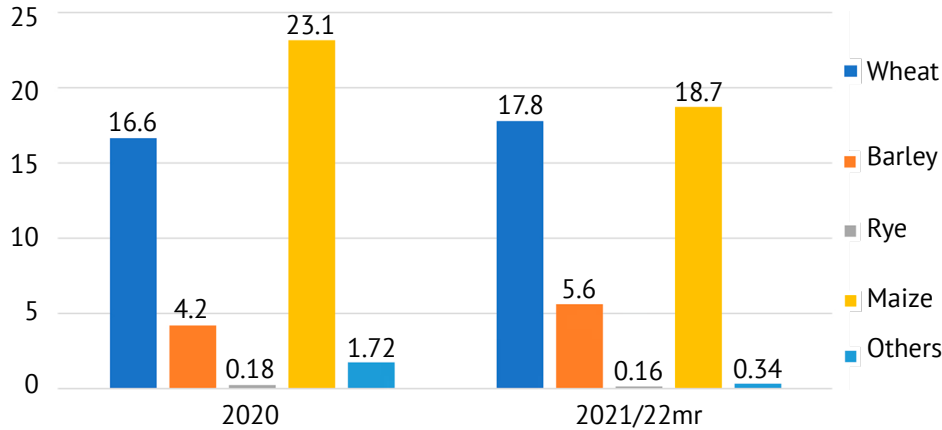***Source:*** *State Statistics Service of Ukraine (2022)*
***Note:*** *KT – thousand tonnes*

Currently, the government has been obliged to classify crops as critical goods for import under martial law. The criteria for this decision are defined in (Resolution of the Cabinet of Ministers of Ukraine No. 153, 2022) and reflect the fact that grain is a food commodity, the lack of which can result in a humanitarian and food crisis, and it is part of the production cycle of critical food commodities. The influence of this fact is considered in establishing the purposes of the study (Ukraine 2022, 2022). The study of trends in the grains market is connected to an analysis of the level of total grain yield in the country: according to (FAOSTAT: Ukraine, 2022), it has almost doubled, from 2.77 t/ha in 1992 to 5.38 t/ha in 2021, according to the data. Researchers argue that it has significantly affected the structure and priorities of the national economy and confirms a significant export potential (Kyzym *et al.*, 2014; Klymenko *et al.*, 2013). According to data (Kyrylenko *et al.*, 2017) Ukraine aspires to join the world's leading economic alliances, which requires the development of strong, extensive international economic relations and the conclusion of appropriate foreign economic agreements. Up to 70% of Ukraine's agricultural production is exported through transnational corporations, which unfortunately does not guarantee continued investment in the industry and provides little stability in the agribusiness complex (Nakonechna & Yakubovska, 2018).

At the beginning of 2022, there is a tendency for Ukrainian grain exports to decrease and export prices to increase from $200-250 to $400-450/t in world markets (Grain: World Markets and Trade, 2022). It contributes to the termination of existing and lack of commercial interest in new contracts for the supply of grain products to the European Union (EU) and other countries (Garbelini *et al.*, 2022). Compounding the trend is the forced transportation of crops by rail through congested land border crossings, which has resulted in longer delivery times and more complicated grain logistics (Lomotko *et al.*, 2019). To reduce the level of uncertainty in the grain market, a necessity emerged to forecast trends and developments in the market. Regrettably, the analysis of most of the reviewed studies demonstrates insufficient consideration of current

trends in the agricultural industry. Therefore, the obstacles to the conclusion of long-term contracts due to martial law and the situation of the Ukrainian economy, against the background of the rapid integration into the EU, cannot ensure stability in the production and export volumes of grain crops. Ukraine has exported 45.8 million tonnes of grain in 2020 and 42.6 million tonnes in 2021-2022 marketing year (mr) (as of February 21, 2022), as presented in Figure 3 (State Statistics Service of Ukraine, 2022).



**Figure 3**. *Structure of grain and leguminous crops exports in Ukraine*
**Source:** *State Statistics Service of Ukraine (2022)*

The gross harvest and yield of the crop vary according to natural-geographical and anthropogenic factors (Nakonechna & Yakubovska, 2018; Vasylkovska & Malakhovska, 2019). Natural factors include the availability of cultivated areas, natural soil fertility, climatic conditions and photosynthetic activity. Technogenic factors refer to the level of modern technology used to provide plants with moisture, the required amount of mineral and organic matter (Guo *et al.*, 2022). The main input data for the analysis of grain production indicators are considered for 2010-2021 and are presented in Table 1.

**Table 1**. *Main indicators of Ukraine's agro-industrial complex for the production of grain and leguminous crops in all categories of farms*

| Year | Cultivated area of grain and leguminous crops, thousand ha | Production volume (gross harvest) of grain and leguminous crops, thousand tonnes | Grain export, thousand tonnes | Mineral fertiliser application for grain and leguminous crops (excluding maize) thousand tonnes | Organic fertiliser application for grain and leguminous crops (excluding maize) thousand tonnes | Average prices of agricultural grain products, UAH/t |
|---|---|---|---|---|---|---|
| | $W_1$ | $W_2$ | $S_t$ | $W_3$ | $W_4$ | $W_5$ |
| 2010 | 15090 | 39271 | 12180 | 185.3 | 2939.5 | 1120.9 |
| 2011 | 15724 | 56747 | 23230 | 261.8 | 2916.8 | 1374.2 |
| 2012 | 15449 | 46216 | 22190 | 340.6 | 2825.3 | 1547.1 |
| 2013 | 16210 | 63051 | 32520 | 439.6 | 2620 | 1299.8 |
| 2014 | 14801 | 63859 | 35600 | 404.7 | 2253.4 | 1801.4 |
| 2015 | 14739 | 60126 | 38620 | 342.3 | 2332.5 | 2912.1 |
| 2016 | 14401 | 66088 | 44990 | 410.7 | 2025.4 | 3414.0 |
| 2017 | 14624 | 61917 | 40270 | 478.8 | 1873.9 | 3771.6 |
| 2018 | 14839 | 70057 | 50090 | 482.5 | 2316.6 | 4315.0 |
| 2019 | 15318 | 75143 | 55090 | 528.0 | 2368.5 | 3867.5 |
| 2020 | 15392 | 64933 | 45810 | 659.9 | 2060.7 | 4794.1 |
| 2021 | 15995 | 86010 | 50800 | 630.5 | 1875.7 | 6296.1 |

**Source:** *based on data from (State Statistics Service of Ukraine, 2022; FAOSTAT: Ukraine, 2022)*

The publications (Kyrylenko *et al.*, 2017; Nakonechna & Yakubovska, 2018) consider exports to be an essential factor for economic growth and the integration of the state into international relations with EU countries and the world economy, i.e., exports are already acquiring the features of potential. Thus, exports of agro-industrial products ensure Ukraine's ability to attain the general economic purposes of European integration and the ability to solve the problems of grain and leguminous products supply not only for a particular country but to contribute to the solution of the world food problem in general. Since the early 2022, EU grain markets have been significantly affected by the situation in the Ukrainian economy and the nearly completely discontinuation of Ukrainian grain exports compared to previous years (Table 1). As Ukraine is a major exporter of wheat and maize, the result has been a sudden shift in demand to suppliers from outside Europe and a 2-3x increase in grain export prices. The trend is an attempt to start transporting crops by rail rather than by sea, which has caused sharp fluctuations in quotations on world markets. For example, quotations for maize exports declined slightly due to the level of harvests in South America (Grain: World Markets and Trade, 2022). In comparison, there is stability in the rice market, whose producers are in relatively calmer economic conditions outside Europe, which contrasts with the volatility of wheat and maize (Fig. 4).
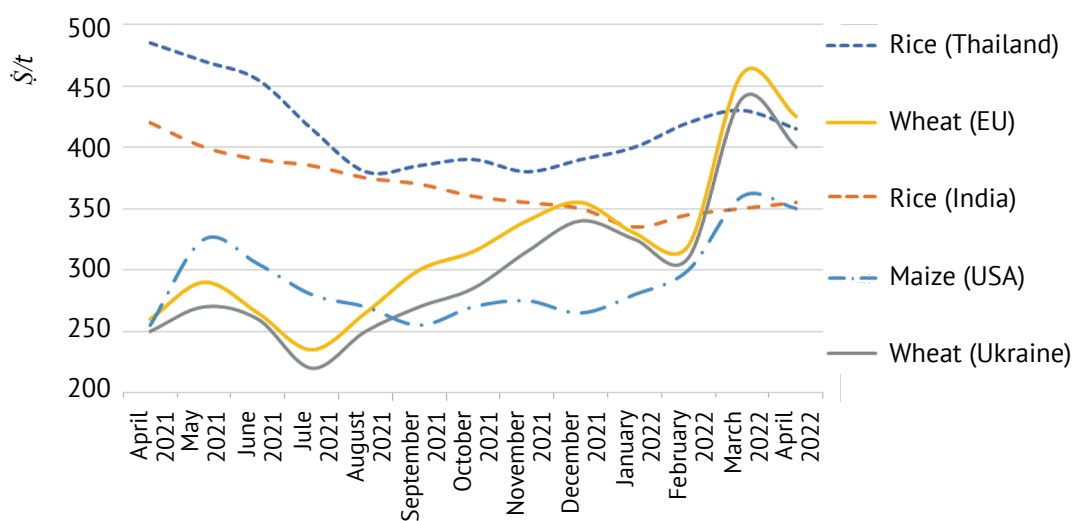


*Figure 4*. The dynamics of quotations on the world crop market
**Source:** *Grain: World Markets and Trade (2022)*

Ukraine's grain export potential correlates with global grain market trends. The data analysis presented in (Nakonechna & Yakubovska, 2018; Melnyk, 2017) indicates that world grain production in the short and long term can generally fulfil the demand for grain products, even if the world population continues to increase by 80 million people each year. Under these conditions, it is forecasted that the growth in grain crop production will be mostly due to its development in those countries where there are suitable conditions for it. Therefore, the conditions of the Ukrainian agricultural market should be attributed precisely to promising regions with strong grain crop producers. A negative trend that could constrain further increases in global grain production is the limited amount of land available for grain cultivation. It is explained by the high level of urbanisation and the necessity to preserve forests, further involvement of unused fertile lands in the conditions of limited water resources for agricultural purposes. The Ukrainian grain and legume market is significantly affected by this, as most grain seeds are exported at prices that are established on international stock exchanges. However, the latter level is influenced by the global trend in grain production and consumption, as tracked by relevant indicators of global price fluctuations and quotations on the world crop market (FAOSTAT: Ukraine, 2022). To reduce the level of uncertainty in the grain market, a necessity emerged to forecast trends and developments in the market.

The forecasting of the export capacity of crops was performed using the Holt-Winters exponential triple-smoothing method using formulas (2) and (3) with a 95% confidence interval, the result is presented in Figure 5.
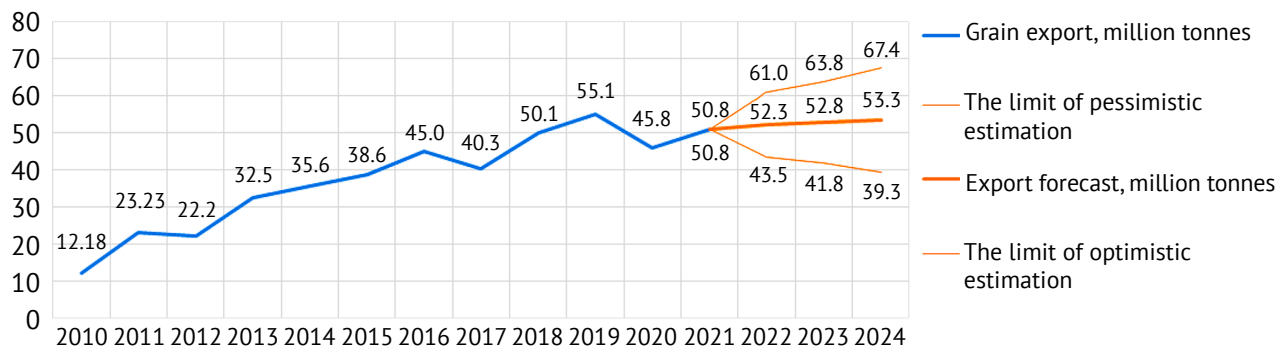
**Figure 5**. *Forecast of grain export potential dynamics*

*Source: authors' research*

Thus, if the current trend in grain export volumes continues, the slight increase to 52.3 million tonnes in 2022 and 52.8 million tonnes in 2023 is more realistic. However, the situation in the Ukrainian economy allows asserting that the pessimistic scenario – 43.5 million tons in 2022 and 41.8 million tons in 2023, or a reduction of grain export by 18% – is a more realistic forecast. The accuracy of the forecast was estimated at 84%, which is a rather high value for the forecasting method applied. In contrast to the proposed approach, studies (Ingle *et al.*, 2022; Silva *et al.*, 2019) are based on ARIMA (autoregressive integrated moving average) models of an integrated autoregressive moving average model for the time-series analysis. They are used to forecast demand for grain, flour, food products. The authors demonstrate that their model is sufficiently reliable and can be used for demand forecasting, both for the industry in general, for individual farms, retail outlets, supply chains and transport, and inventory management purposes. But the Holt-Winters model used is well-established in agricultural and food production research due to its prevalence and relative simplicity of construction, and, as calculations have demonstrated, sufficient predictive validity (Lomotko *et al.*, 2019).

Forecasting the demand for resources such as food, grain, and water is one of the key objectives of most companies and economies in general (Klymenko, 2013). Resource consumption varies according to several factors, including periodicity over time and accidental occurrence. That is why resource demand forecasting is performed using models, the results of which have been analysed in detail in (Hunk *et al.*, 2003; Ingle *et al.*, 2021; Sirohi *et al.*, 2021). The forecast data obtained by the authors from such models are used for managing, controlling and adjusting the existing production and supply of the resource, and for designing the elements of the required infrastructure for this purpose. However, it may be observed that there is no universal method for forecasting and modelling crop production and exports. For this reason, the authors (Hunk *et al.*, 2003; Holt, 2004; Winters, 1960) proposed a solution in which the dynamics of the process under study are determined

by trend analysis and a random factor. The implementation of such prediction models has demonstrated a good correspondence with empirical and predictive data and a relatively accurate reflection of the fluctuations of the research process over time. Therefore, the results obtained in the study in this research using the Holt-Winters method demonstrate this as a good tool for forecasts in agricultural production.

The search for the main factors influencing grain exports was performed using formulas (3) and (4) using the least squares method, the following regression equation was obtained (regression equation estimation):

$$S_t = 108107.6223 - 12.4083W_1 + 0.8576W_2 + \\ + 60.9059W_3 + 16.0424W_4 + 0.08657W_5. \quad (6)$$

The regression coefficients have the following interpretation:

Constant estimates the aggregate impact of factors other than those considered in the model (6) on the volume of grain exports $S_t$, which would amount to 108107.62 thousand tonnes. Coefficient $\beta_1$ indicates that with an increase in the cultivated area of grains and leguminous plants per 1 thousand ha the volume of grain export decreases by 12.4083 thousand tonnes. It is explained by the specific features of grain cultivation technology under extensive farming conditions and by the fact that the expansion of the cultivated area is generally performed for domestic consumption. This influence naturally has some limits, the establishment of which is beyond the scope of this study. Coefficient $\beta_2$ demonstrates that with an increase in the gross harvest of grains and leguminous crops by 1 thousand tonnes, the volume of grain exports increases by 0.8576 thousand tonnes. It is explained by the desire of agricultural companies to export grain residues (if any).

Coefficient $\beta_3$ indicates that with an increase in mineral fertiliser application under crops of grains and leguminous crops by 1 thousand tonnes, the volume of grain export increases by 60.9059 thousand tonnes. It can be explained by the natural causes of the impact of mineral fertilisers on the level of yield. Evidently, the positive impact has some limits, the establishment of which is beyond the scope of this study (Nakonechna &

Yakubovska, 2018). Coefficient $\beta_4$ demonstrates that with an increase in organic fertiliser application under grains and leguminous crops by 1 thousand tonnes, the volume of grain export increases by 16.0424 thousand tonnes. It can be explained by the natural causes of the effect of organic fertilisers on yield levels, by analogy from the previous factor. Coefficient $\beta_5$ indicates that with an increase in the average price of agricultural grain products by 1 UAH/t, the volume of grain exports increases by 86.57 t. It is explained by the desire of agricultural companies to export grain residues at the most attractive price.

The list of factors influencing the volume of grain exports is not exhaustive and can be expanded by considering additional factors (Grain: World Markets and Trade, 2022; Vasylkovska & Malakhovska, 2019), and model (6) will result in an enriched and more refined one. The correlation coefficient is known to reflect the degree of connection between two indicators. If the coefficient is close to 0, it indicates the absence of a connection between the variables. To find the degree of influence of the main factors on grain exports, the following results were obtained for the raw data in Table 1 using formula (6): coefficient $R_1 = -0.137$ indicates a low level of influence of the cultivated area of grains and leguminous crops on the volume of grain exports; coefficient $R_2 = 0.904$ demonstrates a very strong level of influence of the gross grain harvest on grain export volumes; coefficient $R_3 = 0.840$ indicates a strong influence of the amount of fertiliser applied to grain and leguminous crops on grain export volumes; coefficient $R_4 = 0.798$ indicates a strong influence of the amount of organic fertiliser applied to grain and leguminous crops on grain export volumes; coefficient $R_5 = 0.839$ indicates a strong level of influence of the average price of agricultural grain products on the volume of grain exports.

A qualitative evaluation of the resulting model (6) was performed by testing the hypothesis of nullity of the coefficient of determination of the data by Fisher's F-criterion. The Fisher's F-criterion for the model is 42.751, the critical value for 5 degrees of freedom is 4.39. Since 42.751>4.39, the influence of the factors can be considered statistically significant and the regression equation (6) is statistically reliable. According to experts (How much grain does Ukraine export, 2022), the cultivated area of grains in Ukraine has recently decreased by 10-12%. Most experts are inclined to believe that the decline in the main indicators of grain and fertiliser production will be in the range of 10-15%. Based on this, the resulting regression model (6) was applied to predict the export potential of grain crops. Grain exports in 2022 are estimated at 47.7 million tonnes and in 2023 at 42.8 million tonnes, assuming current trends remain unchanged. It corresponds to the pessimistic scenario in the previous forecast model, with the discrepancy between the results not exceeding 9%. Considering this, it can be assumed that the models obtained are of sufficiently high quality and appropriate.

Notably, changes in the amount of cultivated area, in the quality of the crop due to the evolution of production technology and fluctuations in world procurement prices have a significant impact on the export potential of the state. Meanwhile, an analysis of the resulting impact of the factors concludes that seasonal demand for grain products requires compensation. It can be used at specific times of the year in the domestic market, but agribusinesses have the option of exporting to foreign markets at different times of the year. Selling the excess production volume of grain products to exports, if the proposed forecast model is applied, would facilitate the ability to sell their products in the foreign market without giving large discounts to foreign buyers or not lead to the elimination of excess production of agro-industrial products. At the present stage of Ukraine's economic transformation, the issue of adapting foreign trade to EU requirements arises. A significant factor influencing the Ukrainian agricultural sector is the pre-crisis excess of its production potential over domestic market demand (Nakonechna & Yakubovska, 2018). It has established a vector for national export policy development, but requires a complex process of transition to international quality standards in the areas of agricultural products themselves, customs regulations and transport technologies (Esfahani *et al.*, 2019; Council Directive 92/106/EEC, 1992).

Unfortunately, Ukrainian exporters of grain and leguminous crops, compared to all major trade competitors, have no efficient system of insurance, crediting and export guarantees, which cannot fully ensure the promotion of their agricultural exports. Based on the forecast models obtained, it is possible to propose actions to improve the normative regulation of export relations in the market of agro-industrial products by strengthening measures to protect the interests of Ukrainian grain producers in anti-dumping, special protective or countervailing measures against agricultural goods of Ukrainian origin. Recent events in Ukraine have proved the necessity to increase the effectiveness of work on preventing price discrimination of Ukrainian grain products on foreign markets, establishing an updated contractual and legal framework with partner countries to protect the interests of Ukrainian producers of agro-industrial products on foreign markets and improving the efficiency of information and advisory support and export development of grain crops. Summarising the data of the above sources and (Vasylkovska & Malakhovska, 2018; Melnyk, 2017) it is possible to estimate the export potential of grains as the ability of the national economy to produce competitive agricultural products and to sell them on international markets under conditions of continuous growth of efficiency of natural and land resources use, development of the scientific and technical potential of the agro-industrial complex, providing grain producers with foreign exchange and financial and credit support, and service and transport

infrastructure, subject to the establishment of a system of economic security for the country in general. It requires agribusinesses to support constant growth in yields and the efficiency of the applied agro-technologies, which is why the development of the economy in the period up to February 2022 observed a natural alternation of growth and decline in grain production in the absence of a long-term imbalance in the country's export potential for these products.

When assessing the place of the Ukrainian grain producer in the global market, note the EU export forecast for 2021/22, which has been reduced to 34.0 million. The main reason for this is a slowdown in supplies from Ukraine, and two EU members (Bulgaria and Hungary) have given priority to maintaining their reserves to combat high world grain prices (Grain: World Markets and Trade, 2022). Bulgaria and Hungary, which together account for 8% of EU wheat exports, are expected to export less wheat by the end of the trading year as their governments imposed restrictions on grain export volumes. Wheat exports from the EU are highly concentrated, with the five largest wheat exporters to the EU (France, Germany, Romania, Poland and Lithuania) accounting for 80% of total wheat exports. Thus, it is particularly notable that a significant part of the export deficit is the result of slower growth in France, Lithuania and Poland. Under such conditions, it is not easy for Ukrainian agribusinesses to establish their place in the global economic complex, especially since the world markets of major grain producers have already been established. On the other hand, Ukrainian grain exports are mainly a raw material source in the world market for the production of finished grain products, which, as a consequence, the country has to import from abroad. Experts (Grain: World Markets and Trade, 2022) estimate that EU exports will accelerate in the last quarter of 2022 as buyers shift away from supplies from Ukraine. To reach the reduced forecast of 34.0 million tonnes, exports from the EU must average 3.5 million tonnes per month. Demand for crops in Egypt, Turkey, Jordan, Nigeria and other markets in Africa is expected to increase, ending the trading year in line with the revised forecast.

In November 2021, Forbes selected the 13 largest agricultural companies in Ukraine (by annual revenue in 2020) (Ministry of Agrarian Policy and Food of Ukraine, 2022). The total revenue of 13 agricultural companies is UAH 342 billion (14.9%) out of the hundred largest private companies in Ukraine – UAH 2.3 trillion. The most efficient agricultural companies include "Kernel" (UAH 118.7 billion), "MHP" (UAH 51.5 billion), "Nibulon" (UAH 25.8 billion). The 13 largest agricultural companies employ 67,800 people. Considering the forecasts, the question arises regarding not only the financial but the social aspect of the consequences of adverse trends in the grain market. Studies (Nakonechna & Yakubovska, 2018) demonstrate that agricultural production faces the risk of severe water shortages and nitrogen fertiliser

efficiency, which could be another factor significantly influencing the performance of agricultural companies. In (Garbelini *et al.*, 2022) notes that the permanent use of intensive cultivation areas can worsen soil yields, profit margins for agribusinesses and environmental sustainability. Thus, the authors (Sirohi *et al.*, 2021; Guliyev *et al.*, 2021) conducted research on the level of grain yield and profitability of agricultural systems with various levels of plant diversity. It is proposed to do this by predicting yield volumes and automating particular processes. The disadvantage of such systems is their design cost. The proposed set of measures requires budgetary and extra-budgetary funding and foreign investment, the amount of which should be determined based on existing international practices, and an assessment of the national economy and the existing structure of grain exports. Thus, for these purposes, the selection of an efficient formal forecasting method will enhance the functionality of agribusiness operations and have the expected effect of reducing uncertainty in the grain market.

## CONCLUSIONS

The demand for grain crops products on both world and Ukrainian markets has a steady upward trend due to objective (natural influence on grain crop fertility, modern farming technologies, application of the latest fertilisers) and subjective reasons (changing consumption culture of the population, a trend towards the consumption of ecologically clean products). Statistical data analysis of the main features of crop production and exports in Ukraine demonstrates that the country's potential is, regrettably, unstable. Although the trend of grain exports in 2010-2021 is centred on growth, with a maximum of 50.8 million tons in 2021, the forecast obtained in this research demonstrates that the export potential of grains is expected to decrease. EU exports are expected to accelerate in the last quarter of 2022, as buyers unfortunately shift away from supplies from Ukraine. To reach the reduced forecast of 34.0 million tons, exports from the EU must average 3.5 million tons per month. That forecast estimate of grain supply to Egypt, Turkey, Jordan, Nigeria and some other countries demonstrates an increasing trend in demand.

The Holt-Winters exponential triple-smoothing method was selected as the methodological apparatus for forecasting economic processes in the grain market, and regression methods were proposed for identifying the main trends and the degree of influence of factors on grain exports. The influence of the main factors on a country's export potential has been defined, in particular, the amount of cultivated land, the amount of mineral and organic fertilisers applied, grain purchasing prices, etc. The resulting models demonstrated sufficient statistical reliability, and the discrepancy between the results obtained by the various methods did not exceed 9%. Assuming that the current trend in the volume of Ukrainian

grain exports continues, it is established that a slight increase to 52.3 million tons in 2022 and 52.8 million tons in 2023 is the most probable. At the same time, the proposed forecast models reflect current economic trends, which allows asserting the reality of pessimistic expectations for grain exports with its reduction by 18% to 43.5 million tonnes in 2022 and 41.8 million tonnes in 2023. The reliability of the forecast is estimated at 84%, which demonstrates the quality of the applied forecasting method. The way to reduce the possibility of a decline in the export potential of crops is to expand strong and extensive international economic connections and to conclude appropriate long-term foreign trade agreements for agro-industrial and foreign trade institutions. Thus, in the terms of the agreements, the predicted results obtained and the level of influence of the main factors investigated in the research should be considered. Taking into account the current state of Ukrainian crop production and its export, conducting further research to identify ways to avoid an economic imbalance in the grain market of Ukraine in the next 5-10 years was justified from a scientific point of view.

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## Аналіз потужностей експортного потенціалу зернових культур України, можливих причин занепаду та напрямів розвитку

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**Анотація**. У статті представлено аналіз виробництва та обсягів експорту зерна в Україні у 2010–2021 роках. Основними загальними факторами, що останнім часом вплинули на макроекономічні показники країни та визначили можливість їх занепаду, стали знищена та пошкоджена інфраструктура, високий рівень військової загрози для посівних площ, масова внутрішня та зовнішня міграція працездатного населення та бізнесу. Тому аналіз наявності та закономірностей змін резерву виробництва цих культур для внутрішньодержавного використання господарства та для зовнішніх споживачів визначає актуальність досліджуваного питання. Метою дослідження є аналіз основних показників виробництва зернових культур в Україні та виявлення чинників, що суттєво впливають на їх експортний потенціал. За допомогою використання формальних статистичних методів розроблено моделі, що відбивають можливі коливання обсягів експорту зерна з урахуванням можливого розвитку ситуації в економіці країни. Використання регресійних методів дозволило встановити основні фактори, що впливають на експортний потенціал зернових. Доведено, що до цих факторів, зокрема можливо віднести валові обсяги збору врожаю, наявність та кількість мінеральних та органічних добрив, закупівельні ціни на продукцію тощо. Показано стійку тривалу тенденцію до збільшення обсягів експорту зернових протягом 10 останніх років, але встановлено, що значний експортний потенціал України може суттєво змінитися. Це може вплинути на стан економік країн-імпортерів українського зерна. Пропонується зменшити негативний вплив можливих причин занепаду експортного потенціалу України шляхом подальшого розвитку технологій вирощування, зберігання та транспортування зернових культур. Практична цінність отриманих результатів полягає у зменшенні невизначеності на ринку сільськогосподарської продукції для агропромислових та зовнішньоторговельних установ шляхом врахування ними впливу основних показників виробництва та експорту зернових культур

**Ключові слова**: експорт зерна, економічний аналіз, врожайність зернових культур, посівна площа, вирощування пшениці