



OPEN ACCESS

EDITED BY

Maria Isabel Miguel,
University of Coimbra, Portugal

REVIEWED BY

Jana Majerova,
AMBIS University, a. s., Czechia
Stelian Curceac,
Karlsruhe Institute of Technology
(KIT), Germany

*CORRESPONDENCE

Nestor Shpak
✉ nestor.o.shpak@lpnu.ua

RECEIVED 26 December 2023

ACCEPTED 28 May 2024

PUBLISHED 10 July 2024



CITATION

Shpak N, Matviyishyn Y, Dziurakh Y and Gvozd M (2024) Simulation of the impact of changes in the volume of production and export of products on the food security of the country: on the example of Ukraine. *Front. Sustain. Food Syst.* 8:1361625. doi: 10.3389/fsufs.2024.1361625

COPYRIGHT

© 2024 Shpak, Matviyishyn, Dziurakh and Gvozd. This is an open-access article distributed under the terms of the [Creative Commons Attribution License \(CC BY\)](https://creativecommons.org/licenses/by/4.0/). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.

Simulation of the impact of changes in the volume of production and export of products on the food security of the country: on the example of Ukraine

Nestor Shpak^{1*}, Yevhen Matviyishyn ², Yurii Dziurakh ³ and Maryana Gvozd⁴

¹Department of Management and International Business, Institute of Economics and Management, Lviv Polytechnic National University, Lviv, Ukraine, ²Department of Regional and Local Development, Lviv Polytechnic National University, Lviv, Ukraine, ³Department of Administrative and Financial Management, Lviv Polytechnic National University, Lviv, Ukraine, ⁴Department of Management of Organizations, Institute of Economics and Management, Lviv Polytechnic National University, Lviv, Ukraine

Changes in the production of agricultural products in Ukraine are analyzed. Forecasting of the volume of exports of agricultural products from Ukraine until 2027 was carried out. The following factors were taken into account: projected changes in real GDP in those countries that are the main importers of these products; reduction of cultivated agricultural land caused by military actions; forecasted changes in the population of Ukraine during the forecast period. It was concluded that there are no threats to Ukraine's food security caused by changes in the production and export of agricultural products. The research was based on a forecasting method, which made it possible to take into account retrospective information and a number of internal and external factors affecting the processes of production and export of agricultural products. The sources of information were the data of the International Monetary Fund and the State Statistics Service of Ukraine. The hypotheses of the study were confirmed, and the results showed that the volume of production of agricultural products will be sufficient to support the population of the country, while maintaining the previous proportion of exports. At the same time, there is a potential for growth of the share of products that Ukraine can export. The forecast volumes of export of Ukrainian agricultural products obtained can serve as a guideline for regulating exports, taking into account the issue of food security in Ukraine.

KEYWORDS

agricultural production, import of Ukrainian products, food, food security, Ukrainian export

1 Introduction

Food security is a certain indicator that gives predictions about the probability of hunger in different countries of the world. Today, a lot of attention is paid to the issue of fighting hunger (Horn and Ferreira, 2022). This is evidenced by the content of the Sustainable Development Goals (SDGs), among which Goal #2 is formulated as follows: End hunger, achieve food security

and improved nutrition and promote sustainable agriculture (<https://ourworldindata.org/sdgs/zero-hunger>). After all, global warming, natural disasters (floods, droughts, fires, and earthquakes), wars, and the rapid growth of the population are the cause of the imbalance of food security, which causes hunger, especially in developing countries. The Food and Agriculture Organization of the United Nations (FAO) notes that the share of undernourished people is an indicator of a country's food security. Research data indicates that the world population is growing and is projected to reach 9.2 billion by 2050 (Silva, 2018). This will lead to an increase in the demand for food. The author notes that it is necessary to increase agricultural production by ~60–70% in order to ensure adequate nutrition for the world population by 2050 (Our World in Data Team, 2023). In their study, scientists (Pawlak and Kołodziejczak, 2020) emphasized the role of agriculture (Bashynska, I.,) in ensuring food security in developing countries in the context of the problem of sustainable food production. Indeed, many sub-Saharan African regions are highly dependent on imported crops (e.g., rice and wheat) and agricultural inputs (e.g., fertilizers), which exposes such countries to a greater risk of food insecurity imbalances due to disruptions in the global supply chain (Koval et al., 2023) caused by the COVID-19 pandemic and the ongoing war in Ukraine (Ben Hassen and El Bilali, 2022).

State governments ensure that food products are available to all categories of the population, as well as that strategic food stocks are replenished in case of emergency situations (harvest failure, natural disasters, man-made disasters, military actions, etc.). International organizations, together with FAO (FAO et al., 2022), draw attention to the fact that the war in Ukraine disrupts supply chains and significantly affects the prices of grain, fertilizers and energy. In particular, in the first half of 2022, this led to a further increase in the price of food products in the world (Horn and Ferreira, 2022). Military conflicts can create a threat to food security, both in Ukraine itself and in other countries of the world where Ukrainian products are exported (Bochko et al., 2022, 2023). It is important to emphasize that it is Ukrainian agricultural products that play an important role in ensuring the food security of many countries. However, the war and the consequences of military operations created such conditions that became barriers to the normal operation of the country's agricultural sector. The specified circumstances may cause a decrease in the volume of production of agricultural products in Ukraine and its export to other countries of the world, as well as affect the food security of Ukraine.

Taking into account that agriculture has a much greater impact on reducing poverty and improving food security than other sectors of the economy, the purpose of the article is to investigate how the change in the volume of production and export of Ukrainian agricultural products affects the food security of Ukraine itself. At the same time, it is necessary to take into account that during the period of the Russian-Ukrainian war and after its end the economic conditions will continue to change not only in Ukraine, but also in other countries, including those that import a significant amount of Ukrainian agricultural products.

To achieve the set goal, the actual task is to forecast these volumes (for the period until 2027) taking into account changes in export directions, which are also caused by logistics problems, political and economic relations of importing countries with Ukraine. An important task from the point of view of the strategic

vision of the development of the national economy of Ukraine and ensuring food security is forecasting the volumes of production and export of Ukrainian agricultural products, which in combination with the results of research previously conducted in the field of the agricultural sector (Dziurakh et al., 2022; Nagursky et al., 2022) will contribute to the solution of these problems.

2 Literature review

A large number of scientific works and practical research data indicate the growing interest of both scientists and practitioners in the development of issues that raise vital issues at the global level (Horin, 2020; Pawlak and Kołodziejczak, 2020; García-Díez et al., 2021; Shpak et al., 2021a,b; Tanveer et al., 2024; Verni et al., 2024). In order to achieve the goal of the research, the main attention will be focused on a more detailed study of such areas of problems as food safety; the relationship between agriculture and food security, as well as the key role of the agricultural sector of Ukraine in the formation of its food security, since this directly affects the food security of other countries at the global level.

2.1 Food security

Food security is considered a measure of population access to food (García-Díez et al., 2021). Scientists Lv et al. (2022) emphasized that food security is achieved when every individual has continuous physical, social, and economic access to an ample supply of safe, nutritious food that aligns with their dietary requirements and personal nutritional preferences, promoting active and healthy lifestyle. Often, researchers attribute food security to economic security. For example, Hrynshyn (2020) argues that crafting a national development strategy involves taking into account various indicators of economic security, with particular emphasis on factors such as food self-sufficiency and food sovereignty. He suggests defining the food security system as a comprehensive framework encompassing organizational, economic, social, legal, informational, scientific, innovative, and ecological measures. These measures aim to safeguard the essential interests of individuals, communities, regions, and the state by ensuring the physical, economic, and social accessibility, safety, and quality of food products, as well as the stability of food supply and food sovereignty. Horin (2020) attributes food security to national and economic security and suggested considering a number of indicators that characterize food security. Among these indicators, she considers it expedient to take into account those that determine the actual state of food consumption by the country's population, compared to specific threshold criteria, the values of which are given in official government documents and statistical data. This is also stated in the *Methodology for calculating the level of economic security of Ukraine* (Ministry of Economic, 2013), where for the assessment of food security, calculations of indicators are provided, most of which are based on data from the statistical collections "Balances and consumption of basic food products by the population of Ukraine" and "Availability and income of grain and oilseeds to enterprises engaged in their storage and processing." By the way, in the previously mentioned *Methodology*

for calculating the level of economic security of Ukraine, food security is defined as the condition of food production within the country capable of meeting the nutritional needs of every member of society with food of suitable quality, under the condition that it is balanced and accessible to all members of society. The Law of Ukraine “On the National Security of Ukraine” does not directly refer to food security, but it is clear that it is an important element of the country’s national interests, which provide for “safe living conditions and the wellbeing of its citizens,” which must be protected “from real and potential threats” (Law of Ukraine on National Security of Ukraine, 2018) (Verhovna Rada, 2018). Most of the above definitions link food security with protection against internal and external threats. Food security is also about access to food under healthy economic conditions, so knowing the basic tools that guarantee the safety of these types of food is essential to achieve food stability and subsequent food security (Tanveer et al., 2024; Verni et al., 2024). Scientists developed the issue of food security and substantiated that it is important to have a balanced diet and access to different categories of food: meat, vegetables, fruits, dairy products, nuts, etc. (Amao et al., 2023).

2.2 The relationship between agriculture and food security

Food security, agricultural policy and economic growth are interrelated and interdependent processes (Bremann, 2019). Agriculture provides the largest share of food resources and provides a critical number of ecosystem services (e.g., food supply; Podolchak et al., 2022a; Rehman et al., 2022). As such, agriculture is vital for food security and supports Sustainable Development Goal (SDG) particularly Goal 2, which aims to fight hunger. The analysis of scientific studies showed that in various regions of the world, in the context of increasing food and nutritional security, special attention is paid to the agricultural land system (Kniaz et al., 2023). Due to the importance of agriculture in the rural economy of both developed and developing countries, the sector can contribute to the creation of an enabling environment for increasing food security. Increasing the resilience of (rural) food systems can be ensured by the creation of smart agroclusters (Bashynska et al., 2022), and this can contribute to increasing the food security of households and communities in conditions of instability (García-Díez et al., 2021). Scientists (Lv et al., 2022) have shown that the main factors affecting food security are the area of arable land and limited water resources for land irrigation.

2.3 The key role of the agricultural sector of Ukraine in the formation of its food security

Since food security is directly determined by the state of the agricultural sector of a specific country, it is appropriate to assess food security, taking into account the functioning of this branch of the national economy. Regarding Ukraine, the agricultural sector remains among the leaders in its economy, which is due to the peculiarities of natural and climatic conditions

and the structure of the country’s economy. Approximately 2.9 million people were employed in this sector, of which ~80% were employed in the personal peasant economy, and almost every second employed rural person worked in the informal sector of the rural economy (Omotoso et al., 2022); the number of economically active rural population aged 15–70 was ~5.6 million people (Kukel et al., 2020). It is currently difficult to talk about these indicators due to significant migration phenomena, in particular internal population movements and forced emigration. Part of the problems associated with staffing of agricultural enterprises can be compensated for by implementing an innovative risk management system developed on the basis of the transfer of the best European technologies (Podolchak et al., 2022b). Nadvinichnyi (2018) noted that the regional organization of the agrarian sphere is largely determined by the “territorial-localization component” itself, as well as the features of the regional organization of the agrarian sphere (such as the specifics of the agrarian system, the level of production intensity, specialization, etc.). In the current conditions, it is also necessary to add the negative consequences of Russian military aggression, which are especially acute in the eastern and southern regions of Ukraine. It is important to preserve the territorial localization aimed at the development of the agricultural sector during the post-war reconstruction of Ukraine (Potcovaru and Majerová, 2022). From this point of view, it is important to pay attention to food security in Ukraine. After all, to ensure it, not only food stocks are necessary, but also their proper storage and balanced decisions regarding the export of agricultural products (Ostashko, 2022). The agricultural sector is one of the leaders in the economy of many countries, as it creates the basis for their economic growth. Each region in each country has its own unique sphere of social reproduction due to different resource potential, that is, fertile soils, favorable climatic conditions, etc. (Shpak et al., 2021a,b). Scientists of the Institute of Economics and Forecasting of the National Academy of Sciences of Ukraine assessed the prospects for increasing agricultural production and strengthening the role of the agricultural sector in the national economy. In their monographic study (Borodina and Shubravskaya, 2018; Mordovtsev et al., 2022), two qualitatively different phases in the processes of production and domestic consumption of agricultural products in Ukraine are distinguished: during 2004–2008 there was an “intensification of import expansion,” and in 2012–2016—“decrease in the level of import dependence,” and for the next period these researchers predicted “increase in import dependence.” We consider this forecast to be unlikely, but it requires additional research in order to justify possible scenarios of changes in the volume of export of Ukrainian agricultural products and the total volume of its production.

Mudrak (2022) investigated the impact of Russian military aggression on global and national food security. He revealed the trends of constant growth of the share of Ukrainian exports of certain types of agricultural products in world exports. She emphasized that the circumstances caused by the war worsen the state of providing other countries with sunflower oil, grain and other types of products supplied by Ukraine. However, his research lacks predictive estimates regarding future volumes of production and export of Ukrainian agricultural products. The strengthening of the limitations of logistics chains, which

affect the supply of food to other countries, is also evidenced by the research of other scientists, which revealed negative dynamics of the aggregated logistics efficiency index (Stetsiv, 2022).

The main factors in the decrease in the volume of agricultural production in Ukraine are the removal of a large part of the land from agricultural use due to temporary occupation and their littering with ammunition and remnants of military equipment, the destruction of infrastructure and damage to agricultural machinery. It is obvious that significant funds will be needed to restore this industry, including demining and clearing agricultural land; these works will take several years. Therefore, in forecast calculations for the nearest period, it is necessary to rely on the assumption that the volume of production of agricultural products will be smaller, compared to the period until 2022, in proportion to the decrease in the area of land suitable for processing and growing agricultural crops. The war has resulted in a roughly 22% reduction in arable land suitable for agriculture in 2022 (Movchaniuk and Diachenko, 2023). Even following the liberation of the occupied territories, it will take several years before these lands can be cultivated, as they will require demining and field clearing first. In the future, as they are freed and cleared, they will be used again for agricultural production (Viana et al., 2022).

The conducted analysis of literary sources became the basis for formulating the research hypothesis.

H 1: Ukraine's food security depends on the volume of production of agricultural products.

H 2: Ukraine's food security depends on the volume of exports of agricultural products.

3 Methodology and data construction

For reasonable forecasting of the agricultural production volume in Ukraine, it is necessary to use such a methodology that would make it possible to take into account retrospective information and a number of internal and external factors that affect the processes of production and export of agricultural products. Bogomazova (2012) suggested using two groups of methods for forecasting, depending on the content of the initial information. The first group includes methods of extrapolation and modeling, whereas the second deals with expert methods that involve taking into account the opinions of authoritative specialists (these methods are useful for forecasting in conditions of some uncertainty of the investigated processes). Expert methods sometimes involve qualitative rather than quantitative predictive visions. In our opinion, the results of forecasting should be exactly quantitative indicators that make it possible to compare the actual state of the process in the past and the predicted future state. Therefore, those indicators that are essentially qualitative should be expressed quantitatively. Information about factors related to military actions on the territory of Ukraine, for example, changes in the area of land available for agricultural use, is given in the publications of experts in the agrarian sphere.

The volumes of agricultural products of Ukraine expressed in actual prices (in hryvnias) practically coincide with those calculated in US dollars at the official average annual exchange rates in

previous years (Figure 1). The volume of production of agrarian products had an increasing trend in recent years.

This research will use the forecasting method. In order to forecast the volume of production of agricultural products an assumption was made of their decrease in 2022 by 22% from the volume in 2021. This is approximately the same estimate given by experts in October 2022 (Neiter et al., 2022). According to this scenario, the reduction in production in 2022 should be calculated as the average value for the previous 5 years, reduced by 22% (the area of arable land has decreased by that much). The mathematical model of this forecast is described by the equation.

$$Q_{2022} = (1 - 0,22) * (Q_{2017} + Q_{2018} + Q_{2019} + Q_{2020} + Q_{2021}) / 5$$

According to the forecast for 2022, the volume of production of agricultural products in Ukraine is: $Q_{2022} = (1 - 0,22) * (26,609 + 31,161 + 32,602 + 33,118 + 49,331) / 5 = 26,960$ million dollars USA.

The forecast growth rates of Ukrainian agricultural production are taken as average to the previous ones, with the exception of the anomalous (record) year 2021. The rates calculated in this way are ~7.8% per year:

$$\begin{aligned} TQ &= [(1 - Q_{2018}/Q_{2017}) + (1 - Q_{2019}/Q_{2018}) + (1 - Q_{2020}/Q_{2019})] / 3 = \\ &= [(1 - 31,161/26,609) + (1 - 32,602/31,161) + (1 - 33,118/32,602)] / 3 = \\ &= 0,078. \end{aligned}$$

The mathematical model for forecasting Ukrainian agricultural production volumes in 2023–2027 is described by the equation:

$$Q_N = Q_{N-1} * (1 + TQ).$$

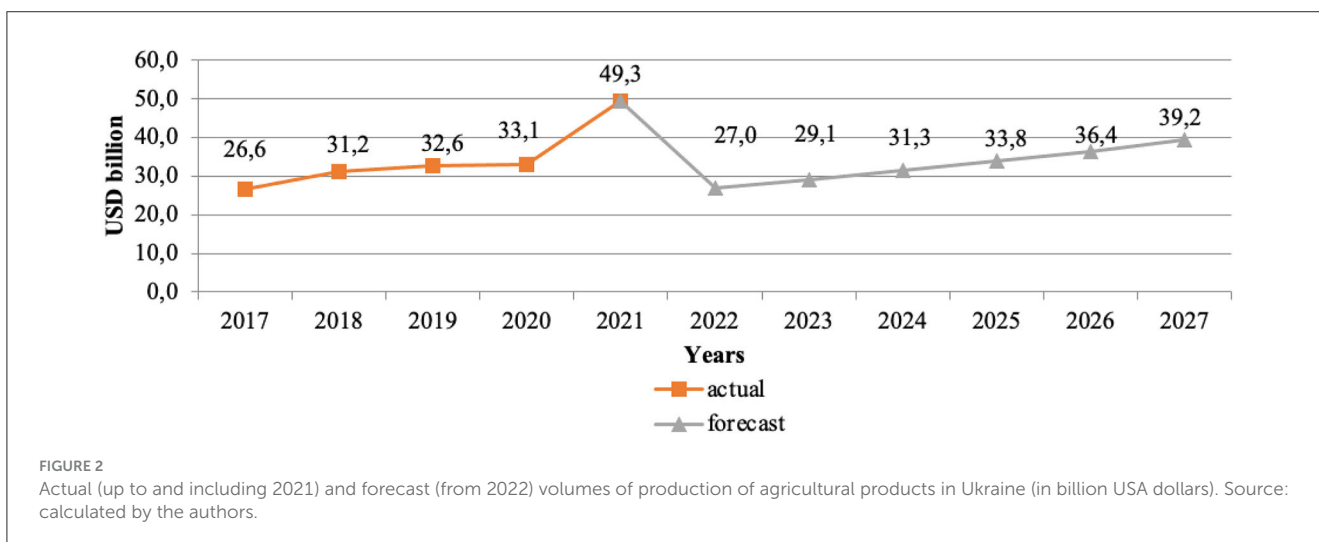
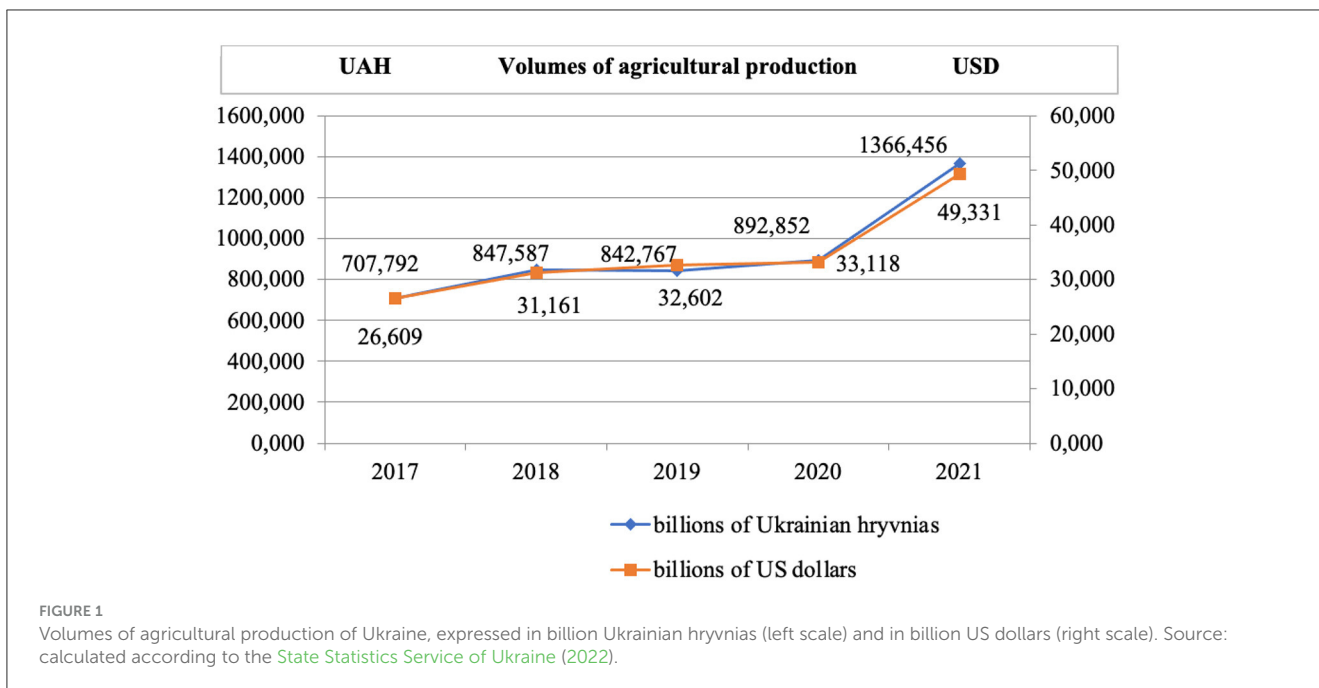
In particular, for the period 2023–2027, the forecast values are:

$$\begin{aligned} Q_{2023} &= Q_{2022} * (1 + TQ) = 26,960 * (1 + 0,078) = 29,063 \text{ million dollars USA;} \\ Q_{2024} &= Q_{2023} * (1 + TQ) = 29,063 * (1 + 0,078) = 31,330 \text{ million dollars USA;} \\ Q_{2025} &= Q_{2024} * (1 + TQ) = 31,330 * (1 + 0,078) = 33,774 \text{ million dollars USA;} \\ Q_{2026} &= Q_{2025} * (1 + TQ) = 33,774 * (1 + 0,078) = 36,408 \text{ million dollars USA;} \\ Q_{2027} &= Q_{2026} * (1 + TQ) = 36,408 * (1 + 0,078) = 39,248 \text{ million dollars USA.} \end{aligned}$$

The results of forecasting the volume of production of agricultural products in Ukraine for the period until 2027, expressed in US dollars, are shown in Figure 2.

At the time of writing, the State Statistics Service of Ukraine (2023) released estimates for the agricultural production volume in Ukraine in 2022, totaling ~29.4 billion USD. This indicates that the actual volume surpassed the forecasted value by ~8.7%.

It should be taken into account that as a result of the Russian invasion, the actual population of Ukraine at the end of 2022 decreased by ~8 million people (UNHCR, 2022), that is, by almost 20% compared to January 2022 (then, according to official data, the population of the country was more than 41 million people, excluding the Autonomous Republic of Crimea). This gives grounds for the assertion that the internal consumption of agricultural products will decrease accordingly. Therefore, according to the given scenario, the volume of production of agricultural products will be sufficient to provide for the country's



population while maintaining the previous proportion of exports. At the same time, there is a basis for an increase in the share of products that Ukraine can export.

To forecast the volume of production and export of Ukrainian agricultural products, it is necessary to take into account not only the change in the area of cultivated agricultural land, but also the general state of the economies of the countries that import Ukrainian products. Information on gross domestic product (GDP) values and forecasts of their annual changes for the period until 2027 for the countries of the world are provided on the website of the [International Monetary Fund, 2022](#). Data on the dynamics of agricultural production in Ukraine and its export are available in the sources of the State Statistics Service of Ukraine.

In order to forecast the volume of export of Ukrainian agricultural products, assumptions regarding the state of

the economies of the importing countries (changes in real GDP) and their shares in exports are taken into account. On this basis, the forecast values of average annual percentage changes in export volumes were calculated as the sum of products of percentage changes in real GDP of importing countries and their shares in the export of agricultural products from Ukraine. The forecast model uses the assumptions of analysts of the International Monetary Fund regarding annual changes in real GDP for the period until 2027 ([Table 1](#)).

Forecast calculations of the export of agricultural products were made according to two scenarios. Forecasting according to the first scenario covers two stages. At the first stage, expert assumptions were made regarding the shares of the main importing countries in the export of Ukrainian agricultural products ($dEXP_C$). For each year of the forecast period, annual percentage forecast changes in

export volumes (TE_N) were calculated as the sum of $dEXP_C$ and $dGDP_C$ products.

At the second stage, export volumes (Q_N) were calculated sequentially for each year of the forecast period, based on the forecast value of exports in the previous year (Q_{N-1}). The mathematical model for this scenario is described by the following expression:

$$Q_N = Q_{N-1} * (1 + TE_N).$$

The second scenario is based on the assumption that it will be possible to export a part of agricultural products, which will remain from the total volume of production, excluding the volume of domestic consumption.

TABLE 1 Forecast values of annual changes in real GDP of countries that are the main importers of Ukrainian agricultural products.

Country	Annual changes in real GDP (%) in the forecast period (dGDPc)				
	2023	2024	2025	2026	2027
Romania	2.1	2.8	3.6	3.8	3.8
China	5.2	4.6	4.1	3.8	3.6
Turkey	4.5	3.1	3.2	3.3	3.4
Spain	2.5	1.9	2.1	1.8	1.6
Poland	0.2	3.1	3.5	3.3	3.0
Netherlands	0.1	0.6	1.3	1.9	1.9
Egypt	3.8	3.0	4.4	4.7	5.1
Italy	0.9	0.7	0.7	0.2	0.3
Germany	-0.3	0.2	1.3	1.5	1.1
Hungary	-0.9	2.2	3.3	2.8	3.0

Source: compiled according to International Monetary Fund (2023).

4 Research results

In previous years, the share of exported agricultural products tended to increase in absolute numbers and decrease compared to the total volume of its production (Figure 3).

The peculiarity of the export of agricultural products is that products produced in the previous period can be sold in the current year. Therefore, in order to estimate the share of exports in the total volume of manufactured goods, it is advisable to calculate the corresponding ratio for several years. On average, the share of exports was 66% for the period 2017–2021.

The accession of Ukraine to the World Trade Organization and the implementation of the Association Agreement with the European Union (EU) provided additional opportunities for the development of the agricultural sector of the national economy of Ukraine, in particular for expanding the export of agricultural products to European countries. According to the results of 2021, Ukraine exported agricultural products in the amount of 27.7 billion US dollars, which is almost 25% more than the volume in 2020 (22.4 billion USD). Exports of agricultural products to EU countries and Great Britain increased by 12%: from 7.5 billion dollars USA in 2019 to 8.4 billion US dollars in 2021. The share of the EU in Ukrainian exports of agricultural products was 30.1% in 2021 (Makuha, 2022). Shares of exports to other countries are likely to remain at the level they were in 2021. The main importers of Ukrainian agricultural products in 2021 were China, India, Egypt, Turkey, Indonesia, a number of European countries, in particular members of the European Union (Figure 4).

The shares of countries in the export of Ukrainian agricultural products are calculated in proportion to the volume of exports to them. Due to the Russian occupation and blockade of Ukrainian ports in the Black Sea, the export shares to importing countries have changed. In 2023, the top 10 importers included Romania, China, Turkey, Spain, Poland, the Netherlands, Egypt, Italy, Germany, and Hungary (Table 2).

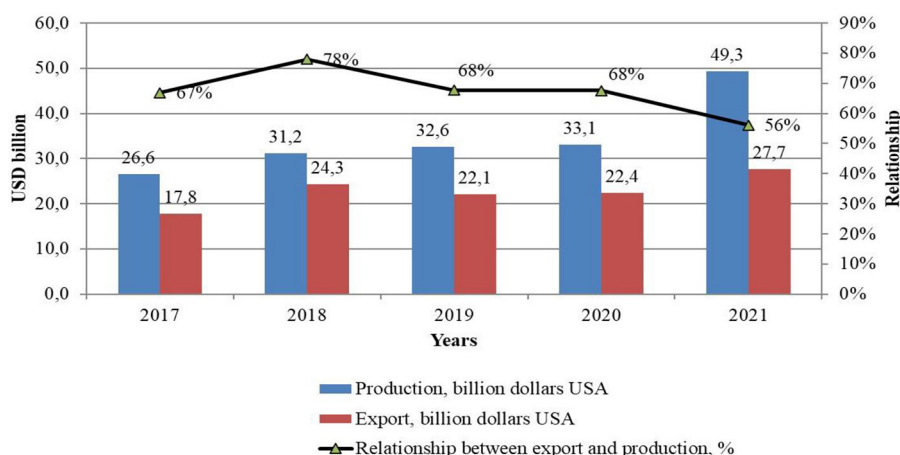


FIGURE 3 Dynamics of production and export of Ukrainian agricultural products and the relationship between them. Source: calculated by the authors.

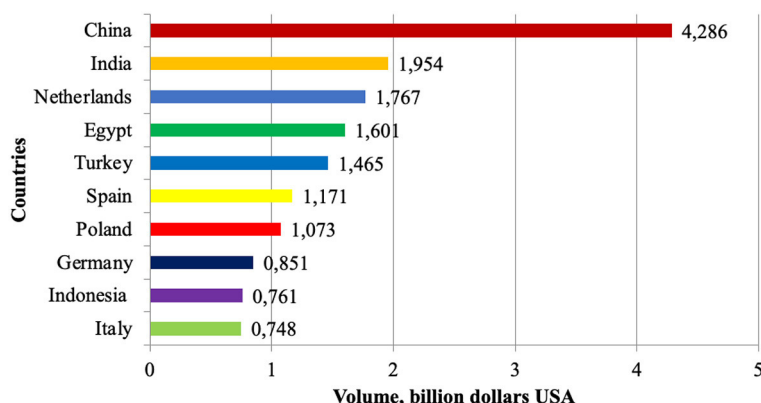


FIGURE 4 Export volumes of agricultural products of Ukraine to the largest importers in 2021 (billion USD). Source: summarized according to statistical data.

According to our assumption, these import shares (as listed in Table 2) will remain the same in the following years until 2027. For each year of the 2023–2027 forecast period, annual percentage forecast changes in export volumes (TE_N) were calculated based on the data from Tables 1, 2. For example, for 2023, TE_N was calculated as follows:

$$TE_{2023} = 19.0\%*2.1\% + 14.4\%*5.2\% + 13.1\%*4.5\% + 11.8\%*2.5\% + 11.1\%*0.2\% + 8.5\%*0.1\% + 7.2\%*3.8\% + 6.5\%*0.9\% + 5.2\%*(-0.3\%) + 3.3\%*(-0.9\%) = 2.35\%$$

The results of this stage are given in Table 3.

At the time of preparation of the article, the actual volume of exports of Ukrainian agricultural products for 2022 became known—in the amount of 23.4 billion dollars (UAEA, 2023). For the period 2023–2027, the forecast values of the export of Ukrainian agricultural products according to the first scenario are:

$$Q_{2023} = Q_{2022}*(1+TE_{2023}) = 23.4*(1+0.0235) = 23.9 \text{ billion dollars USA};$$

$$Q_{2024} = Q_{2023}*(1+TE_{2024}) = 23.9*(1+0.0256) = 24.5 \text{ billion dollars USA};$$

$$Q_{2025} = Q_{2024}*(1+TE_{2025}) = 24.5*(1+0.0297) = 25.2 \text{ billion dollars USA};$$

$$Q_{2026} = Q_{2025}*(1+TE_{2026}) = 25.2*(1+0.0296) = 25.9 \text{ billion dollars USA};$$

$$Q_{2027} = Q_{2026}*(1+TE_{2027}) = 25.9*(1+0.0291) = 26.7 \text{ billion dollars USA}.$$

Further calculations have been carried out based on the second scenario (based on the assumption that it will be possible to export a part of agricultural products, which will remain from the total volume of production, excluding the volume of domestic consumption).

The average value of the share of Ukrainian agricultural products used for domestic consumption during 2017–2021 was 32.9%. This was $\sim(26.609 + 31.161 + 32.602 + 33.118 + 49.331)*0.329 = 11.372$ billion dollars. US every year or about 277.4 USD. of the USA per resident of Ukraine yearly (considering the then population of 41 million people). This approach takes into account the need to support Ukraine’s food security. At the same time, the projected changes in the number of the country’s population, caused primarily by the expected return to Ukraine

TABLE 2 Export volumes of agricultural products of Ukraine to the largest importers in 2023.

N	Country	Volume (billion USD)	Share (%)
1	Romania	2.9	19.0
2	China	2.2	14.4
3	Turkey	2.0	13.1
4	Spain	1.8	11.8
5	Poland	1.7	11.1
6	Netherlands	1.3	8.5
7	Egypt	1.1	7.2
8	Italy	1.0	6.5
9	Germany	0.8	5.2
10	Hungary	0.5	3.3

Source: summarized according to statistical data.

TABLE 3 The results of the calculation of annual percentage forecast changes in the export of Ukrainian agricultural products.

Year (N)	2023	2024	2025	2026	2027
Annual percentage forecast changes in export volumes (TE _N)	2,35%	2,56%	2,97%	2,96%	2,91%

Source: calculated by the authors.

of fellow citizens from abroad, are taken into account. In 2023, the International Monetary Fund published demographic forecasts, according to which the population figures for Ukraine were projected as follows: in 2023–33.2 million, in 2024–33.7 million, in 2025–34.7 million, in 2026–35 million, and in 2027–35.9 million people (IMF, 2023). The assumption of changes in domestic consumption in proportion to the corresponding changes in the population of Ukraine, included in the second scenario of forecasting changes in the export of Ukrainian agricultural products, is shown in Table 4.

The remaining volume of domestically produced food can be exported. For example, in 2024, production is forecasted to be 31.3

billion USD, so a volume of 22.0 billion USD can be exported (31.3–9.3). The results of forecast calculations of the volume of export of Ukrainian agricultural products under two scenarios are shown in Figure 5.

The second scenario takes into account the likely return of part of the population from abroad to Ukraine, leading to an increase in its total population. Therefore, in the coming years, the volumes of domestic consumption of agricultural products will increase. This will result in limitations on the volume that can be exported. However, due to the growth of agricultural production at higher rates than the population growth, export volumes may potentially increase. This growth (according to the second scenario) has higher rates than the first scenario. This is because the first scenario was based solely on changes in the economic situation of countries importing Ukrainian agricultural products.

The forecast volume of exports of Ukrainian agricultural products obtained under the second scenario can serve as a guideline for regulating exports, taking into account the issue of food security in Ukraine. With the return of Ukrainian refugees to Ukraine after the end of the war, domestic consumption of agricultural products will increase somewhat. However, at the same time, the area of lands suitable for cultivation after their clearing and demining will increase. Therefore, food security in Ukraine will remain satisfactory.

TABLE 4 Assumptions regarding changes in the volume of domestic consumption in Ukraine for the forecast period of 2023–2027 (based on changes in population).

Year	2023	2024	2025	2026	2027
Projected population size, million people	33.2	33.7	34.7	35.0	35.9
The volume of domestic consumption of agricultural products in Ukraine is billions of US dollars.	9.2	9.3	9.6	9.7	10.0

5 Discussion

The results of the above calculations showed that the forecasting of agricultural production volumes in Ukraine is based on the assumption of a decrease in 2022 (by ~22%) of land areas suitable for agriculture due to Russian military aggression. After 2023, the annual growth of agricultural production may be at the level of average growth rates (7.8%) until the record harvest of 2021. To forecast exports, changes in the economic status of the main importers of Ukrainian agricultural products and changes in domestic consumption are taken into account in proportion to the projected population of Ukraine. During 2023–2027, changes in the volume of production of Ukrainian agricultural products, according to the calculations, will amount to ~29.1–39.2 billion US dollars. Export volumes during this period will also grow ~19.9–23.9–26.7–29.2 billion dollars USA.

In general, research on food security at the global level has shown that this indicator depends on the coherence of the work of various systems and sectors of countries (Tarasuk et al., 2019; Haghghi and Namdar, 2024). In particular, in China (Lv et al., 2022), the interdependence of agricultural, social and economic spheres explains the level of food security in the country. Scientists emphasize the need to develop agriculture and suggest reducing the development of agricultural land due to the expansion of cities; increase subsidies to encourage farmers to develop agriculture; improve the agricultural infrastructure and increased investment in agricultural development.

Mehrabi et al. (2022) presents the prioritization of threats to global food security from extreme events. Among the threats that have the strongest impact on global food security, the following are named: growing dependence on water resources, especially groundwater; droughts in Africa in regions south of the Sahara desert; heat and other extreme phenomena in the coastal regions of poor countries, where they eat mainly seafood; the simultaneous occurrence of extreme events that threaten the proper provision of water supply services (for irrigation), pest control, and the supply of feed for fish and livestock production; seizure of resources on land

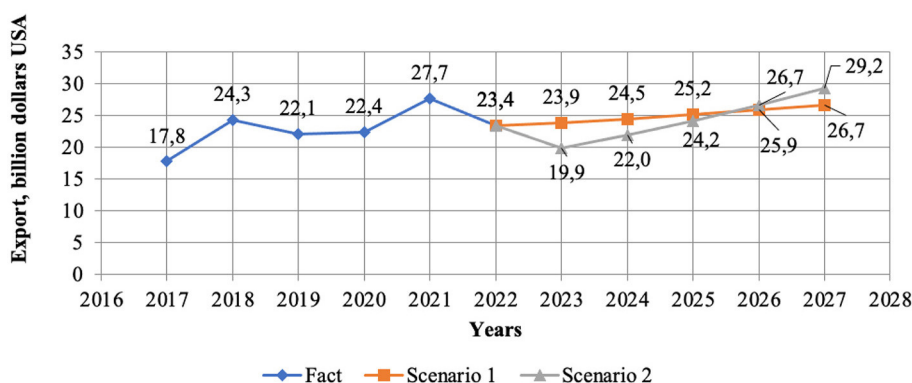


FIGURE 5 Export of Ukrainian agricultural products: fact (2018–2022) and two forecast scenarios (2023–2027), billion dollars USA. Source: calculated by the authors.

and at sea by powerful countries, and others. Military operations and their consequences are not mentioned in this study, but their impact due to the destruction of agricultural, logistical (Shpak et al., 2018) infrastructure should be taken into account.

In Ukraine, in addition to the above-mentioned main factors, it is necessary to take into account factors that have an indirect effect on food security, in particular the state of the energy infrastructure (Androniceanu and Georgescu, 2023), which is being destroyed as a result of hostilities on the part of Russia. In this context, an important strategic alternative to ensure sustainable development is the production of green energy (Androniceanu and Sabie, 2022). It is also necessary to consider the state and level of the shadow economy in public administration (Shpak et al., 2021a,b), which affects the development of the economy that shapes food security. All these and others factors have a significant impact on food security, since a study of changes in the indices of the global indicator of food security starting from 2018 shows that, along with its general decrease in the world by 1%, in Ukraine there was a tendency to increase by an average of 6% (Stetsiv, 2022), but with the start of a full-scale invasion in 2022, this indicator deteriorated sharply.

The results of the study proved that the main resource for the production of agricultural products in Ukraine is arable land. A large part of the territory of Ukraine becomes unfit for agricultural production due to the conduct of military operations there caused by the war Russian military aggression. After the liberation of the occupied territories, it takes a long time to return the agricultural lands to a condition suitable for their use for growing agricultural products. It will also be necessary to restore agricultural buildings and structures and to update the park of agricultural machinery. An additional negative factor is the decrease in the number of workers in the agricultural sector due to the fact that a large part of the population, including the rural population, left the temporarily occupied territories.

This research can be useful for various groups of people and organizations, in particular for:

- The government. The study can provide government agencies and authorities with important information to develop and implement effective policies and strategies to ensure food security in the country.
- Agricultural producers. Agricultural enterprises and farms can use research to plan their production and expand agricultural activities, according to the needs of the national market and export opportunities.
- The research community. Scientists and researchers can use the research results for further analytical work, as well as for improving methods and approaches to food security assessment.
- International organizations. International organizations such as the World Food and Agriculture Organization (FAO) can use data on food security in Ukraine to coordinate global efforts to ensure food security.
- Business and investors. Private companies can use food security information to make investment and business development decisions in the agricultural and food industries.

The limitation of the study is that the analysis of the impact of production volumes and export of products on the food security of Ukraine was carried out during the period of active hostilities, which is characterized by instability and unpredictability of further development and the state of the indicators that were taken as the basis of the study. The conducted research also has the following limitations: firstly, it does not consider the assumption of possible annexation of additional territories by the aggressor and the resulting decrease in agricultural land; secondly, the assumption about the return of Ukrainian refugees is hypothetical—as it is difficult to make a reliable forecast about future migration processes caused by war.

Further research should be devoted to identifying the relationship between changes in the population of Ukraine in the post-war period and the physical volume of domestic consumption and export of Ukrainian agricultural products.

6 Conclusions

Today, in the world society, great attention is paid to creating conditions for strengthening food security. After all, overcoming poverty and hunger is the second most important goal in the worldwide Millennium Development Goals.

The article analyzes changes in the production of agricultural products in Ukraine and develops forecasts for the volume of exports of these products from Ukraine until 2027. The presented analysis takes into account several factors, including projected changes in real GDP in countries that are the main importers of Ukrainian agricultural products, a decrease in processed agricultural land due to military actions and projected changes in the population of Ukraine over the next few years. Based on this analysis, it was concluded that there is no threat to Ukraine's food security caused by changes in the production and export of agricultural products.

The study confirmed the hypotheses and indicated that the volume of production of agricultural products in Ukraine will be sufficient to meet the needs of the country's population, without violating the previous export ratio. There are even reasons to increase the share of products that Ukraine can export. The forecasted export volumes obtained as part of the study can be used as an indication for export regulation taking into account food security issues in Ukraine. With the return of Ukrainian refugees to Ukraine after the end of the war, domestic consumption of agricultural products will increase somewhat. However, at the same time, the area of lands suitable for cultivation after their clearing and demining will increase. Therefore, food security in Ukraine will remain satisfactory.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

NS: Writing – review & editing. YM: Writing – original draft. YD: Writing – original draft. MG: Writing – original draft.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

References

- Amao, I. O., Ogunniyi, A. I., Mavrotas, G., and Omotayo, A. O. (2023). Factors affecting food security among households in Nigeria: the role of crop diversity. *Sustainability* 15:8534. doi: 10.3390/su15118534
- Androniceanu, A., and Georgescu, I. (2023). The impact of CO₂ emissions and energy consumption on economic growth: a panel data analysis. *Energies* 16:1342. doi: 10.3390/en16031342
- Androniceanu, A., and Sabie, O. M. (2022). Overview of green energy as a real strategic option for sustainable development. *Energies* 15:8573. doi: 10.3390/en15228573
- Bashynska, I., Kichuk, Y., Danylyuk, S., and Levytska, L., Zaitsev, O. (2022). Smart agro-clustering based on the chain education-science-business for sustainable development. *J. Agri. Crops* 8, 208–215. doi: 10.32861/jac.83.208.215
- Ben Hassen, T., and El Bilali, H. (2022). Impacts of the Russia-Ukraine war on global food security: towards more sustainable and resilient food systems? *Foods* 11:2301. doi: 10.3390/foods11152301
- Bochko, O., Bachynska, M., and Hrynkevych, S., Ryndzak, O. (2023). Determinants influencing the socially-vulnerable population of Ukraine during the Russo-Ukrainian War. *Studia Regionalne i Lokalne*. 2, 3–34.
- Bochko, O. Y., Maletska, O. I., Tsitska, N.?, and Kapral, O. R. (2022). Paradigm of a country competitiveness under conditions of digital economy. *Rev. Econ. Fin.* 20, 572–580. doi: 10.55365/1923.x2022.20.65
- Bogomazova, V. M. (2012). Classification and scope of medium-term forecasting methods. *Format. Mark. Relat. Ukraine* 5, 31–35.
- Borodina, O. M., and Shubravskaya, O. V. (2018). *Agrarian and Rural Development for the Growth and Renewal of the Ukrainian Economy: Scientific Report* (Kyiv: Institute of Economics and Forecasting of the National Academy of Sciences of Ukraine), 152.
- Breman, H. (2019). Niek Koning: food security, agricultural policies and economic growth. Long-term dynamics in the past, present and future. *Food Sec.* 11, 481–482. doi: 10.1007/s12571-019-00914-1
- Dziurakh, Y., Halanets, V., Kulakovska, T., Pugachov, M., and Pugachov, V. (2022). Economic assessment and state regulation of the agri-industrial sector in Ukraine: solutions for ensuring food security (modeling and analysis). *Econ. Aff.* 67, 777–786. doi: 10.46852/0424-2513.4s.2022.11
- FAO, IFAD, UNICEF, WFP, and WHO (2022). *The State of Food Security and Nutrition in the World 2022. Repurposing Food and Agricultural Policies to Make Healthy Diets More Affordable*. Rome: FAO.
- García-Díez, J., Gonçalves, C., Grispoldi, L., Cenci-Goga, B., and Saraiva, C. (2021). Determining food stability to achieve food security. *Sustainability* 13:7222. doi: 10.3390/su13137222
- Haghighi, Z., and Namdar, R. (2024). Social path assessment and food security status of rural households in Iran. *Front. Sustain. Food Syst.* 8:1354421. doi: 10.3389/fsufs.2024.1354421
- Horin, N. (2020). Individual indicators of Ukraine's food security in the global dimension. *Visnyk of the Lviv University. Series Int. Relat.* 48, 208–217.
- Horn, B., Ferreira, C. and Kalantari, Z. (2022). Links between food trade, climate change and food security in developed countries: a case study of Sweden. *Ambio* 51, 943–954. doi: 10.1007/s13280-021-01623-w
- Hrynshyn, V. (2020). Methodological foundations of the country's food security research. *Econ. State* 2, 141–146. doi: 10.32702/2306-6806.2020.2.141
- IMF (2023). *World Economic Outlook Database, October 2023*. International Monetary Fund. Available online at: <https://www.imf.org/en/Publications/WEO/weo-database/2023/October/select-subjects?c=926> (accessed October 27, 2023).
- International Monetary Fund (2022). *Real GDP Growth*. Available online at: https://www.imf.org/external/datamapper/NGDP_RPCH@WEO/OEMDC/ADVEC/WEO/EGY (accessed November 12, 2023).
- International Monetary Fund (2023). *Real GDP Growth*. Available online at: https://www.imf.org/external/datamapper/NGDP_RPCH@WEO/OEMDC/ADVEC/WEO/EGY (accessed October 28, 2023).
- Kniaz, S., Podolchak, N., Dziurakh, Y., Karkovska, and Anatolii, K. (2023). Development of government regulation on investment activities in agriculture of Ukraine. *Econ. Stud. J.* 2, 136–150.
- Koval, V., Sribna, Y., Prokopenko, O., and Ivata, V., Arsawan, I. W. E. (2023). Management supply chains electric vehicle battery recycling. *Green Energy Technol.* 3, 33–54. doi: 10.1007/978-3-031-30800-0_3
- Kukel, H., Roleders, V., and Semchuk, I. (2020). Assessment of employment in the agricultural economy of Ukraine. *Probl. Syst. Appr. Econ.* 1, 48–51. doi: 10.32782/2520-2200/2020-1-30
- Lv, F., Deng, L., Zhang, Z., Wang, Z., Wu, Q., and Qiao, J. (2022). Multiscale analysis of factors affecting food security in China, 1980–2017. *Environ. Sci. Pollut. Res.* 29, 6511–6525. doi: 10.1007/s11356-021-16125-1
- Makuha, M. (2022). *The Fourth Record in Four Years: Agricultural Exports in Ukraine Increased By 25%*. The Page—Economy of Ukraine. Available online at: <https://thepage.ua/ua/economy/record-agrarnij-eksport-ukrayini-zris-na-25percent>
- Mehrabi, Z., Ignaciuk, A., Levers, C., Delzeit, R., Braich, G., Bajaj, K., et al. (2022). Research priorities for global food security under extreme events. *One Earth* 5:756. doi: 10.1016/j.oneear.2022.06.008
- Ministry of Economic (2013). *Methodological Recommendations for Calculating the Level of Economic Security of Ukraine, Approved By the Order of the Ministry of Economic Development and Trade of Ukraine dated October 29, 2013 No. 1277*. Available online at: <https://zakon.rada.gov.ua/rada/show/v1277731-13/print> (accessed November 21, 2023).
- Mordovtsev, O., Andrenko, O., and Mordovtsev, S. (2022). Conceptual aspects of the use of information and communication technologies as a basis for strengthening the food security of the state. *Econ. State* 5, 90–95. doi: 10.32702/2306-6806.2022.5.90
- Movchaniuk, A., and Diachenko, M. (2023). Agricultural sector of Ukraine in the conditions of war. *Eff. Econ.* 2.
- Mudrak, R. (2022). The impact of the Russian-Ukrainian war on global and domestic food security. *Bulleti. Khmelnytskyi Natl. Univ.* 3, 294–298. doi: 10.31891/2307-5740-2022-306-3-44

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fsufs.2024.1361625/full#supplementary-material>

- Nadvinichnyi, S. (2018). *Economic Development of the Agrarian Sphere of the Regions of Ukraine in the Conditions of Globalization: Theory, Methodology, Practice: Monograph* (Ternopil: Economic Thought), 400.
- Nagurskyi, O., Krylova, H., Vasiichuk, V., Dziurakh, Y., Nahursky, A., and Paraniak, N. (2022). Safety usage of encapsulated mineral fertilizers based on polymeric waste. *Ecol. Eng. Environ. Technol.* 23, 156–161. doi: 10.12912/27197050/143139
- Neiter, R., Bogonos, M., Nivyeyskyi, O., and Makarenko, O. (2022). *Review of Indirect Losses From the War in the Agriculture of Ukraine. The Second Release*. KSE Agrocenter. Available online at: https://kse.ua/wp-content/uploads/2022/11/Losses_report_issue2_ua-1.pdf
- Omotoso, A. B., Daud, S. A., Okojie, L., and Omotayo, A. O. (2022). Rural infrastructure and production efficiency of food crop farmers: implication for rural development in Nigeria. *Afri. J. Sci. Technol. Innov. Dev.* 14, 197–203. doi: 10.1080/20421338.2020.1821441
- Ostashko, T. O. (2022). Agricultural export of Ukraine in war conditions and ways of its recovery. *Econ. Ukraine* 5, 26–37. doi: 10.15407/economyukr.2022.05.026
- Our World in Data Team (2023). *End Hunger, Achieve Food Security and Improved Nutrition and Promote Sustainable Agriculture*. Available online at: <https://ourworldindata.org/sdgs/zero-hunger> (accessed November 21, 2023).
- Pawlak, K., and Kołodziejczak, M. (2020). The role of agriculture in ensuring food security in developing countries: considerations in the context of the problem of sustainable food production. *Sustainability* 12:5488. doi: 10.3390/su12135488
- Podolchak, N., Karkovska, V., Dzyurakh, Y.u., Prokopyshyn-Rashkevich, L., Lukashevskaya, U., and Yaremko, G. (2022a). Ukrainian ecosystem transformation challenges of fintech products in the COVID-19 conditions. *Fin. Credit Activ. Probl. Theory Pract.* 4, 254–266. doi: 10.55643/fcaptop.4.45.2022.3847
- Podolchak, N., Tsygulyk, N., and Dziurakh, Y. (2022b). Building an effective personnel risks management system of the organization. *East. Europ. J. Enterpr. Technol.* 4, 44–52. doi: 10.15587/1729-4061.2022.262547
- Potcovaru, A. M., and Majerová, J. (2022). Multi-sensor fusion technology, spatial simulation and environment mapping algorithms, and real-world connected vehicle data in smart sustainable urban mobility systems. *Contemp. Read. Law Soc. Just.* 14, 105–120. doi: 10.22381/CRLSJ14120227
- Rehman, A., Farooq, M., Lee, D. J., and Siddique, D. D. M. (2022). Sustainable agricultural practices for food security and ecosystem services. *Environ. Sci. Pollut. Res.* 29, 84076–84095. doi: 10.1007/s11356-022-23635-z
- Shpak, N., Dvulit, Z., Luchnikova, T., and Sroka, W. (2018). Strategic development of cargo transit services: a case study analysis. *Eng. Manag. Prod. Serv.* 10, 76–84. doi: 10.2478/emj-2018-0024
- Shpak, N., Kulyniak, I., Gvozdz, M., and Pyrog, O., and Sroka, W. (2021a). Shadow economy and its impact on the public administration: aspects of financial and economic security of the country's industry. *Adm. Manag. Publ.* 36, 81–101. doi: 10.24818/amp/2021.36-05
- Shpak, N., Kulyniak, I., Gvozdz, M., Vveinhardt, J., and Horbal, N. (2021b). Formulation of development strategies for regional agricultural resource potential: the Ukrainian case. *Resources* 10:57. doi: 10.3390/resources10060057
- Silva, G. (2018). *Feeding the World in 2050 and Beyond-Part 1: Productivity Challenges*. Michigan State University Extension. Available online at: <https://www.canr.msu.edu/news/feeding-the-world-in-2050-and-beyond-part-1> (accessed December 3, 2018).
- State Statistics Service of Ukraine (2022). *Agriculture of Ukraine. Statistical Collection for 2021* (Kyiv), 222.
- State Statistics Service of Ukraine (2023). *Agriculture of Ukraine in 2022*. Available online at: https://ukrstat.gov.ua/druk/publicat/kat_u/2023/zb/09/S_gos_22.pdf
- Stetsiv, I. (2022). Public administration of food security: conceptual basis and rational approaches. *Agri. Resour. Econ.* 8, 215–243. doi: 10.51599/are.2022.08.04.10
- Tanveer, M., Ntakiyisumba, E., and Won, G. (2024). Prevalence and risk factors of seafood-borne *Vibrio vulnificus* in Asia: a systematic review with meta-analysis and meta-regression. *Front. Microbiol.* 15:1363560. doi: 10.3389/fmicb.2024.1363560
- Tarasuk, V., Fafard St-Germain, A. A., and Mitchell, A. (2019). Geographic and socio-demographic predictors of household food insecurity in Canada, 2011–12. *BMC Publ. Health* 19:12. doi: 10.1186/s12889-018-6344-2
- UAEA (2023). *Agro-Food Exports of Ukraine According to the Results of 2022*. Ukrainian Agriculture Export Association. Available online at: <https://uaexport.org/2023/01/26/agroprodovolchij-eksport-ukrayini-za-pidsumkami-2022-roku/> (accessed March 11, 2024).
- UNHCR (2022). *Ukraine Refugee Situation. The Operational Data Portal*. Available online at: <https://data.unhcr.org/en/situations/ukraine> (accessed February 19, 2024).
- Verhovna Rada. (2018). *On the National Security of Ukraine: Law of Ukraine Dated June 21, 2018 No. 2469-VIII*. Available online at: <https://zakon.rada.gov.ua/laws/show/2469-19#n355> (accessed November 18, 2023).
- Verni, M., Holt, S., and Rizzello, C. G. (2024). Microbial fermentation for improved sensory properties and functionality of sustainable foods. *Front. Microbiol.* 15:1387745. doi: 10.3389/fmicb.2024.1387745
- Viana, C. M., Freire, D., Abrantes, P., Rocha, J., and Pereira, P. (2022). Agricultural land systems importance for supporting food security and sustainable development goals: a systematic review. *Sci. Tot. Environ.* 806:3. doi: 10.1016/j.scitotenv.2021.150718