CHANGES IN THE CROP WORLD MARKET: WHAT WILL BE THE FOOD SUPPLY WITHOUT THE RUSSIA-UKRAINE WAR?

VÁLTOZÁSOK A TERMÉNY VILÁGPIACÁN: MILYEN LESZ AZ ÉLELMISZERELLÁTÁS AZ OROSZ-UKRÁN HÁBORÚ NÉLKÜL?

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Abstract

After COVID-19 and the ongoing war between Russia and Ukraine, we have suffered the most severe food crisis since 2007/2008 world financial and economic crisis. However, the two countries at war are significant world food suppliers, indicating the negative influence of war on food security. In this research, we aimed to predict the main crop export quantity in Ukraine for the period 2022 (the year when the war started) till 2024. We used time series analysis as a research methodology and Matlab software to carry out the analysis. In the end, we found that Russia and Ukraine are estimated to play increasingly important roles in the world food supply regarding wheat, maize, barley, and sunflower seed. This research result can also be a solid basis for the future comparative study on the influence of the Russia-Ukraine war on the world food supply.

Keywords

food supply, food security, crop export quantity, time series analysis, Russia-Ukraine war

Absztrakt

A 2007/2008-as élelmiszerválságot követően a COVID-19 járvány után a világ a folyamatban levő orosz-ukrán háború idején szenvedi el ismét egy élelmiszer válság következményeit. A háború két résztvevő országa a világ alapvető élelmiszer ellátója. A kialakult élelmiszer krízis is mutatja a háború negatív hatásait. Ebben a kutatásban arra törekedtünk, hogy megjósoljuk Ukrajnában a fő terményexport mennyiségét a 2022-től (a háború kitörésének évétől) 2024-ig tartó időszakra. Kutatási módszertanként idősoros elemzést használtunk. Azt találtuk, hogy Oroszország és Ukrajna a becslések szerint egyre fontosabb szerepet fog játszani a világ élelmiszerellátásában a búza, a kukorica, az árpa és a napraforgómag tekintetében. Ez a kutatási eredmény szilárd alapja lehet annak a jövőbeni összehasonlító vizsgálatnak is, amely az orosz-ukrán háború világ élelmiszerellátására gyakorolt hatását vizsgálja.

Kulcsszavak

élelmiszerellátás, élelmiszer biztonság, gabonaexport, idősor analízis, Orosz-Ukrán háború

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INTRODUCTION

The acute food insecurity crisis continues to grow, and the rate is alarming from the increasing number of people in food insecurity who need urgent life-saving food assistance and livelihood support in 2022 [1], [2]. Acute food insecurity refers to people being unable to obtain enough food, resulting in lives or livelihoods in immediate danger. Chronic hunger describes a person suffering from an extended period of lack of adequate calories (diet energy) basis of a normal, active, and healthy life. The Prevalence of Undernourishment is used as an indicator to estimate the extent of hunger in the world by FAO. And hunger can also be regarded as undernourishment. Integrated Food Security Phase Classification (IPC) and the Cadre Harmonisé are the internationally-accepted measures of extreme hunger.

Global Network Against Food Crises (GNAFC), an international alliance of the United Nations, the European Union, and governmental and non-governmental agencies [1], was launched by the European Union, Organization of Food and Agriculture (FAO), and World Food Program (WFP) at the 2016 World Humanitarian Summit (WHS). The co-founding and core steering members are the European Commission for International Partnerships (DG INTPA) and European Civil Protection and Humanitarian Aid Operations (DG ECHO), the Organization of Food and Agriculture (FAO), and the World Food Program (WFP). The aim of the Global Network Against Food Crises (GNAFC) is to tackle the root causes of food crises, prevent, prepare for, and respond to the food crisis, promote sustainable solutions, and achieve the Zero Hunger goal of the Sustainable Development Agenda 2030 [2], [3].

However, even though we are trying to handle the food security risks, we still cannot avoid some catastrophic influences, such as the war between important world food supply countries.

In the face of the severe food crisis, we aimed to know how important Ukraine and Russia [4] are in the world food supply, which are the countries at conflict, and the other important world food supply country's role in the future world food supply such as China [5]. Due to the war happening in Ukraine, obviously, agriculture got a profound negative influence in Ukraine, but Russia's agriculture as well. Therefore, our observation data is from 2010 to 2021, the last year before the war started. And we predicted the main crop export quantity from 2022 (when the war started) to 2024. In the end, we can conclude the importance of Ukraine and Russia in the world food supply if there is no war between them and the other country, such as China. On the other hand, when the war finishes, the value of our research result can provide a basis to compare with the real crop export quantity so that we can conclude the influence of war on the world food supply from the perspective of the important world food supply countries at war such as Ukraine and Russia. And if the conflict can also influence other important world food supply country that is not at war, where we take China as an example. Further study can contribute to the topic of how important it is to avoid the risks from war to world food security.

REVIEW OF THE LITERATURE

According to the Annual Global Report on Food Crises announced by Global Network Against Food Crises (GNAFC) [2] in Figure 1 in May 2022, the main drivers of food crises are conflicts and insecurity, weather extremes, and economic shocks. In 2021, nearly

193 million people were exposed to acutely food insecurity and need urgent assistance across fifty-three countries and territories. This number has leaped by eighty percent since 2016, with around 108 million across forty-eight countries. According to the World Food Programme (WFP) estimation, close to 323 million people will suffer acute food insecurity due to the war in Ukraine in 2022 [4].

Figure 1. Numbers of people in Crisis or worse (IPC/CH Phase 3 or above) or equivalent by the key driver in 2021

Both Russia and Ukraine, the countries at war, are among the important top producers of agricultural commodities, such as foodstuffs and fertilizers, to the world population. Especially, Russia is also an important global oil and gas supplier [4]. In 2021, Russia and Ukraine (either or both of them) will be among the top three global exporters of wheat, maize, rapeseed, sunflower seeds, and sunflower oil, and Russia will also play the leading role as world's exporter of nitrogen fertilizers, potassium fertilizers, and phosphorous fertilizers. Many countries heavily rely on imported foodstuffs and fertilizers from the export of Russia and Ukraine to meet their consumption demands. Between 2016/7 and 2020/21 (Figure 2), the significant contribution of Russia and Ukraine combined to global production is from two main aspects: the cereal sector and the oilseed sector. During this time, the two countries contributed over half of the world's output of sunflower oil on average. The global rapeseed output is 6%, and the global soybean output is 2%. In the cereal complex, the share of barley, wheat, and maize in world production accounted for 19%, 14%, and 4%, respectively [6]. From 2018 to 2020, Ukraine supplied 50% sunflower seed oil to the whole global market [7].

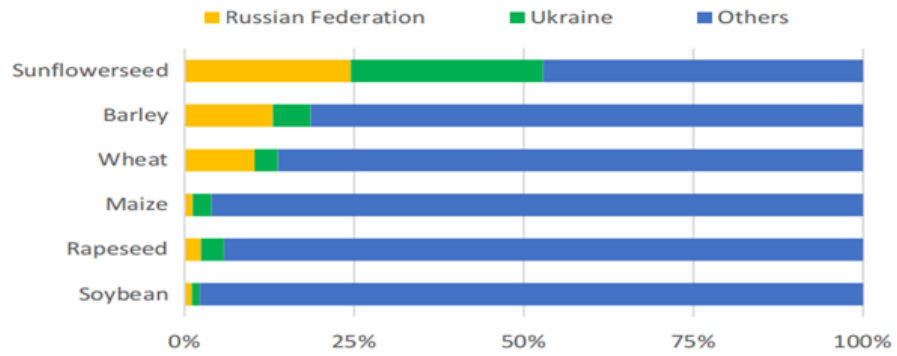

Figure 2. Russia Federation and Ukraine share in global production of selected crops 2016/17-2020/21 Avg.)

As a large agricultural developing country, China has huge amounts of crop production [8], and China's total crop output is among the top ranking in the world [9]. China is feeding a 1.41 billion population [10], with one-fourth of the world's grain yields but less than 10% of the world's arable land [8], [11]. In 2021, China's total crop yield was 682,85 million tons, ranking first in the world. And Russia took fourth place, Ukraine was ninth. At the same time, China was the biggest country to import grain and the third country to export grain [5]. And the total cereal yield in 2021 was 632,76 million tons, such as barley, wheat, maize, etc. [12]. In terms of producing cereals, cotton, fruit, vegetables, meat, poultry, eggs, and fishery products yield, China has hit first in the world output [8].

Nevertheless, China, Russia, and Ukraine are critical players in the world food system. Any shocks to these countries will bring the world population to a catastrophic stage. Therefore, it is our inevitable responsibility to pay attention to unpredictable insecurity issues, such as the COVID-19 pandemic and the war between Russia and Ukraine.

To gauge the influence of the war on the world food supply and avoid the risks from war to world food security, from the view of the Russia-Ukraine war, firstly, we need to notify their important roles in the world food supply in the future from the main crop export quantity if there is no Russia-Ukraine war, such as wheat, maize, barley, and sunflower seed. The next step is to compare the predicted main crop export quantity to the real data. The following section outlines the research methodology used to predict the data for 2022-2024.

TIME SERIES ANALYSIS OF OBSERVED DATA

This research was conducted in May 2022 amid the ongoing war between Russia and Ukraine, and the aimed data are from main crop products export quantity (2010-2021) in Ukraine, Russia, and China from FAOSTAT (Food and Agriculture Organization Corporate Statistical Database) [13]. In order to make sure the research results are accurate, the main crop export quantity from these three countries comes from the same data source, FAOSTAT. In this research, we aimed to predict the future world food supply if there is no Russia-Ukraine war from two perspectives, important world food supply countries at war and the important world food supply country not at war. We chose Ukraine and Russia because they are important world food supply countries [4], [6], [7], but at the same time, they are the countries at war. We chose China as an example because there is no war, and it is also an important world food supply country [5], [8], [11].

The annual time series data pertaining to wheat, maize, barley, and sunflower seed export quantity. After observing the main crop export quantity taken sequentially from 2010 to 2021. The observed and analysed data for Russia, Ukraine and China can be seen in Table 1, Table 2, and Table 3 respectively.

	Russia			
	wheat	**maize**	**barley**	**sunflower**
2010	11848321	230041	1541613	9644
2011	15185953	721626	2067324	113824
2012	16088832	2196553	3430077	274747
2013	13796347	2599289	2324981	79842
2014	22139263	3487880	4009568	90634
2015	21234225	3697593	5294968	60291
2016	25326784	5324066	2862500	186523
2017	33025971	5178687	4632057	313637
2018	43965626	4784344	5441666	87093
2019	31873170	3119665	3940653	713990
2020	37267014	2289269	4963402	1369907
2021	27366370	2936350	3962674	92427

Table 1 Observed data for crop export quantity from Russia in tons for years 2010-2021

	Ukraine			
	wheat	**maize**	**barley**	**sunflower**
2010	4302773	2888339	4593353	307993
2011	4097309	7806319	2144736	406070
2012	8679388	15630889	2582018	282097
2013	7762279	16729468	2339530	70209
2014	10543788	17556531	4165877	73896
2015	13451830	19048697	4629500	47690
2016	17920945	17275407	4801693	196583
2017	17314278	19394541	4855317	73230
2018	16373389	21440629	3597474	58704
2019	13901207	25362998	2386784	101314
2020	18055673	27952483	5046350	187900
2021	19394934	24539480	5344594	84176

Table 2 Observed data for crop export quantity from Ukraine in tons for years 2010-2021

	China			
	wheat	**maize**	**barley**	**sunflower**
2010	72	127420	13419	145857
2011	39808	136123	6279	169608
2012	29	257414	4589	184224
2013	2563	77714	1075	190432
2014	962	20247	116	175714
2015	5302	12455	65	252045
2016	10538	12248	37	296050
2017	9971	69040	64	409684
2018	7344	12205	66	463545
2019	8524	26070	297	480380
2020	33	2675	196	508017
2021	4396	6814	48	426984

Table 3 Observed data for crop export quantity from China in tons for the years 2010-2021

As an example, data series considering Russia is depicted in Figure 3.

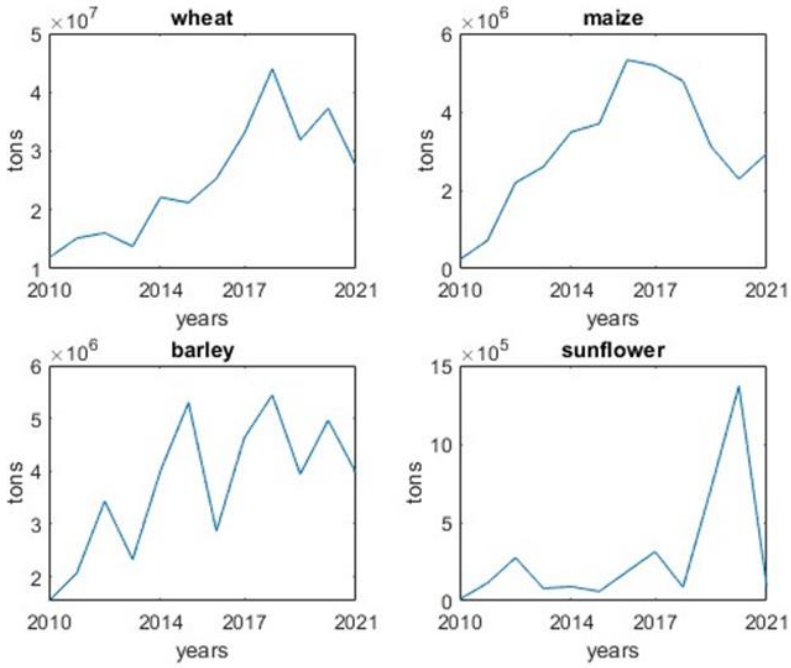

Figure 3 Crop export quantities from Russia in tons for years 2010-2021

A time series analysis has been applied to making forecasts to examine these data. The main perspective in this article is predicting export quantity for the next few years for every crop type for examined countries. The data series summarized in Table 1 can be considered a time series, and the same is true for the other two examined countries. For time series analysis, there exists a commonly applied, sophisticated model, the Box-Jenkins method (ARMA, ARIMA, SARIMA, etc. process) [14], [15] but on the one hand, for these methods, data series must be stationary, which means that expected value (mean) and standard deviation must be constant over time. Considering observed data (for example, Figure 3. for Russia), it is obvious that these data series are not stationary. Expected value and standard deviation change in time. On the other hand, in this analysis, there are only 12 pieces of data in one-time series, which is not sufficient for ARMA, ARIMA, etc. analysis, and for these methods, much more data would be required.

Therefore for modeling and analyzing data series for crop quantities and making predictions, a different mathematical tool, the Holt-Winters exponential smoothing additive model, has been applied [16]–[19]. The mathematical form of this exponential smoothing method is as follows. Every time series data yt is decomposed for three additive terms:

$$y_t = l_t + S_t + e_t$$

Where lt is a general "level" term, St is the seasonal component if, in the time series, a seasonal behavior can be identified, and the final term et is the error component that expresses the uncertainty of the model. For these quantities (except for the error term), a recursion equation system is constructed. This system, in the most general form, is as follows:

$$l_t = \alpha\left(y_t - S_{t-T}\right) + \left(1-\alpha\right)\left(l_{t-1} + b_{t-1}\right)$$
$$b_t = \beta\left(l_t - l_{t-1}\right) + \left(1-\beta\right)b_{t-1}$$
$$S_t = \gamma\left(y_t - l_t\right) + \left(1-\gamma\right)S_{t-T}$$

If, in the time series, a trend (increasing or decreasing) can be identified, the quantity bt is used for modeling the slope of the time series. In the above-given system, T is a time period of the seasonal component, if there exists such a component at all. The Holt-Winters model is identified by the constants α, β and γ. These parameters are chosen from interval [0, 1] independently. For the best-fitting model, the least squares method can be applied to find the best parameters. The effect of these constants for the model is that every predicted value will be a weighted average of previous observations. If the parameter equals 0, the current observation is ignored absolutely; therefore, previous observations will be dominant, and if the parameter equals 1, previous observations are ignored, and the current observation will be dominant. The basic problem is finding the balance between the effect of current and previous observations [16, 17].

The method, in general, is the following. On the basis of observed data, using the least squares method for giving parameters α, β, and γ, the system given above is used for modeling the observed time series and predicting values for the next few years. According to this method, the forecast for the time t + k is given by the formula:

$$y_{t+k} = l_t + kb_t + S_{t+k-nT}$$

Considering Figure 3, it is obvious that examined data series does not contain a seasonal component, and it is also valid for the data series of the other two countries. But some trends can be identified in every series. Therefore in the analysis, a simplified version of the Holt-Winters method was applied. The seasonal component must be deleted from recursion. The simplified system is summarized as follows:

$$l_t = \alpha y_t + \left(1-\alpha\right)\left(l_{t-1} + b_{t-1}\right)$$
$$b_t = \beta\left(l_t - l_{t-1}\right) + \left(1-\beta\right)b_{t-1}$$
$$0 \le \alpha, \beta \le 1$$
$$y_{t+k} = l_t + kb_t$$

In this simpler and more applicable model, the prediction is given by a linear function. The last slope bt is used for forecasting data for the next few years. The initial value of the recursion is obvious for the level component lt, which are observed values y1, y2, etc. The initial value for the slope component can be the first observed slope or the average of the first two or three slopes:

$$b_1 = y_2 - y_1;\ or\ b_1 = \frac{y_3 - y_1}{2};\ or\ b_1 = \frac{y_4 - y_1}{3};$$

In this analysis, the last option was used. The software Matlab has been applied for calculations to carry out the time series analysis and make predictions. In the following section, the result of the analysis will be presented considering every examined country and

cereal. Basically, the behavior of every data series is similar, which can be seen in the figures in section 4, independently of the examined country. Therefore for every data series, the same algorithm has been applied.

In order to know the main crop export quantity if there is no Russia-Ukraine war, the time series analysis predicted the year 2022, when the war started. Considering the ongoing war, data are only predicted until 2024 since the further forecast could be unreliable. In the end, the research result can be compared to the real main crop export quantity from the year 2022, and we will be able to see the influence of Russia-Ukraine war on world food supply.

FORECASTING EXPORT QUANTITIES

The time series data on the main crop export quantity was collected from the 2010-2021 trend data from Ukraine, Russia, and China, including wheat, maize, barley, and sunflower seed. The time series data analysis has been carried out in every case, and the result is demonstrated below for the forecasting period 2022-2024.

Main crop export quantity from 2010-2021 and forecasting for years 2022-2024 in Ukraine

From the FAOSTAT data, the Ukrainian wheat export quantity was only 4 million tons in 2010, and it increased to 19 million tons in the 2021 year by year. The Ukrainian maize export quantity was 2 million tons in 2010, increasing almost ten times after ten years. The Ukrainian barley export quantity remained relatively stable, with 4 million tons in 2010 and 5 million tons in 2021. In 2010, the Ukrainian sunflower seed export quantity was 307 thousand tons, and in 2021 dropped to 84 thousand tons.

A. The forecasting of Ukrainian wheat export quantity for 2022-2024

Year	2022	2023	2024
Forecast (tons)	16373389	13901207	18055673

Table 4 Forecasting results of wheat export quantity for 2022-2024 in Ukraine

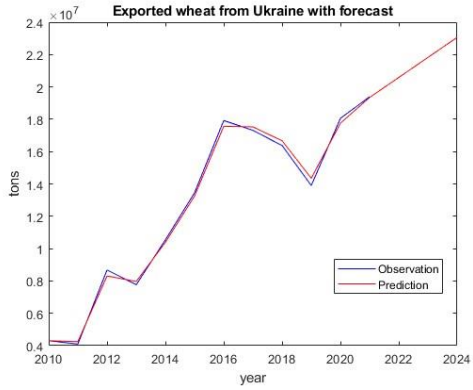

Figure 4 Observed and fitted data series on wheat export quantity in Ukraine

B. The forecasting of Ukrainian maize export quantity for 2022-2024

Year	2022	2023	2024
Forecast (tons)	27664165	30195585	32727006

Table 5 Forecasting results of maize export quantity for 2022-2024 in Ukraine

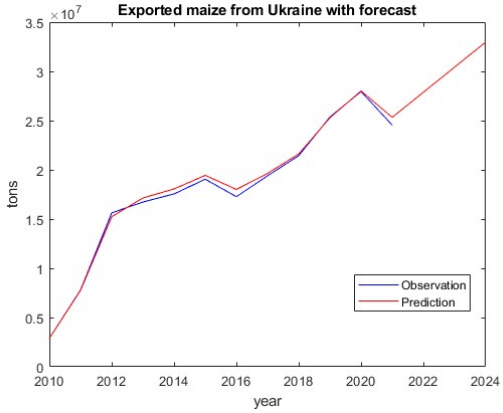

Figure 5 Observed and fitted data series on maize export quantity in Ukraine

C. The forecasting of Ukrainian barley export quantity for 2022-2024

Year	2022	2023	2024
Forecast (tons)	5210667	5140722	5070777

Table 6 Forecasting results of barley export quantity for 2022-2024 in Ukraine

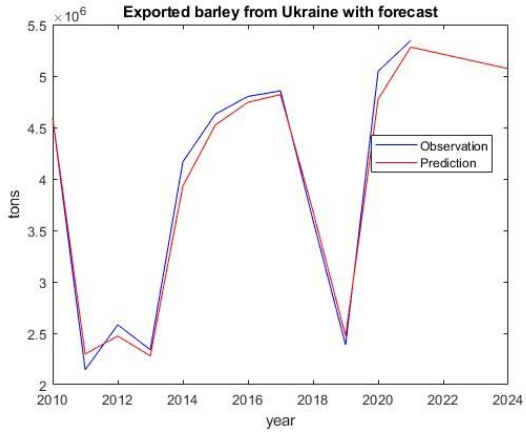

Figure 6 Observed and fitted data series on barley export quantity in Ukraine

D. The forecasting of Ukrainian sunflower seed export quantity for 2022-2024

Year	2022	2023	2024
Forecast (tons)	76607	59842	43078

Table 7 Forecasting results of barley export quantity for 2022-2024 in Ukraine

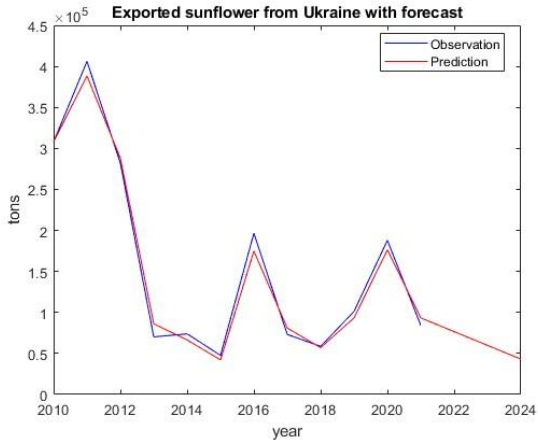

Figure 7 Observed and fitted data series on sunflower export quantity in Ukraine

Main crop export quantity from 2010-2021 and forecasting for 2022-2024 in Russia

As mentioned in this research, Russia is one of the main contributors to the world food supply chain. Between 2016/7 and 2020/21, Russia and Ukraine contributed over half of the world output of sunflower oil on average, and the global share of barley, wheat, and maize among the world production accounted for 19%, 14%, and 4%, respectively. Ukraine and Russia combined contributed barley, wheat, and maize to world production, accounting for 19%, 14%, and 4%, respectively. Russian wheat export quantity

A. The forecasting of Russian wheat export quantity for 2022-2024

Year	2022	2023	2024
Forecast (tons)	29339606	30171704	31003802

Table 8 Forecasting results of wheat export quantity for 2022-2024 in Russia

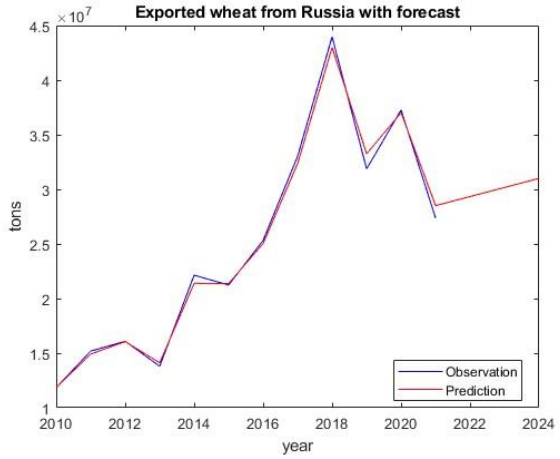

Figure 8 Observed and fitted data series on wheat export quantity in Russia

B. The forecasting of Russian maize export quantity for 2022-2024

Year	**2022**	**2023**	**2024**
Forecast (tons)	3193331	3588229	3983126

Table 9 Forecasting results of maize export quantity for 2022-2024 in Russia

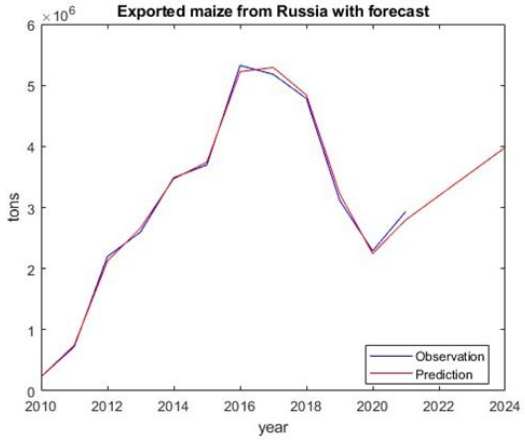

Figure 9 Observed and fitted data series on maize export quantity in Russia

C. The forecasting of Russian barley export quantity for 2022-2024

Year	**2022**	**2023**	**2024**
Forecast (tons)	4252687	4432529	4612370

Table 10 Forecasting results of barley export quantity for 2022-2024 in Russia

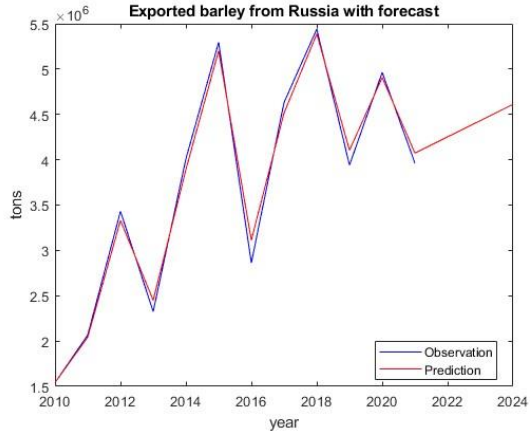

Figure 10 Observed and fitted data series on barley export quantity in Russia

D. The forecasting of Russian sunflower seed export quantity for 2022-2024

Year	**2022**	**2023**	**2024**
Forecast (tons)	220129	228691	237253

Table 11 Forecasting results of sunflower seed export quantity for 2022-2024 in Russia

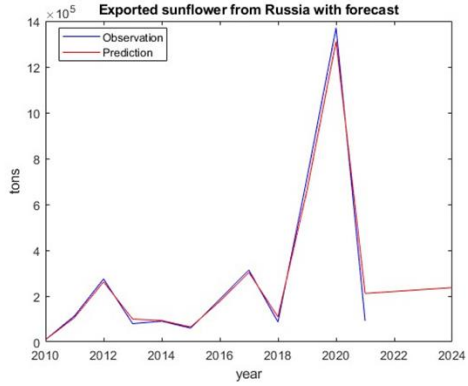

Figure 11 Observed and fitted data series on sunflower export quantity in Russia

Main crop export quantity from 2010-2021 and forecasting for 2022-2024 in China

Besides Russia and Ukraine, China also plays an important role in crop production. China is a large developing agricultural country with a huge amount of crop production. The wheat export quantity was not stable during the period from 2010-2021. The biggest wheat export quantity can reach 4 thousand tons in 2021, and the smallest can be just 29 tons in 2012. Similarly to the Chinese maize and barley export quantity from 2010 to 2021. The Chinese maize export quantity was 12 thousand tons in 2010 and 6 thousand tons in

2021. The Chinese barley export quantity experienced the highest value of 13 thousand tons in 2010 and the smallest value of 37 tons in 2016. The Chinese barley export quantity was 48 tons in 2021. However, the Chinese sunflower seed export quantity kept increasing from 145 thousand tons in 2010 and 426 thousand tons in 2021.

A. The forecasting of Chinese wheat export quantity for 2022-2024

Year	**2022**	**2023**	**2024**
Forecast (tons)	4281	4515	4749

Table 12 Forecasting results of wheat export quantity for 2022-2024 in China

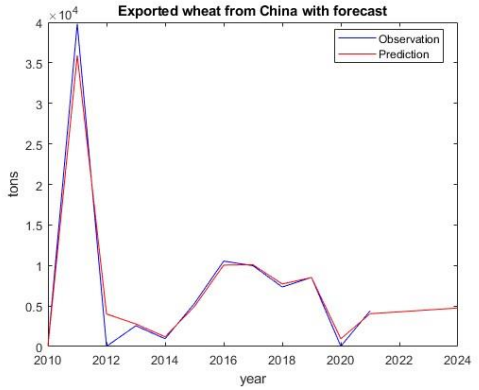

Figure 12 Observed and fitted data series on wheat export quantity in China

B. The forecasting of Chinese maize export quantity for 2022-2024

Year	**2022**	**2023**	**2024**
Forecast (tons)	4521	3790	3059

Table 13 Forecasting results of maize export quantity for 2022-2024 in China

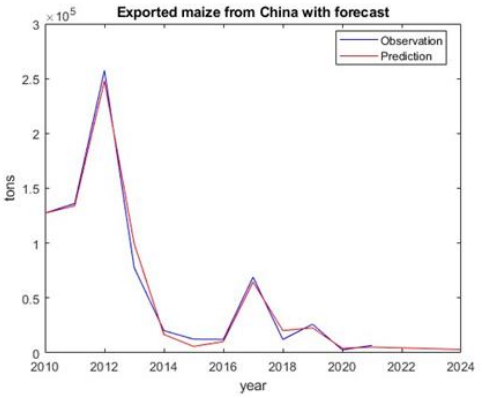

Figure 13 Observed and fitted data series on maize export quantity in China

C. The forecasting of Chinese barley export quantity for 2022-2024

Year	2022	2023	2024
Forecast (tons)	-	-	-

Table 14 Forecasting results of barley export quantity for 2022-2024 in China

Unfortunately, due to the characteristics of the data series, the time series predicting model does not work! The algorithm forecasts negative values as predictions for every possible parameter, which is obviously not acceptable.

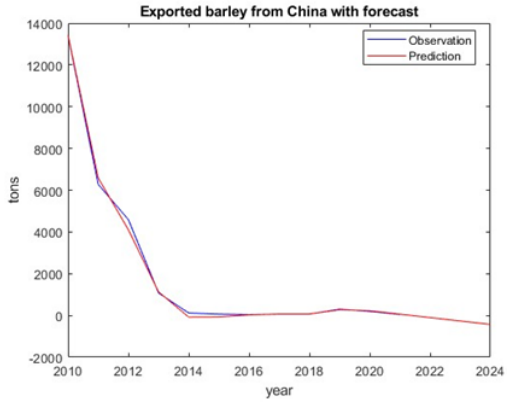

Figure 14 Observed and fitted values series on barley export quantity in China

D. The forecasting of Chinese sunflower seed export quantity for 2022-2024

Year	2022	2023	2024
Forecast (tons)	459916	480637	501359

Table 15 Forecasting results of sunflower seed export quantity for 2022-2024 in China

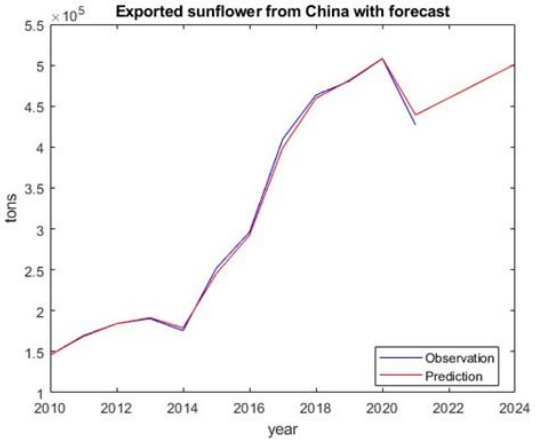

Figure 15 Observed and fitted values series on barley export quantity in China

DISCUSSION

Implications

Based on the main crop export quantity data from FAOSTAT for 2010-2021 investigated in Russia, Ukraine, and China, the time series analysis concluded the forecasting for 2022-2024. We used Matlab software to predict the main crop export quantity from Russia, Ukraine, and China. Russia, Ukraine, or a combination of them will be very important food suppliers to the world, from the aspects of wheat, maize, barley, and sunflower. China will be an important player in the world's sunflower seed supply.

In Ukraine, the wheat and maize export quantity is expected to increase yearly, while the barley and sunflower seed export quantity is projected to decrease for 2022-2024. But the amount after decreasing is still high. Other experts projected that the Ukraine maize export in 2022/23 will be 23.5 million tons [20], while our model shows 25 million tons.

Russia will still play an important role in the world food supply, especially in the world wheat, barley, and sunflower seed supply. Our model predicted in the year 2022-2024, the wheat, maize, barley, and sunflower seed export quantity in Russia would keep increasing. Some experts predicted the export of wheat in Russia in 2022/23 will be between 200 thousand to 43 million tons (Reuters, 2022), making Russia the largest wheat export country (Aleksahhina, 2022), and our model shows a similar number, 30 million tons. The Russian sunflower seeds export quantity is estimated to reach 800 thousand tons (Russia, 2022), which is higher than our model estimation of 200 thousand tons.

In addition to the dominant world food suppliers, Russia and Ukraine, other huge agricultural countries, such as China, are also crucial. During the period 2022-2024, the role of China is predicted to be important still for the world food supply from the aspects of wheat, maize, barley, and sunflower seed. The wheat, maize, and barley export quantity is projected to decrease steadily, but the sunflower seed export quantity will increase. It means that China's role is not as significant as Russia and Ukraine to the world food supply regarding wheat, maize, and barley, but Chinese sunflower seed export is crucial to the world.

Limitations and Suggestions

As discussed in the introduction, firstly, our research result can predict the importance of the important agricultural countries Ukraine, Russia, and China to the world food supply if there is no Russia-Ukraine war. Then the research result can be a good base for further studies. Due to the time limit, we cannot access the official data about the main crop export quantity in these countries. Therefore, we cannot compare the data if there is war and no war to see the influence of war on the world food supply. But the future researcher can compare the data from our research to the real data. And further study will contribute to the importance of avoiding the risks from war to world food security, considering the importance of world food supply countries at war and not at war.

CONCLUSION

Russia and Ukraine will be crucial world food suppliers for main crop products, such as wheat, maize, barley, and sunflower seed. Unfortunately, these two important world food supply countries are still in a long-term conflict, pushing global food security into a worse situation. China will also play an important role in the world's sunflower seed supply for the world. As a result, this research can provide suggestions to the Russian and Ukrainian policymakers to develop micro and macro policies and crop production strategies for future food security and food sustainability. At the same time, other food and agricultural products export countries should also realize their responsibility for the world food supply. In order to realize a sustainable future and food security, everyone is considered an active contributor.

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