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RESEARCH ARTICLE

The Agricultural Sector of Ukraine in the Global Food Market: Pre-war State and Post-war Prospects

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Abstract: For a long time, Ukraine played an essential role as a producer of agricultural products in ensuring global and internal food security. The hostilities on the territory of Ukraine have caused significant risks to the activity of its agricultural sector and affected its current export potential. This study set out to assess the importance of Ukraine for world food security and its place in the global agricultural market, to outline current risks and to determine the prospects for the further development of agriculture in the conditions of post-war recovery. In particular, the integration of the agricultural sector into the global economic space was investigated, which showed the rapid expansion of the presence of agri-food products in certain commodity markets of some countries. An increase in the level of involvement of the agricultural sector in the global flows of goods related to food production has been established. This conclusion is based on calculations made using the data of input-output tables at basic prices. It is substantiated that the post-war recovery of Ukraine's economy should ensure the reconstruction of the agricultural sector on the basis of sustainability. In this context, the authors presented the results of the assessment of possible changes in the production of the main types of agricultural products during the implementation of the concept of ecological resource-conserving agriculture. The impact of these changes on the country's export potential and its food security was assessed by developing food balances for the main types of agricultural products. The conducted assessment confirmed the necessity of such restructuring to ensure the preservation of the country's agricultural potential in the long term.

Keywords: Agricultural sector; Agri-food export; Food security; Sustainable development

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1. Introduction

World trade in agricultural and food products is carried out in order to provide the inhabitants of the planet with a sufficient amount of diverse food. Food supply to the population is a strategic priority of the governments of all countries in the world without exception. This problem is especially acute in poor countries, which, moreover, are not able to fully saturate their food market through domestic agricultural production. For such countries, the global food supply is essential to avoid hunger and diseases associated with malnutrition, thereby also providing social stability [1].

According to Food and Agriculture Organization (FAO), the number of people in the world affected by hunger continued to increase in 2020 and amounted to between 720 to 811 million people. Of the total number of undernourished people, more than half live in Asia and more than one-third in Africa [2]. Many of these countries have recently been significant importers of Ukrainian agri-food products. According to our estimates based on data from the State Statistics Service of Ukraine these deliveries to Asia and Africa in 2021 amounted to 49% and 13%, respectively, of the total volume of Ukrainian agri-food exports.

In general, Ukraine supplied more than 14% of the global food market [3], including 12.5% of the world export of wheat and 12.8% of corn, as well as 47% of the world trade in sunflower oil and 54% of sunflower meal [4]. According to USDA estimates, in the last pre-war year, Ukraine was the fourth largest exporter of corn in the world after the USA, Brazil and Argentina. As of the end of 2021, Ukraine was the fourth supplier of food to the EU (with the volume of supplies of 6,896 million euros in 2021). According to estimates of the Kyiv School of Economics, more than 400 million people in the world depend on Ukrainian grain supplies [5].

The war started by Russia in Ukraine radically changed the situation. Increasing military conflicts in developing countries have long been recognized by the FAO as one of the main factors contributing to food insecurity in these countries. Research has shown that there is strong evidence for a link between food security and violent conflict [6]. At the same time, it is obvious that in a situation of a full-scale military confrontation between countries that are among the largest global suppliers of grains and oilseeds (which are Ukraine and the Russian Federation), a food crisis can affect a much larger part of the world's population. The problems with export logistics, reduction of cultivated areas, and the probable decrease in the yield of agricultural crops, caused by the war in Ukraine have already significantly affected the current state of global food security. Thus, the world is witnessing an increase in prices for many products and their shortages, especially felt in the Middle East and North Africa. This has already forced many of them to close agricultural exports in order to maintain their own food security [7].

The long-term high agrarian status of Ukraine became one of the important factors in mitigating the consequences of military actions for the domestic food supply during the war. At the same time, the destruction caused by the war in the field of production and sale of agri-food products can create prerequisites for the further recovery and development of the Ukrainian agrarian sector on the basis of sustainability and structural balance of production and export.

The post-war recovery of the agricultural sector of Ukraine should form the basis for its further long-term development. That is why it is extremely important to choose the priorities of such development and directions of their implementation. The fundamental goals should be to ensure national food security, as well as the reproduction and preservation of natural resources of agricultural production. To achieve this, innovative modernization of the agricultural sector and its structural transformation are needed. As a result, there should be a gradual transition from a highly specialized mono-product structure of agri-food production and export to a structure of agricultural production that is more effective in view of national economic interests.

Considering all the above, the purpose of the article is to reveal the role of the agricultural sector of Ukraine as a guarantor of world food security in the pre-war period, to identify risks of the impact of military operations on the Ukrainian agricultural sector, and to outline the prospects for post-war agricultural production and exports of Ukraine, taking into account the need to comply with the principles of sustainable development.

2. Research Methods and Materials

The authors sought to analyze the changes that have occurred in Ukrainian agrarian production and exports over the past 18 years (2004-2021). Calculations are based on the data from the State Statistics Service of Ukraine.

The time series of export covering the period of 2004-2021 is analyzed from the point of view of the commodity structure. Commodity structure is based on the Ukrainian classification of goods of foreign economic activity (UCGFEA), whereas we have considered the correspondence between the UCGFEA positions and positions of The Combined Nomenclature, designed for the EU statisticians, using eight-digit coding system. The Combined Nomenclature is the primary nomenclature as it is used by the EU Member States to collect detailed data concerning their trade. It is based on the Harmonized Commodity Description and Coding System (managed by the World

Customs Organization). The volume of Ukrainian agrarian foreign trade flows is estimated in US dollars.

The scope of the research includes estimation of effect both trade and production of increasing international fragmentation of production that has occurred over the last decades. The time series of Ukraine input-output tables provide a comprehensive map of transactions of goods and services for estimation. The volume of this flow is estimated in Ukrainian hryvnia.

The authors also used the balance method for the development of model for assessing the possible volumes of export of agricultural products with strict adherence to the principles of sustainability in the further development. During the development of this model relevant international experience in food balance preparation was taken into account, specifically materials and recommendations developed by FAO, USDA and Eurostat [8-12].

As a result, the following general scheme of forecast balances preparation, coherent with international FAO recommendations, was adopted:

DEMAND = SUPPLY

SUPPLY = STOCK at the beginning of the period + PRODUCTION + IMPORT

DEMAND = DOMESTIC CONSUMPTION (human consumption + seeds +livestock and poultry feed + industrial use + losses + other consumption) + EXPORT + STOCK at the end of the period

3. Results and Discussion

3.1 The Dynamics of Foreign Agri-food Trade of Ukraine in the Pre-war Period

The agrarian sector of Ukraine in the pre-war period rapidly integrated into the global economic space, and even more actively than the Ukrainian economy as a whole. This process especially intensified at the beginning of this millennium, after the industry overcame the economic crisis of the mid-90s of the twentieth century and during the country's preparations for accession to the WTO (2005-2008). It was during this period that Ukraine laid the foundations for its current high status in the global food market and formed an agrarian export hyper-specialization [13]. So, only 6 commodity items, namely corn, wheat, barley, rape, sunflower oil and sunflower meal provided almost a third of the national and more than 70% of Ukraine's agri-food exports in the last pre-war years. The high values of RCA (revealed comparative advantage index), or otherwise the Balassa index, for these products (at the level of almost 300 units for sunflower processing products and up to 80 units for grain crops) indicate that these products have strong comparative advantages, which also reflects its high share in the world market (respectively 42%-48% and 8%-13%).

In the pre-war period, Ukrainian agri-food products from year to year expanded their presence both in the EU market and the markets of Asian and African countries (Table 1). This was largely facilitated by the gradual harmonization of the national legislation of Ukraine in the field of ensuring the quality of food products with the relevant European regulations. The result was a noticeable increase in the quality indicators of products, the introduction of modern production standards at all stages.

In recent years, the importance of India, Egypt, China, as well as other countries as importers of Ukrainian products has significantly increased. For example, China for 2011-2021 increased the import of agricultural products from Ukraine by 41.5 times, which increased the share of this country in the structure of Ukrainian agri-food exports from 0.5% to 15.5%. In turn, India was the largest importer of Ukrainian sunflower oil.

However, despite the high position of the Ukrainian agricultural sector in the global space, it is quite obvious that agricultural raw material exports should not dominate in the overall structure of export deliveries due to the high volatility of the conjuncture of the respective markets. Therefore, Ukraine is faced with the task of increasing the share of food products with a higher added value in agri-food exports.

In the meantime, as statistics show, raw material exports continue to dominate. The share of processed products in both exports and imports is declining. The information below on the commodity structure of agricultural trade in Ukraine in 2004-2021 confirms the growth of negative changes in the area of value added (Table 2). Thus, the share of trade in unprocessed commodities has been constantly increasing due to a decrease in the share of processed products (currently down to 40%). Consequently, Ukrainian agricultural exports are becoming more and more raw materials, which requires a revision of the country's agri-food trade policy.

The high level of integration of the agricultural business of Ukraine into the global economic space is also confirmed by the increase in the indicators of its involvement in global value chains(GVC). This, in particular, is evidenced by both the dynamic growth of the index of participation of agriculture and the food industry of Ukraine in global value chains (GVC participation rate), and the decrease in the indicator of domestic value added (DVA) in these areas [14]. Estimates by international experts show that for the period they studied 1995-2015 against the background of the expansion of the presence of agriculture in GVC, its dependence on imported inter-

Table 1. Dynamics of Ukraine's foreign agri-food trade with the main importing countries (USD million).

Countries	2011	2013	2014	2015	2017	2018	2021
EU countries							
Netherlands	513.6	690.2	749.9	575.6	1275.7	1157.6	1762.1
Spain	724.1	759.0	923.0	852.9	1023.8	1039.8	1168.4
Poland	445.8	528.7	536.2	422.7	518.2	557.2	981.5
Germany	151.1	222.5	247.9	188.3	385.0	657.5	842.3
Italy	418.1	598.4	625.4	560.0	749.3	702.7	717.9
Other countries							
China	103.1	484.0	764.9	1239.6	1015.3	1171.0	4282.3
India	944.9	1079.4	1390.9	1082.6	1953.4	1856.1	1953.7
Egypt	862.2	1524.3	1390.9	1022.9	1257.9	888.7	1600.5
Turkey	883.6	688.3	665.6	757.6	928.9	800.2	1464.0
Saudi Arabia	551.7	427.8	629.1	473.3	358.8	588.7	645.8
Iran	403.4	526.1	591.2	440.6	527.6	420.8	612.5
Israel	268.4	443.5	377.6	395.2	411.2	337.0	449.6
Russian Federation	2025.0	1941.1	911.8	276.5	102.3	92.2	45.9

Source: Calculated using the data from the State Statistics Service of Ukraine.

Table 2. Structure of foreign agri-food trade of Ukraine in relation to the processed and unprocessed goods (USD million).

Indicators	2004	2008	2014	2016	2018	2021	Index 2021vs.2004, %
Exports							
Non-processed total (UCGFEA items 1-14)	1784.4	6373.7	9750.6	8868.7	11097.4	16883.2	946.2
Processed total (UCGFEA items 15-24)	1686.5	4463.9	6918.3	6413.1	7515.3	10825.7	641.9
Total	3470.9	10837.6	16668.9	15281.8	18612.8	27708.9	798.3
Share of non-processed (%)	51.4	58.8	58.5	58.0	59.6	60.9	118.5
Share of processed (%)	48.6	41.2	41.5	42.0	40.4	39.1	80.5
Imports							
Non-processed total (UCGFEA items 1-14)	754.4	3164.5	3155.8	1911.1	2446.9	3724.5	493.7
Processed total (UCGFEA items 15-24)	1154.0	3292.1	2903.5	1980.0	2604.8	4022.4	348.6
Total	1908.4	6456.6	6059.3	3891.1	5051.7	7747.0	405.9
Share of non-processed (%)	39.5	49.0	52.1	49.1	48.4	48.1	121.8
Share of processed (%)	60.5	51.0	47.9	50.9	51.6	51.9	85.8

Source: Calculated using the data from the State Statistics Service of Ukraine.

mediate inputs has significantly increased. At the same time, since 2013 the trend has changed. This was the result of a significant increase in gross agricultural and food exports, as well as a decrease (albeit insignificant) in the import component in the export of these goods.

Our estimates for a later period using the input-output tables confirm the persistence of this trend (Table 3). Imports of goods and services matrix allows us to determine the directions of use of imported products in the total amount of goods and services used in the economy. According to input-output tables, in 2020 the share of the import component in the intermediate consumption of agriculture was 25.5%. This can be considered as an approximate level of use of imported resources in general production, including in the production of exported goods.

Consequently, the dependence of Ukrainian agriculture on external resources is somewhat higher than in the economy as a whole, and significantly higher compared to manufacture of food products, since the products of Ukrainian agriculture are its main resource component. At the same time, this dependence tended to decrease, despite the fact that at the input (resource component) agrarian sector is less involved in GVC than the output (Ukrainian exports). So, Table 4 shows the level of involvement of agriculture, forestry and fisheries of Ukraine in the GVC, based on the indicators of input-output tables. It is dif-

Table 3. Dependence on foreign input (at basic prices, million Ukraine Hryvnia (UAH)).

Indicators	2015	2016	2017	2018	2019	2020
Total by types of economic activity						
Use of imported goods and services	705090	827161	994369	1136089	1076165	972899
Intermediate consumption (without taxes and subsidies on products)	2444526	2985429	3680226	4404755	4866204	4981105
Dependence on foreign input rate	0.2884	0.2771	0.2702	0.2579	0.2212	0.1953
Agriculture, forestry and fishing						
Use of imported goods and services	95360	126017	142505	144397	150449	129059
Intermediate consumption (without taxes and subsidies on products)	309222	366186	412767	497649	494916	506638
Dependence on foreign input rate	0.3084	0.3441	0.3452	0.2902	0.3040	0.2547
Manufacture of food products, beverages and tobacco products						
Use of imported goods and services	68152	92359	106439	115109	100018	94700
Intermediate consumption (without taxes and subsidies on products)	329094	400922	475163	498663	539547	601359
Dependence on foreign input rate	0.2071	0.25304	0.2240	0.2308	0.1854	0.1575

Source: Calculated according to Olena Shubravska, 2021 [13].

ficult to single out the export flows that will be included in global value chain, but the table contains data on the export of products of section A (Agriculture, forestry and fishing), which are essentially raw materials and require further processing, and therefore the exported volumes of these products with a high probability will be directed to further processing and may become a component of GVC.

In this case, we estimated the GVC participation rate as the share of added value that came from products involved in GVC. Thus, as we can see, the agriculture of Ukraine in the pre-war period was quite deeply involved in the global value chain.

In addition, during the research we assessed the degree to which the country relies on imported inputs in the production of some exported commodities (in particular cereals). We measured it as the share of value of imported inputs in total exports. The evaluation was carried out according to the author's methodology for wheat and corn. Thus, the following imported resources were evaluated: machinery, plant protection products, mineral fertilizers, and seed material. Export volumes included both grain itself and products of wheat and corn processing (flour, cereals, starch, ready-made dough products, etc.). Since these goods (cereals) are mainly export-oriented, the share of import of production resources in the value of the specified export was insignificant and in 2019-2020 was 16.4%.

3.2 The Impact of Hostilities on the Agricultural Sector of Ukraine

The war in Ukraine affected all areas of the country's socio-economic life. Losses, unfortunately, are already catastrophically great. In this regard, FAO speaks of the unprecedented scale of damage to Ukrainian agriculture, which will have an impact not only on the Ukrainian economy, but also on global food security. "Damage caused by war to a country with an agricultural output and exports as significant as that of Ukraine is unparalleled since the Second World War" [16]. According to the estimates of the KSE Institute Center for Food and Land Use Research and the Ministry of Agrarian Policy and Food of Ukraine, in just three months of Russia's war against Ukraine, direct losses (full or partial destruction of material assets) in the agricultural sector alone reached almost 4.3 USD billion [17], and indirect (due to a decrease in production, the blockade of ports and the increase in the cost of

Table 4. Global value chain participation rate for agriculture, forestry and fishing (at basic prices, million Ukraine Hryvnia (UAH)).

Indicators	2015	2016	2017	2018	2019	2020
Use of goods and services for export	178390	208977	244472	267614	329968	315305
Output	558788	655569	727352	871971	866138	915800
GVC participation rate	0.319	0.319	0.336	0.307	0.381	0.344

Source: Calculated according to State Statistics Service of Ukraine, 2015-2020 [15].

production factors)—23.3 USD billion [18]. The forestry of Ukraine also suffered colossal losses. So, about 600,000 hectares of forest-covered land has already been affected by the war. Landmines have become an extremely serious problem, especially when fighting forest fires. According to the State Agency of Forest Resources of Ukraine, the damage caused to forest ecosystem services is estimated at 185 USD million.

The war in Ukraine also led to the loss of food stocks available in the country before the war due to their physical destruction by the invaders and the placement of a significant number of warehouses in the currently occupied territories; lack of physical ability to conduct agricultural activities in many key agricultural regions of Ukraine (in July 2022 18% cropland were currently occupied, 5% were previously occupied, 3% were just liberated); critically insufficient level of provision of fuel and lubricants to farmers; the destruction of the supply chains of agricultural production resources (plant protection products, seeds, and fertilizers), which negatively affects the resource security of all production processes and causes crop failure (Ministry of Agriculture of Ukraine expects in 2022 a decrease in grain yield by 10%-15% compared to the past year); the increase in the cost of agricultural work against the background of a sharp reduction in exports and the impossibility of replenishing the financial resources of agricultural producers because of this. In Ukraine, there is currently a catastrophic violation of export logistics. Namely before 24 February the maximum throughput of export facilities was 6 mln·t per month (95% by sea, 5% other), in June 2022 it was 2 mln·t per month (15% by trucks, 35% by railway, 50% by river) [19].

Taking into account all of the above, according to our estimates, in 2022, the production of grain crops in Ukraine may decrease by 30-33 mln·t compared to the previous year, when a record harvest of more than 85 mln·t was harvested. International experts estimate the reduction of grain production in Ukraine in the current year in the amount of 35 mln·t [20]. A decrease in the production of sunflower seeds is expected at the level of 6 mln·t, which will cause a corresponding drop in the production of sunflower oil, the export of which Ukraine has ranked first in the world for many years in a row. According to the profile association "Ukroliyaprom", in 2022, the export of oil has already decreased by 8 times compared to 2021, and the export of sunflower meal—by 12 times.

In the August report, the USDA noted that the volumes of Ukrainian wheat production and export in 2022/2023 will decrease compared to the previous period by 13.5 mln·t and 7.8 mln·t, respectively. The production of corn is forecast to be 12.1 mln·t, and exports—12 mln·t less [21].

3.3 Prospects of the Ukrainian Agricultural Sector Post-war Development

In general, the further situation in the field of agricultural production in Ukraine seems to be poorly predictable. Taking into account the problems of the war period noted above, many agrarians may for some time completely abandon their economic activity or radically restructure it. The choice of large producers, who before the war narrowly specialized in the production of grains and oilseeds, will be determined by comparing their own financial and other resource capabilities, as well as the scale of the costs of the autumn sowing and the risks of its implementation with the problems of marketing the grown crop and the profit that is poorly predicted as a result of all this. It is expected that these producers will give preference to crops that bring more income per 1 ha with a smaller mass of grown crop. Thus, it is already known that this spring many agrarians sowed fields with sunflower instead of corn, which they planned to sow before the war. It is assumed that in the future, sunflower and rapeseed, which are in demand on the European market, can significantly replace corn and wheat crops in Ukraine. In addition, already now many large grain producers are concerned about finding effective solutions in the field of processing. The main guidelines are the construction of bioenergy enterprises for the production of bioethanol and biomethane, increasing the production of compound feed, starch, including highly demanded modified, sugar alcohols (sorbitol, xylitol, etc.), the most important organic components of animal feed—amino acids (lysine, methionine, threonine, tryptophan), etc.

Small Ukrainian agrarians, who traditionally have a more diversified production structure and are oriented mainly to the domestic market, demonstrate relatively greater stability during the war (as, indeed, in other periods of crisis). It is on them that the national food security of Ukraine largely depends, regarding such products as milk, vegetables, local fruits—almost completely. However, the entry of such producers into the global food market in the near future seems problematic due to their generally unsatisfactory logistical support and insufficient coordination of actions, which is necessary for the formation of market lots of quality products. The only exception in this context is Ukrainian organic producers, who have been successfully presenting their products on the world market for a long time, mainly in European countries.

Thus, it is obvious that under the influence of the war with Russian Federation, agricultural production in Ukraine may reduce and, moreover, undergoes significant transformations that may persist in the years following the end of the war. This will undoubtedly affect the export op-

portunities of Ukrainian farmers, who, at least in the short term, may lose their status as key players in the global market in the segment of grain crops that were traditional for Ukraine until recently. At the same time, mechanical damage and chemical contamination of large areas of land and water resources provoked by military actions as a result of explosions, mining of the territory and man-made disasters, as well as changes in the structure of production in the direction of the priority development of agricultural crops that deplete land resources (primarily sunflower) are fraught with production in Ukraine with long-term negative consequences. This is especially dangerous, taking into account the unfavorable ecological situation in the sphere of agricultural production in Ukraine even before the war against the backdrop of the growing influence of climate change on it.

Ukraine has the second largest arable land resource in Europe. However, there is a steady trend of further intensive degradation of soils—the main means of agricultural production [22]. The largest risks identified as erosion (38% of agricultural land), soil compaction and loss of humus, exacerbated by a high plowing rate (78% of soils and 56% of land). More than 19% of soils are acidic. The balance of nutrients in the soil, like humus, is negative. In addition, many soils are contaminated. The total forest area of Ukraine (10.4 mln·ha) is much smaller than in EU: forest cover rate is 14%-16% in Ukraine and 39% in EU average. As a result of the military operations, the problem of restoration and preservation of natural resources of agricultural production has significantly increased, since on a significant part of the land, its solution must be preceded by bringing the land into a state suitable for agricultural use (demining, elimination of numerous man-made pollutions, etc.).

So, during the period of post-war reconstruction, Ukraine has no alternative to the development of agricultural production on the principles of sustainability. This approach is also due to the intensification of European integration processes after Ukraine received the status of a candidate member of the EU on June 23, 2022. Thus, issues of sustainable development, a low-carbon strategy, and the European Green Deal course should be prioritized when Ukraine determines the prospects of its agricultural production and forms agrarian policy to achieve them.

The realization of this goal involves the implementation of innovative modernization of agricultural production and the formation of its structure based on the priority of internal food needs and resource opportunities for their implementation, and not on the global market situation and the interests of its leading players [23,24].

This approach, in particular, involves optimizing the structure of land and agricultural landscape; decreasing in agricultural development (by 5 percent) and plowed territory (by 10 percent); increasing the productivity of agricultural land (by 40-50 percent) through the rational use of organic, organo-mineral and mineral fertilizers and chemical meliorants on acidic and saline soils [25].

In this context, the authors estimated the possible volumes of production and export of agricultural products, which can be obtained by complying with the above requirements of the government document and by the following assumptions:

- the post-war territory of Ukraine will be restored to its borders as of February 23, 2022;
- all land will be demined and available for agricultural activity;
- logistics infrastructure, even if it is not completely restored, there will still be opportunities to provide farmers with all the necessary resources and equipment;
- the structure of crop production will fundamentally change in accordance with ecological requirements, and the number of livestock of agricultural animals will correspond to the area of available fodder lands.

The assessment of changes in the structure of crop production was based on calculations of the optimal structure of sown areas on the basis of crop rotations recommended for different soil and climatic zones of Ukraine [26].

In the agricultural sector of Ukraine, as mentioned above, there are two significant producers: enterprises and farmers as well as households. The analysis carried out by the authors [27] proved that the households have a relatively optimal structure of sown areas and there is no possibility of introducing full-fledged crop rotations on small plots, so this group of producers can only recommend directions for improving the structure of production in their farms. In 2021, enterprises and farms that produce products for export had a non-optimal structure of sown areas with the dominance of grain and industrial crops. Therefore, changes in the structure of production were estimated for such farms. In general, the changes related to compliance with environmental requirements can be very significant, as 3 mln·ha of agricultural land, 6 mln·ha of arable land should be taken out of circulation, and the area of pastures and hayfields should be increased by 2 mln·ha.

When making calculations, we assumed that: a) households will not change the structure of crop production and will maintain production volumes; b) producers of livestock products will increase the number of agricultural animals in accordance with the above ecological requirements, without changing the structure. Taking into ac-

count all the assumptions made, one can expect the results of agricultural production given in Table 5. Although the calculations are quite conditional, they still give an idea of the scale of the main changes that can take place in the structure of agricultural production in Ukraine with full compliance with environmental requirements. In accordance with the implementation of structural changes in production, there will also be changes in the country's export potential.

The main method of calculations was the balance sheet method. The balance sheet item of the estimated balance sheet became its "Exports" item, in contrast to the fact balance sheets, where the balance sheet item is usually "Fund of consumption". In the evaluation process, in addition to production volumes, domestic consumption volumes were determined and, in particular, such item of the balance of demand and supply for certain types of products were evaluated, as the consumption fund (which may be formed in the post-war period), expenditures on processing and domestic use (sowing, planting, fodder), as well as losses and wastes. Since the goal of the structural restructuring of the agricultural sector is to achieve food security (that is, food sufficiency) on the basis of sustainable development, when calculating the consumption fund, it was assumed to ensure consumption norms per person, which were formed in the pre-war period. To estimate the consumption fund, it is currently difficult to predict the population size in the post-war period, since migration processes are still ongoing in Ukraine, the scale of which will depend on the activity and duration of hostilities in the country. According to some estimates, depending on the duration of the war, the loss of population will be from 600,000 to 5 million people [28], so for the calculations, losses at the level of 10% were determined.

Estimates indicate that the production of a number of crops may decrease with structural restructuring in accordance with ecological requirements. In particular, the agricultural sector may lose significantly in the production of corn (up to 35%), wheat (up to 8%) and sunflower (about 45%). This may accordingly reduce the production and export volumes of sunflower oil. Soybean and rapeseed production may also decrease. However, these changes are necessary, since the share of cultivated areas under technical crops (primarily sunflower) is now in the range of 35%-50% depending on the region, which is an unacceptable violation of environmental requirements. Such a situation allows obtaining only short-term economic profit, and in the long term it leads to land degradation, a decrease in harvests and the loss of export potential and the ability to ensure food security at the global level.

Insignificant exports of sunflower, soybeans and rapeseed will be due to large volumes of their domestic processing, i.e., mainly products of oil crops processing will be exported. Therefore, it can be expected that Ukraine will be able to avoid significant losses of export revenues due to the reduction of sowing of grain and technical crops, ensuring the development of appropriate processing capacities. This is fully consistent with the need to speed up the transition from raw materials exports to exports of processed products, declared by the government in the Draft Ukraine Recovery Plan [29]. Significant amounts of soybeans and sunflowers are already exported in processed form, but in addition to this, in order to increase the value of exports, it is planned to increase the processing capacity of grain crops, soybeans and rapeseed.

According to calculations, the changes may also lead to

Table 5. Expected export by Ukraine in the post-war period of the main types of agricultural products when transitioning to production taking into account environmental requirements (thousand tons).

Types of products	Production		Changes in the volume of production	Expected domestic consumption	Expected export
	2021	expected			
Grain and legumes	86011	73120	–12891	20575	52545
Wheat	32151	29750	–2401	7200	22550
Corn	42110	27200	–14910	10700	16500
Soya	3493	2610	–329	1300	1310
Rapeseed	2939	2260	–679	260	2000
Sunflower	16392	9140	–7252	9050	90
Potatoes	21356	23920	2564	23750	170
Meat	2438	3650	1212	2000	1650
Milk	8729	13100	5119	8750	4350

Source: Authors' calculations.

an increase in Ukraine's production of potatoes, which is currently recognized as the third most important food crop in the world. At the same time, potatoes are a strategic crop with regard to the requirements of sustainable and ecological food production, as they generate fewer greenhouse gas emissions compared to other main crops and at the same time ensure the receipt of cash by small producers. In Ukraine, the increase in the volume of this product is predicted due to production in enterprises, so it will be suitable for industrial processing and export.

According to the assessment (following the ecological standards), the total area of fodder lands in Ukraine can reach 13.1 million hectares. Thus, Ukrainian farmers will be able to increase the number of livestock by 1.5 times (up to 13.1 million in standard livestock unit) if they comply with the requirement of a 1:1 livestock load on fodder grounds. This will not only give a notable impetus to the development of animal husbandry, but will also allow to significantly activate the process of applying organic fertilizers to improve the condition of the soil. In addition, according to the calculations, increasing the production of livestock products, along with ensuring its domestic consumption, will also increase export.

The Ukrainian agricultural sector also has a significant potential for the development of organic production, as a system of agricultural production that fully complies with all principles of sustainable development, contributes to the restoration of the natural balance and ensures the sustainability of the food system. The Ukrainian National economic strategy for the period until 2030 envisages an increase in the area of land with organic status to at least 3% of the total area of agricultural land against the current slightly more than 1%.

4. Conclusions

Prior to the start of full-scale Russian aggression in 2022, Ukraine for many years was one of the leading suppliers of agricultural, to a large extent raw materials, products to the global food market, providing more than 14% of its total volume. According to our estimates, both the level of participation of the country's agricultural sector in the GVC and its dependence on imported resources have generally increased, albeit to varying degrees.

The current war in Ukraine not only has a catastrophic impact on the national economy, but also poses a threat to food security throughout the world, primarily in low-income countries in Asia and Africa. In Ukraine, people are dying en masse, crops and warehouses with food stocks are being destroyed, agricultural land is rendered unusable by shelling, and well-established supply chains of products and resources are being destroyed. All this is an incomplete list of the consequences of ongoing hostilities. It is already obvious that this year the situation will lead to a significant (by 30%-35%) reduction in Ukraine's production of its global food specialization, in particular, grain.

The ongoing significant destruction of Ukrainian agriculture as a result of the war testifies to the need for a large-scale post-war restoration of agricultural production. The result of this should be the formation of an environmentally sound specialization that meets both nationally oriented goals and international requirements (in particular, the EU Green Deal). This will make it possible to implement the concept of ecological resource-conserving agriculture and preserve national natural resources in the long term. Our assessments have shown the possibility of achieving under these conditions a high level of self-sufficiency of the country's population with food, diversifying agricultural exports, and entering foreign markets with new types of products. In particular, against the background of the expected reduction in the production and export of sunflower, corn, sunflower oil, we can expect an increase in the total area of forage land and the corresponding potential for the production and export of livestock products, an extension of the commercial production of potatoes, an expansion of the organic segment, as well as an accelerated development of processing industries.

To achieve such goals, the state must first of all intensify the stimulation of sustainable technologies' usage by farmers, as well as promote the expansion of capacities for processing agricultural raw materials. For this, following the example of other countries, it is necessary to adopt and finance appropriate programs. Obviously, the cardinal solution to such problems in Ukraine will be postponed until the end of the war, when farmers' incomes stabilize and investment risks are minimized.

Conflict of Interest

There is no conflict of interest.

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