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Wheat supply logistics in wartime in Ukraine

Introduction

The Russian invasion on Ukraine on February 24, 2022 has caused much turbulence not only in the Ukrainian economy but also worldwide. In particular, the production of agricultural products, especially in the grain sector, was severely affected.

According to statistical data, Ukraine, with 33 million tons, was the seventh most important producer and, with 19 million tons, the fifth largest exporter of wheat in the world in the 2021/2022 marketing year.

Thus, following the events of 2022, the logistics of grain supply has become a crucial and urgent issue worldwide, as wheat is the principal staple food in many countries (especially in Africa) and disruptions in its supply can lead to a food crisis in underdeveloped countries.

The purpose of the research is to develop a model of the Ukrainian wheat supply chain in conditions of war in the context of groups of importing countries based on the volume and stability of supplies. The model aims to present the best supply chain for ensuring food security in countries most dependent on Ukrainian wheat.

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In the research, the countries importing Ukrainian wheat were divided into groups using the ABC-XYZ analysis method according to the volume of wheat imports and the level of stability of the orders.

Considering the strategy of Ukrainian grain supplies, it is possible to forecast supply chains to satisfy the needs of the most Ukrainian-dependent importer countries in order to prevent a food crisis in those countries.

The study was conducted concerning the dynamic geopolitical situation in Ukraine in 2022 and was based on the data from analytical reports as of the end of August 2022.

The Ukrainian wheat market, and the share of Ukrainian wheat in the total demand of importing countries, were analysed based on data from 2010 to 2021, obtained from the State Statistics Service of Ukraine and the Food and Agriculture Organisation of the United Nations. Analytical reports of financial and agricultural organisations were also used in this paper.

Literature review and research methodology

Problems with providing high-quality supply logistics, including export logistics of wheat, have been observed in the grain industry of Ukraine. During the wartime, resolving these challenges have become more acute and, therefore, urgent due to the increased risk to global food security. Therefore, the security of wheat supply chains has become the object of research and analysis by scientists and experts.

I.I. Savenko and D.V. Sedikov are the authors of scientific works in which the issues of grain logistics (Sedikov, 2018) and food security as a priority of the agro-industrial policy of Ukraine (Savenko, Sedikov, 2019) are considered.

Yu. M. Makhanyova (Makhanyova, 2015) considers the issue of the export of grain crops from Ukraine, the European Union, and the countries of the world in the conditions of modern integration processes.

The main source of statistical information for writing the paper was the data of the State Statistics Service of Ukraine (State Statistics, 2010–2020), in particular, its express releases with data and analytics on Ukraine's foreign trade in 2022.

The authors also used publications posted on the website of the Ministry of Agrarian Policy and Food of Ukraine (Ministry of Agrarian, 2022). Data regarding the global grain market is covered in the "Agro international" section. To analyse the volume of exports and imports of Ukrainian wheat, data from the Food and Agriculture Organization of the United Nations (Food and Agriculture, 2010–2020) were used.

The authors analysed Ukraine's export potential on the world wheat market, and identified the main importers of Ukrainian grain. According to the methodology

developed by the authors, the share of Ukrainian wheat in the total demand of importing countries, and the share of Ukrainian wheat exports to these countries in the total Ukrainian export of wheat E(%) were compared. A comparison of these indicators provides information on Ukraine's external activities as a wheat exporter.

Since Ukraine exports wheat to over 50 countries around the world, the logistic method of ABC-XYZ-analysis was used to group these countries and justify the selection of the most strategically important groups of countries for further cooperation.

According to S.V. Koryagina (Koryagina et al., 2014), the ABC analysis method "means identifying and evaluating a small number of quantitative values, which are the most valuable and have the largest share in the total set of cost indicators". The authors adopted this method to the issue of wheat export and the grouping of importing countries, and the importing countries with which Ukraine cooperates in the supply of wheat were divided into groups A, B, and C:

– group A includes the countries that create the greatest demand for Ukrainian wheat and provide the greatest revenue. The cumulative demand share of such countries in the total volume of exports is up to 85%;
– group B includes the countries that produce average demand; their cumulative demand share in total exports is up to 5–10%;
– group C includes the countries that make up only 5% or less of orders for Ukrainian wheat.

E.V. Krykavskyi (Krykavskyi, 2004, p. 163) adds that "along with quantitative-qualitative method of ABC analysis, continuity or discreteness of consumption, assessment of sustainability is important for planning… supply and transportation… Such an understanding… forms the basis of the XYZ analysis".

The XYZ-analysis divides the importing countries into groups based on the stability of their demand for wheat. The basis of this analysis is the calculation of the variation coefficient, the essence of which is the assessment of the percentage deviation of the volume of deliveries to the average value for the analysed period.

The number of values in the statistical series, that is, the number of years on which the XYZ analysis is based, must be equal to "at least three periods for which the report is made. If the product has a turnover of more than a year, then it is necessary to take a period that is at least three times higher than the turnover" (Kolomin, 2022). The period 2017–2021, i.e. five years, was chosen for the study.

The greater the coefficient of variation, the less stable the volume of deliveries to a certain country:

– group X – countries with the most stable demand (coefficient of variation up to 10%);

– group Y – countries with medium variability of demand for wheat (coefficient of variation from 10% to 25%);
– group Z – countries with unstable demand (coefficient of variation over 25%).

The combination of ABC-analysis and XYZ-analysis makes it possible to divide the importing countries into nine groups, each of which is characterised based on indicators of the volume of Ukrainian wheat imports and the stability of demand for grain (Figure 1).

	A	B	C
X	**AX** greatest demand + stable demand	**BX** average demand + stable demand	**CX** low demand + stable demand
Y	**AY** greatest demand + medium variability of demand	**BY** average demand + medium variability of demand	**CY** low demand + medium variability of demand
Z	**AZ** greatest demand + unstable demand	**BZ** average demand + unstable demand	**CZ** low demand + unstable demand

Figure 1. Matrix of combinations of ABC and XYZ analyses

Source: based on: (Krykavskyi, 2004, p. 166).

According to Yu.V. Tyuleneva (Tyuleneva, 2017, p. 602), "the ABC-XYZ-analysis method is used to… classify consumers and suppliers of resources, distinguishing among them the main players to whom should be given the most attention". This advantage of the method was used by the authors to develop the model of the Ukrainian wheat supply chain in conditions of war for the purpose of ensuring food security in the most Ukrainian wheat-dependent countries.

RESEARCH RESULTS

Russia's invasion on Ukraine, which is one of the world's largest producers of wheat, maize, and barley, has caused damage to the grain sector worldwide. Therefore, disruptions in grain supplies caused by the seaport blockade forced importing countries to consider alternative supply options, in particular for wheat, which in terms of consumption is in third place after rice and maize.

We should emphasise that Russia also plays an important role in the grain market and is the third-largest wheat producer. In 2021, it exported approximately 13.1% of the total world export of wheat (*World Economic Forum, 2022. These are the top…*, http).

In Ukraine, more than 40 million hectares of fertile land is used for agricultural production. In 2000–2020, the country ranked 10th among wheat producers. In 2021, the total export of Ukrainian wheat amounted to 5.1 billion dollars (1,900,000 metric tons). In the structure of global wheat exports, Ukraine has 9% and ranks 5th among global exporters (Figure 2) (*World Economic Forum, 2022. Ukraine's food exports…*, http).

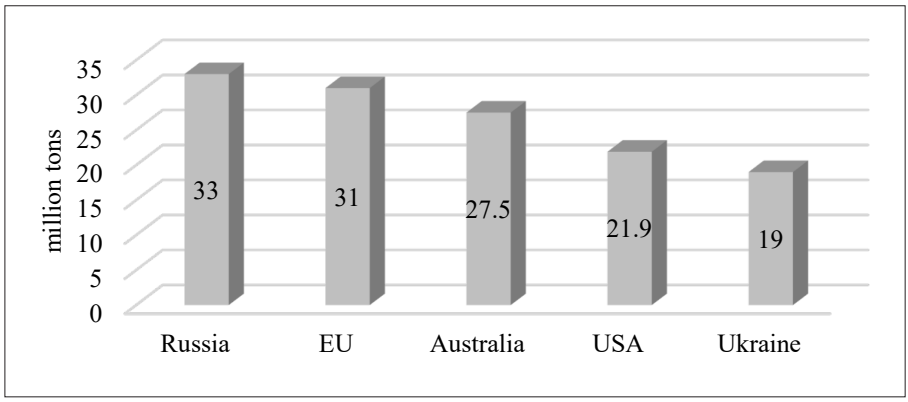

Figure 2. TOP-5 wheat exporting countries in 2021/2022 marketing year

Source: based on: (*World Economic Forum,2022 …*, http).

Over 2010–2021, the harvesting area ranged from 5 to 7 million hectares and tended to increase, especially in 2019–2021. However, in conditions of war, significant losses of cultivated areas are predicted in such regions as Chernihiv, Sumy, Kyiv, Kharkiv, Luhansk, Donetsk, Zaporizhzhya, Kherson, and Mykolaiv. Crops in the Zhytomyr, Poltava, and Dnipropetrovsk regions are also threatened (*State Statistics Service of Ukraine…*, http).

The volume of wheat production during the analysed period doubled from 16 to 32 million tons per year. This was facilitated by the use of proven growing technologies, thereby achieving an increase in the yield from 2.6 to 4.5 tons per hectare.

In Ukraine, 20–35% of wheat was used for domestic consumption in 2018–2021 (data for previous years are not available), and up to 20% of the produced wheat was used for food purposes. In 2021, this percentage decreased to 13%, which was associated with a decrease in its processing into flour due to low profitability of production, a change in taste preferences of Ukrainians, and a decrease in the population (*APK INFORM, 2022…*, http).

The key factor in maintaining demand for Ukrainian wheat is the price. Such a price should cover the growing production costs in war conditions and be acceptable to the importing countries, considering their purchasing power.

During 2010–2021, the export price of Ukrainian wheat increased from 186 to 250 dollars per ton, which was a 34.5% increase. Figure 3 shows the factors that determine both the increase and the decrease in the export price.

Beyond the economic aspect of the Ukrainian wheat supply system, the factor of food security should not be forgotten. In the conditions of the war, supplies should be directed to those countries where the problem of poverty and hunger is acute today. The Kyiv School of Economics conducted research and found that more than 400 million people around the world depend on grain supplies from Ukraine alone.

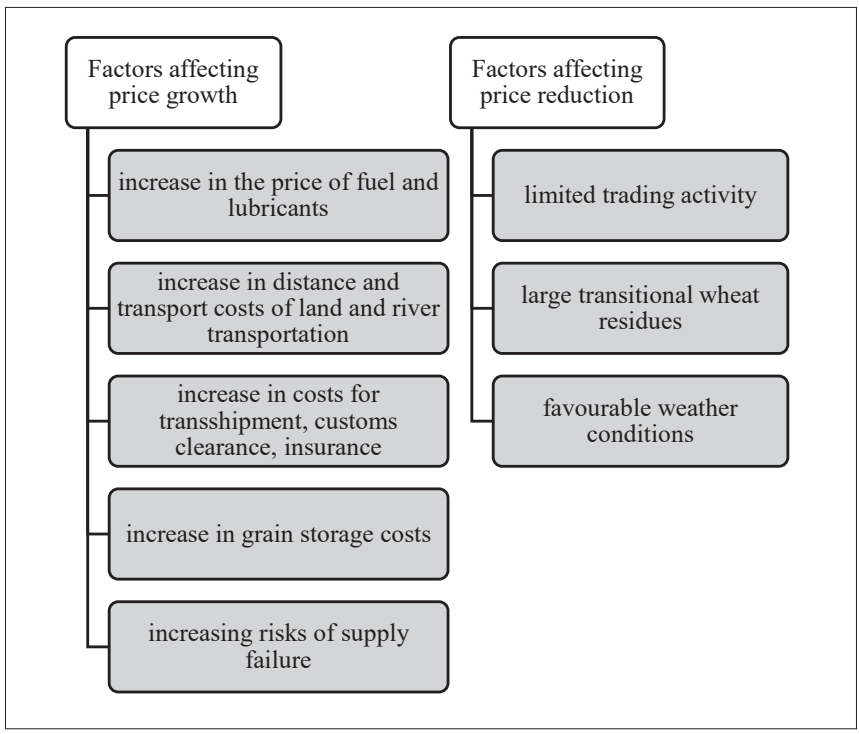

Figure 3. Factors of wheat export price formation

Source: based on own research.

The main importing countries of Ukrainian wheat, their ability to produce wheat on their own and their need for imported wheat, including from Ukraine, were considered (Table 1). Such countries as Bangladesh, Pakistan, Egypt, and Indonesia have remained the main importers of Ukrainian wheat for a long time.

Yet, Indonesia, Lebanon, and Libya are the most dependent on imported Ukrainian wheat: their share in the total wheat demand of the countries ranges from 15 to 90%.

Table 1. Share of Ukrainian wheat in the total demand of importing countries (D (%) and the share of Ukrainian wheat imports in the total Ukrainian export of wheat E (%) in 2010–2020

Importing country / Period	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
BANGLADESH D (%)	10.1	2.9	–	7.4	10.1	16.2	27.3	24.7	15.4	40.8	21.5
BANGLADESH E (%)	8.6	2.9	–	4.4	4.2	6.3	10.5	11.4	5.6	11.4	8.4
EGYPT D (%)	4.4	2.0	12.5	9.9	14.2	8.9	11.8	12.5	6.7	18.6	17.0
EGYPT E (%)	16.1	9.0	29.1	25.2	27.0	13.4	13.4	15.4	8.5	17.7	17.0
ISRAEL D (%)	27.0	22.0	39.6	18.5	21.6	35.3	28.6	29.7	28.5	25.7	16.4
ISRAEL E (%)	10.1	9.1	8.9	3.8	3.7	4.3	3.0	3.0	3.4	2.3	1.6
INDONESIA D (%)	–	–	–	4.0	4.2	13.1	20.1	19.7	25.8	27.6	26.4
INDONESIA E (%)	–	–	–	3.5	3.0	7.2	11.8	11.9	15.9	14.8	15.1
LEBANON D (%)	22.8	-	29.4	14.5	25.8	31.0	61.8	51.8	40.7	65.7	86.9
LEBANON E (%)	2.8	-	2.3	1.4	1.8	1.8	2.3	2.3	1.8	2.2	3.7
THAILAND D (%)	–	–	–	21.9	28.1	37.2	43.4	29.4	20.1	31.5	18.2
THAILAND E (%)	–	–	–	5.0	4.1	12.6	11.1	4.6	3.5	4.3	3.1
PHILIPPINES D (%)	7.1	–	–	9.6	9.7	19.0	20.4	15.9	26.2	14.2	10.3
PHILIPPINES E (%)	2.7	–	–	3.0	2.6	4.8	5.3	5.1	10.7	5.1	3.5

Source: based on (*State Statistics Service, 2022…* http*; Food, and agriculture, 2022…* http).

According to Table 1, the considered countries had different dynamics of wheat consumption in terms of domestically produced and imported wheat. All of the countries except the Philippines and Israel, for the period from 2010 to 2019, increased supplies of Ukrainian wheat while simultaneously reducing their own production and imports from other countries.

Israel and the Philippines, in contrast, reduced the consumption of Ukrainian wheat, especially in 2020. In Israel, the share of Ukrainian wheat in the country's total imports during the years 2010–2020 decreased from 25–35% to 16.4%. In 2020, the share of Ukrainian wheat exports to this country in the total of its exports decreased from 10% to 1.6%. Such dynamics relate to the use of alternative sources of wheat supply and the formation of the country's own grain stores.

The Ukrainian wheat import to the Philippines is also characterised by a decrease in the share of Ukrainian wheat in the total demand of this country from 20–26% to 10.3%. In the structure of Ukrainian wheat exports, the country's share decreased from 5–10% to 3.5%. According to 2021 data, the Philippines also increased purchases from Australia, as Australia had high production volumes and Ukraine was not competitive on the wheat market.

Other countries, such as Bangladesh, Egypt, Indonesia, Lebanon, and Thailand, increased the volume of purchases of Ukrainian wheat during 2010–2019. Those most dependent on Ukrainian wheat were Bangladesh, Indonesia, and Lebanon: the share of Ukrainian wheat in the countries' total demand in 2019 were, respectively, 40.8%, 27.6% and 65.7%.

In 2020, the situation changed, the countries reduced supplies of Ukrainian wheat because of the formation of sufficient temporary wheat stores and the expectation of good harvests.

To identify the most strategically important importing countries of Ukrainian wheat, an ABC-XYZ analysis was carried out.

According to the results of the ABC-analysis, such countries as Egypt, Indonesia and others have the largest share in Ukrainian wheat exports (16.5% and 15%, respectively) (Table 2). All countries whose cumulative share was up to 85% were included into group A.

Table 2. Results of ABC analysis of wheat imports in 2021, tons

Importing country	Amount of import, tons	Share on the total Ukrainian export, %	Cumulative share, %	Group of ABC-analysis
1	*2*	*3*	*4*	*5*
Egypt	3,314,424.69	16.513	16.513	A
Indonesia	3,059,797.85	15.245	31.758	A
Turkey	1,766,344.00	8.800	40.558	A
Pakistan	1,343,948.36	6.696	47.254	A

1	*2*	*3*	*4*	*5*
Bangladesh	849,373.40	4.232	51.486	A
Morocco	846,533.02	4.218	55.704	A
Yemen	796,808.37	3.970	59.674	A
Saudi Arabia	712,164.15	3.548	63.222	A
Tunisia	645,894.10	3.218	66.440	A
Lebanon	636,737.39	3.172	69.612	A
Ethiopia	607,029.16	3.024	72.636	A
Libya	569,509.43	2.837	75.474	A
Philippines	412,881.74	2.057	77.531	A
Republic of Korea	396,011.37	1.973	79.504	A
Israel	361,878.10	1.803	81.307	A
Kenya	355,497.66	1.771	83.078	A
Thailand	354,543.00	1.766	84.845	A
Nigeria	348,119.00	1.734	86.579	B
Vietnam	278,564.18	1.388	87.967	B
Iran (Islamic Republic)	264,189.00	1.316	89.283	B
Oman	207,108.62	1.032	90.315	B
Djibouti	193,749.47	0.965	91.280	B
Mexico	190,408.27	0.949	92.229	B
Mauritania	177,822.63	0.886	93.115	B
Algeria	167,890.31	0.836	93.951	B
Italy	126,500.40	0.630	95.372	C
Tanzania, United Republic	113,594.84	0.566	95.938	C
Sri Lanka	104,520.55	0.521	96.459	C
Jordan	63,051.50	0.314	96.773	C
Mozambique	63,008.17	0.314	97.087	C
Sudan	53,237.37	0.265	97.352	C
Uganda	46,808.00	0.233	97.585	C
Somalia	43,992.06	0.219	97.805	C
The Netherlands	43,879.56	0.219	98.023	C
Malaysia	42,142.97	0.210	98.233	C
Ghana	40,000.00	0.199	98.433	C
Greece	39,803.23	0.198	98.631	C
Eritrea	33,000.00	0.164	98.795	C
Madagascar	32,730.00	0.163	98.958	C
Cameroon	31,999.56	0.159	99.118	C

1	*2*	*3*	*4*	*5*
Myanmar	31,206.20	0.155	99.273	C
Angola	22,000.00	0.110	99.522	C
Albania	14,610.01	0.073	99.595	C
Colombia	14,396.32	0.072	99.667	C
Switzerland	10,794.63	0.054	99.720	C
Côte D'Ivoire	10,000.00	0.0498	99.770	C
Mali	10,000.00	0.0498	99.820	C
Senegal	8,000.00	0.0399	99.860	C
United Arab Emirates	5,015.41	0.0250	99.915	C
Poland	3,033.49	0.0151	99.930	C
Germany	3,010.95	0.0150	99.945	C
Burkina-Faso	3,000.00	0.0149	99.960	C
Gabon	3,000.00	0.0149	99.975	C
Seychelles Islands	1,551.97	0.0077	99.983	C
China	788.30	0.0039	99.987	C
Taiwan, Republic of China	668.16	0.0033	99.990	C
Republic of Moldova	610.01	0.0030	99.993	C
Hungary	384.77	0.0019	99.995	C
Kazakhstan	301.75	0.0015	99.998	C
Czech Republic	301.02	0.0015	99.9995	C
Georgia	20.00	0.00010	99.9998	C
Lithuania	20.00	0.00010	99.9999	C
Norway	18.30	0.00009	100.0000	C
Russian Federation	0.004	0.00000002	100.0000	C
Belgium	0.0005	0.000000002	100	C
Total	**20,071,252.9**	**100**	**-**	**-**

Source: based on (*State Statistics Service, 2022*… http*; Food, and agriculture, 2022*… http).

Nigeria, Vietnam, Iran, and others with an average level of demand for Ukrainian wheat are in group B (their cumulative share is up to 10%). And such countries as Tanzania, Italy, Sri Lanka, and others were included into group C as these countries carry out minor purchases of Ukrainian wheat (their cumulative share is up to 5%).

Table 3 shows the results of the conducted XYZ analysis for 2017–2021.

The XYZ-analysis revealed that no country importing Ukrainian wheat was included into group X. This means that during the analysed period, the countries made unstable grain purchases, with their size having both increasing and decreasing dynamics.

Table 3. Results of XYZ analysis for 2017–2021

Importing country / Period	Amount of import, tons					Coefficient of variation, %	Group of XYZ analysis
	2017	2018	2019	2020	2021		
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Indonesia	2,054,523.27	2,606,433.39	2,959,869.54	2,718,664.16	3,059,797.85	14.70%	Y
Tunisia	818,131.40	1,026,529.42	1,017,242.22	984,016.25	645,894.10	18.30%	Y
Israel	511,330.94	560,945.71	453,601.05	280,473.82	361,878.10	26.10%	Z
Morocco	619,307.43	1,385,244.96	904,992.84	956,482.71	846,533.02	29.60%	Z
Egypt	2,658,839.26	1,396,266.96	3,537,990.46	3,075,224.33	3,314,424.69	30.32%	Z
Libya	253,570.41	637,832.81	697,657.40	546,409.69	569,509.43	31.66%	Z
Thailand	803,489.36	573,134.63	863,545.10	563,448.24	354,543.00	32.46%	Z
Lebanon	396,888.68	287,585.87	443,248.70	669,663.17	636,737.39	33.37%	Z
Kenya	280,186.08	238,759.17	308,385.00	84,443.78	355,497.66	40.87%	Z
Bangladesh	1,971,307.44	914,599.09	2,288,224.19	1,514,724.68	849,373.40	42.07%	Z
Yemen	158,350.00	519,585.88	665,524.30	708,249.13	796,808.37	44.03%	Z
Malaysia	0.00	146,341.48	246,765.84	395,192.56	0.00	47.64%	Z
Italy	457,438.66	271,068.20	173,625.17	219,209.20	126,500.40	51.28%	Z
Philippines	876,557.45	1,754,936.34	1,016,269.67	631,965.71	412,881.74	54.50%	Z
Turkey	597,390.07	237,373.96	1,170,359.38	1,009,699.16	1,766,344.00	60.77%	Z
Mexico	184,043.17	179,738.35	285,538.02	0.00	190,408.27	61.69%	Z
Mauritania	311,841.30	293,731.00	170,410.00	0.00	177,822.63	65.39%	Z
Republic of Korea	723,595.53	925,055.83	460,181.18	0.00	396,011.37	70.08%	Z
Nigeria	107,170.00	0.00	294,784.00	0.00	348,119.00	86.49%	Z

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Spain	686,534.47	829,852.90	291,740.00	0.00	158,680.24	89.57%	Z
Djibouti	0.00	169,590.01	164,061.82	0.00	193,749.47	91.90%	Z
Sudan	115,087.14	0.00	160,116.18	109,549.00	0.00	94.78%	Z
Jordan	106,833.67	115,560.48	179,613.93	0.00	0.00	97.75%	Z
Senegal	133,183.00	180,116.74	0.00	0.00	0.00	118.03%	Z
Ethiopia	0.00	0.00	344,388.17	0.00	607,029.16	145.37%	Z
Algeria	0.00	0.00	0.00	0.00	167,890.31	200.00%	Z
The Netherlands	0.00	208,326.03	0.00	0.00	0.00	200.00%	Z
India	1,649,302.16	0.00	0.00	0.00	0.00	223.61%	Z
United Arab Emirates	0.00	0.00	137,316.53	0.00	0.00	223.61%	Z
Tanzania. United Republic	0.00	0.00	0.00	0.00	113,594.84	223.61%	Z
Pakistan	0.00	0.00	0.00	0.00	1,343,948.36	223.61%	Z
Vietnam	0.00	0.00	0.00	0.00	278,564.18	223.61%	Z
Iran (Islamic Republic)	0.00	0.00	0.00	0.00	264,189.00	223.61%	Z
Saudi Arabia	0.00	0.00	0.00	0.00	712,164.15	223.61%	Z
Mozambique	0.00	0.00	0.00	103,500.00	0.00	223.61%	Z
Oman	0.00	0.00	0.00	0.00	207,108.62	223.61%	Z
Sri Lanka	0.00	0.00	0.00	0.00	104,520.55	223.61%	Z
Total	**17,312,745.69**	**16,373,388.08**	**20,022,070.85**	**18,059,776.62**	**20,071,252.89**	-	-

Source: based on (*State Statistics Service, 2022*… http*; Food, and agriculture, 2022*… http).

Such countries as Indonesia and Tunisia had an average level of stability of purchases of Ukrainian wheat during 2017–2021. These countries are classified as Y-countries. Such countries as Israel, Morocco, Egypt, Libya, Thailand, Lebanon, Kenya, Bangladesh, and others had the most variable demand for Ukrainian grain, and so they were classified into group Z.

Combining the ABC-analysis and the XYZ-analysis produced a matrix (Figure 4) which makes it possible to consider alternative options for developing a model of Ukrainian wheat supply chains, taking into account two factors: the volume of supplies and the stability of supplies.

	A	**B**	**C**
X	-	-	-
Y	Indonesia Tunisia	-	-
Z	Egypt Turkey Pakistan Bangladesh Lebanon Ethiopia Libya Philippines Republic of Korea Israel and others	Nigeria Vietnam Iran (Islamic Republic) Oman Djibouti Mexico Mauritania Algeria	Italy Tanzania, United Republic Sri Lanka Jordan Mozambique Sudan Uganda Somali The Netherlands and others

Figure 4. Matrix of ABC- and XYZ-analysis combinations (results)

Source: own research.

The matrix highlights the AY group (Indonesia and Tunisia) which ensures a stable growing demand for grain. Therefore, they are important partners for Ukraine and, in the future, Ukraine should prioritise the requests of these countries.

The countries of the AZ group (Egypt, Turkey, Pakistan, Bangladesh, Lebanon, Ethiopia, Libya, Philippines, Republic of Korea, and Israel) are also strategically important for Ukraine's cooperation on the wheat market because they support large orders.

The countries of the BZ and CZ groups form periodic orders for Ukrainian wheat in small quantities. Because of the obstacles to exporting wheat during the war in Ukraine and the growth in logistics costs, it is recommended for these countries to consider alternative options for the supply of wheat.

According to the ABC-XYZ matrix, the countries in the AY and AZ groups are Ukraine's main strategically important wheat export partners. These countries are mainly located in South-West Asia and North Africa, and make up Ukraine's main

grain sales markets due to the close distance and convenient sea transportation to these countries.

The BZ group is less interesting for Ukraine, both in terms of volumes and stability of orders. Half of the countries in this group are located in remote East Asia and Central Africa. That means that transportation of wheat to these countries is complicated. And, of course, the war also forces unfavourable changes in Ukrainian cooperation with these countries.

The authors summarised the information regarding the changes in the logistics of Ukrainian grain supply during the war (Table 4).

Table 4 shows that the war forced changes in the transport system, including a transition to land- and river-based transportation as a result of the blockade on the seaports. Insurance companies are also refusing to insure Ukrainian grain because of the high level of geopolitical uncertainty. Moreover, warehouse logistics are finite, and limited by existing capacities for wheat storage. All these circumstances lead to higher costs of delivery.

New restrictions in supply logistics are affecting the behaviour of both the supplier and the customers, and therefore the model of wheat supply chains as a whole. However, the authors found that the main importing countries of Ukrainian wheat remain dependent on Ukrainian imports and expect further deliveries. These countries cannot meet their own grain needs due to internal limitations, among which are arid climate, insufficient agricultural land, low fertility of these lands, growing populations, and even the acute shortage of food, which leads to famine.

Table 4. Characteristics of changes in the logistics system of the Ukrainian wheat supply during the war

Before the war in Ukraine	During the war in Ukraine
1	*2*
Transportation routes	
Export by sea prevailed, seaports accounted for 80% of the agricultural product exports. Most of the wheat was sent to countries in the Middle East and Africa, such as Egypt.	Transportation by land and rivers prevails. Most of the Ukrainian grain is taken to Europe.
Choice of transport	
Water transport prevailed. Seaports accounted for 80% of the agricultural product exports.	Transition to the use of rail and road transport has occurred.
Grain storage conditions	
Total volume of operating grain storage capacity was 75 million tons.	Only 45% of warehouses remain active and free; temporary polyethylene grain sleeves, handling equipment and longer-term modular storage are used.

1	*2*
Cargo insurance	
Insurance in accordance with international rules and conditions of delivery.	Insurance companies are not ready to insure on the territory of Ukraine, as it is not known whether the safety of the Odessa region will be guaranteed when the ports are opened.
Structure of logistics costs	
Logistics costs were 20% of the price. Cost of transshipment was 5–6 euros per ton.	Logistics costs are almost 80% of the price. One fifth of the logistics costs are the railway costs, the rest are the costs at border terminals, transshipment terminals. The cost of transshipment is 25 euros per ton.

Source: based on (*Latifundist*, 2022; Tkachev, 2022; *Ministry of Agrarian Policy and Food of Ukraine*, 2022; *European business*, 2022; *Food and agriculture*, 2022; *Lebid'*, 2022; *Agropolit*, 2021).

Thus, the established model of Ukrainian wheat export with an orientation towards the countries of the AY and AZ groups should continue to work even in war conditions, in conditions of new economic, social and political challenges. According to the authors, the priority should continue to be ensuring global food security, taking into account the limited capabilities of Ukraine and the growing needs of the most dependent countries.

Conclusions

Wheat is the third most-produced cereal, and the second most-produced for human consumption worldwide. The issue of wheat supply logistics is crucial, particularly for underdeveloped countries due to their inability to produce and provide it for domestic demand. These countries are dependent on imports from other producers.

The fifth-largest exporter of wheat in the world, with a share of 9% in the 2021–2022 marketing year, was Ukraine. According to the authors' analysis, Ukraine was ranked 10th globally among wheat producers in 2010–2020, having 40 million hectares of fertile black soil. Since February 24, 2022, Ukraine has lost part of its harvest, in particular in such regions that were leaders in wheat production as Zaporizhzhia, Kharkiv, Zhytomyr, Kyiv, Dnipropetrovsk, and Kherson. The Russian invasion caused damage not only to the Ukrainian economy and agriculture but also endangered the export of Ukrainian wheat. Therefore, the authors set the goal of identifying the countries that are most dependent on the Ukrainian wheat supplies and of developing a model of its supply chains.

To achieve this goal, the ABC-XYZ analysis method was used, which divided the importing countries into groups according to their volume of wheat imports (groups A, B, and C) and the level of stability of their orders (groups X, Y, and Z). The authors supplemented this method with indicators of the share of Ukrainian wheat in the total demand of importing countries and the share of wheat imports to the given country in the total Ukrainian export of wheat.

The authors found that the main importing countries of Ukrainian wheat in 2010–2020 were Egypt, Indonesia, Bangladesh, and Pakistan. Such countries as Lebanon, Libya, and Indonesia have a share of Ukrainian wheat in the total volume of its consumption of up to 90%. Since 2010, Ukraine has been increasing the share of those countries in the total Ukrainian export of wheat.

The results of the ABC-XYZ analysis made it possible to single out two countries – Egypt and Indonesia – which had the largest supplies of Ukrainian wheat in terms of volume, and two others – Tunisia and Indonesia – which had the most stable supplies during 2017–2020. The developed matrix shows that the AY and AZ groups of countries, which are mainly located in South-West Asia and North Africa, constitute the main wheat sales markets of Ukraine. The authors emphasise that these countries should become the main partners in the supply of wheat in the long run.

The countries of the BZ group (such as Nigeria, Vietnam, Mexico, and Algeria) do not purchase stable supplies of Ukrainian wheat. In the short term, these countries would have difficulties cancelling and replacing their Ukrainian wheat supply. In the long term, under conditions of prolonged war, they may need to consider alternative options for suppliers. The authors' opinion is that it could be risky for both sides – Ukraine and the importing country. Firstly, Ukraine, without exports, would not generate the revenues that play a significant role during wartime. Secondly, for the importing countries, it would be difficult to fill the domestic gap in the wheat supply. Both sides – Ukraine as the exporter and the importing country – should resolve the problems with factors limiting the import of Ukrainian wheat: the increased transportation cost, insurance, and storage of stocks. The aim of this action is to maintain the required level of global food security.

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Summary

The year 2022 was marked for the world as the year of the full-scale invasion of Ukraine by the Russian Federation. The war caused considerable damage, not only to the Ukrainian economy, but also disrupted global economic relations. The agricultural sector was especially affected as agricultural enterprises cannot transfer their capacity to other, safer regions, like other sector enterprises, to conduct their activities.

A significant part of the grain harvest was lost due to the war, so taking into account that Ukraine is one of the main exporters of grain, many countries did not receive the ordered deliveries. Among grains, in terms of value, wheat ranks third after corn and rice. Wheat is used not only for consumption but is also exported as seeds. Obstacles to harvesting, transportation, and export of wheat have become an extremely urgent issue for countries that are very dependent on the supplies of Ukrainian wheat.

The purpose of the study is to develop a model of the Ukrainian wheat supply system in war conditions for groups of importing countries in terms of the volume and stability of supplies, to ensure food security.

The ABC-XYZ analysis was used while conducting the study. This method is based on the use of statistical data on the volume of Ukrainian wheat supplies to other countries. According to this method, all countries are grouped in terms of their order volume and stability. This approach indicates the countries that are strategically important for Ukraine as a wheat exporter.

As the results of the analysis show, at the beginning of the war, the behaviours of the wheat-importing countries changed. If they could previously diversify the wheat supply channels, choosing the most profitable channels for themselves, since 2022, many countries have cancelled supplies of wheat from the Russian Federation and have become more dependent on other producers. In addition, unfavourable weather conditions and the desire of powerful wheat producers to create additional stocks of wheat for their own needs have been added. It was found that such countries as Egypt, Indonesia, Morocco, Yemen, Tunisia, Lebanon, and Libya are most dependent on Ukrainian wheat and have positive previous experiences of cooperation with Ukraine.

The presented logistics model of wheat supply can be adapted to new changes, but the ultimate goal of its implementation should be to indicate conditions to ensure global food security.

Keywords: wheat supply, food security, Ukrainian wheat export, supply logistics, ABC-XYZ analysis.

Logistyka dostaw pszenicy w czasie wojny na Ukrainie

Streszczenie

W 2022 roku świat doświadczył pełnoskalowej inwazji Federacji Rosyjskiej na Ukrainę prowadzącej do zakłócenia globalnych stosunków gospodarczych. Wojna spowodowała znaczne szko-

dy w gospodarce Ukrainy. Z perspektywy gospodarki światowej, szczególnie ważne były straty w sektorze rolniczym. Wynikało to z faktu braku możliwości przeniesienia działalności gospodarczej i zdolności produkcyjnych do innych, bezpieczniejszych regionów, tak jak robiły to przedsiębiorstwa innych branż.

Znaczna część zbiorów zboża została utracona z powodu wojny, więc biorąc pod uwagę, że Ukraina jest jednym z głównych eksporterów zboża, wiele krajów importujących nie otrzymało zamówionych dostaw w pełnym wymiarze i na czas. Szczególne miejsce w eksporcie zbóż z Ukrainy zajmuje pszenica, która pod względem wartości zajmuje trzecie miejsce, po kukurydzy i ryżu. Warto podkreślić, że eksportowana pszenica jest wykorzystywana zarówno do konsumpcji, jak również jako materiał siewny. Przeszkody w zbiorze, transporcie i eksporcie tego zboża stały się niezwykle pilnym problemem dla krajów, których gospodarki są uzależnione od dostaw ukraińskiej pszenicy.

Celem artykułu jest opracowanie modelu systemu dostaw ukraińskiej pszenicy, zapewniającego bezpieczeństwo żywnościowe dla krajów importujących pogrupowanych według wielkości i stabilności dostaw w warunkach wojny.

Badania przeprowadzono przy użyciu analizy ABC-XYZ. Metoda ta opiera się na wykorzystaniu danych statystycznych dotyczących wielkości dostaw pszenicy z Ukrainy do innych krajów. Zgodnie z tą metodą, kraje importujące zostały pogrupowane pod względem wielkości i stabilności zamówień. Takie podejście pozwalało wskazać grupy krajów, które są strategicznie ważne dla Ukrainy jako eksportera pszenicy.

Jak pokazują wyniki analiz, na początku wojny zmieniło się zachowanie krajów importujących pszenicę. O ile przed 2022 rokiem mogły one swobodnie dywersyfikować kanały dostaw pszenicy, to od rozpoczęcia pełnoskalowej inwazji wiele krajów rezygnowało z dostawy pszenicy z Federacji Rosyjskiej. Uwarunkowania rynku pszenicy pogarszały niekorzystne warunki pogodowe i presja producentów do tworzenia dodatkowych zapasów na własne potrzeby. Stwierdzono, że takie kraje jak Egipt, Indonezja, Maroko, Jemen, Tunezja, Liban i Libia są najbardziej uzależnione od ukraińskiej pszenicy, a ich import jest długookresowy, co pozytywne świadczy o dotychczasowej współpracy z Ukrainą.

Przedstawiony model logistyczny dostaw pszenicy może być dostosowywany do nowych zmian, ale ostatecznym jego celem jest wskazanie rozwiązań zapewniających bezpieczeństwo żywnościowe na świecie.

Słowa kluczowe: dostawy pszenicy, analiza ABC-XYZ, bezpieczeństwo żywnościowe, eksport pszenicy z Ukrainy, logistyka dostaw.

JEL: F13, F14, F17, Q11, Q13, Q17, Q18.