
The War's Impact on Ukraine's Agricultural Production – Projections Vs. Real Data

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Abstract:

Purpose: Agricultural production of Ukraine's is vitally important either for Ukraine itself or its partners all over the world. Therefore, the aims of the research were to analyse the agricultural production of Ukraine, including its natural and climatic conditions, and the country's production value by kinds, encompassing those important for the Ukrainian exports, as well as to compare both the projected trends and values for the said production with the real – time ones, in order to assess the war's impact.

Design/Methodology/Approach: Such methods of scientific research as empirical and comparative analysis, time series analysis, modelling and forecasting, method of trends as well as textual and tabular methods added by bar charts for better data presentation and comparison were used while conducting the research presented in the given paper. The data analysed in the article were taken from the official web page of the State Statistics Service of Ukraine. The time frame under analysis is 2000/2010 – 2020/2022, depending on the data availability.

Findings: The difference between the projected and real – time data values are especially big in the cases of maize, wheat, sunflower seeds and barley, implying, that war has influenced tremendously the production amounts of the agro products under research, nevertheless being one of the factors impacted the said production as it's rather the combination of different factors influenced the production amount under research, with the war being the most powerful among them. The production potential of Ukraine's agriculture has been influenced by the war greatly in a negative way though remaining strong enough even on the global level.

Practical Implications: The all-encompassing analysis approach applied in the conducted research would be of great use for the scientists in general and researchers interested in similar topics in particular, while the information and data presented in the article would be useful for educators of all the levels as a helping tool in their lessons/lectures/seminars conduction. The presented research is interesting and useful for big and small agricultural companies, including family farmers, administrative bodies officials connected either with agriculture or agro products trade, big and small firms indulged in international trade in general and agro products one in particular, politicians and decision makers, as well as beginners and experienced statisticians and data analysts.

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Originality/Value: *In the presented research it was attempted to make a general analysis for the agro production of Ukraine starting from its natural and climatic conditions description through the soils availability research to the agricultural production of Ukraine by kinds in general and the ones important for the agro exports of Ukraine in particular, attempting to compare the projected trends and values for the said production amounts with the real – time ones, which, in turn, can be considered the novelty approach of the research presented in the given paper.*

Keywords: *Agricultural Production, Climatic Conditions, Fertile Soils, Factors of Production, Agricultural Products Exports.*

JEL codes: *E23, E27, C53, Q15.*

Paper type: *Research Article.*

1. Introduction

Ukraine and everything connected with the country have become a major topic discussed in mass media all over the world partly, because the country is rich in natural resources, which are found in Ukraine only and, therefore, are important for the whole world (VisitUkraine.Today, 2023) and partly because of the horrible events going on in the country.

That is, because of Russia's unprovoked and unjustified aggression against Ukraine, which has caused many issues with negative impacts on a great number of countries globally directly and indirectly, Ukraine, one of the leading grain exporters, has seen a dramatic drop in its exports, which, in turn, has resulted in major food security concerns for millions of people around the world (European Council, 2023) as Ukrainian exports – especially of wheat – are of crucial importance to some Asian and African countries, as, for example, from 2016 to 2021, they received 92% of Ukrainians' wheat (European Council, 2024).

Another consequence of the said invasion is the fluctuation of both world agricultural products and food prices, reacting on every event caused by the war, like Black Sea Grain Initiative, especially the parties stepping in and - out, overland solidarity lanes, Ukraine's borders blockage by the demonstrating farmers, etc.

Next to the global impacts, the war in Ukraine has had local effects as well, since damage made to Ukraine's agriculture and agro production losses created severe economic uncertainty, driving many Ukrainian farmers to the brink of bankruptcy and substantially depressing the country's agricultural output (Martyshhev, Nivievskiy, and Bogonos, 2023).

The EU's attempts to help Ukraine survive in the course of the ongoing war by temporarily lifting customs duties on Ukrainian imports, including agri-food imports (Centre for Eastern Studies, 2023), have caused concerns in many European agro market players because of the sudden inflow of the Ukrainian grain, which was supposed to be transited to the European sea ports to be consequently exported to the Asian and Middle Eastern countries.

As Ukraine is one of the biggest agro producers, the country has sufficient amounts of agro products to be exported. How sustainable the agricultural production of Ukraine is, how seriously it was damaged by the war and whether the projections for the year 2022 made on the basis of the past years coincide with the real time data – these are the questions, that concern many European decision makers and agro market subjects and these are also the ones to be answered in the presented article.

Therefore, the research questions to be answered in the course of the research presented in the given paper are as follows what the natural and climatic conditions of Ukraine are, what the structure of Ukraine's agricultural land is and how it changed in the course of a definite time frame, what the agricultural production structure of Ukraine is, how important the agro production is for the Ukrainian exports and whether the projected values/trends are close to the real-time ones.

So, for the reasons stated above, the following aims of the presented article were outlined:

- to research both natural and climatic conditions of Ukraine,
- to analyse the structure of Ukraine's agricultural land as well as its dynamics in the time frame from 2000 to 2020 included, paying a special attention to its change in 2020 if compared to either 2000 or 2015,
- to analyse the agricultural production structure of Ukraine in constant prices of 2016 as well as its division by kinds dynamics during the time frame under research,
- to analyse the production dynamics of agricultural products important for Ukraine's exports,
- to build trend lines for the production dynamics of agricultural products important for Ukraine's exports with the projection for another time period, that is for the year 2022,
- to compare the projected values for the production of agricultural products important for Ukraine's exports with the real-time ones.

The theoretical background for the presented research is considered to be "production theory", the early postulates of which appeared in the works of A. Smith, K. Marx and F. Engels, A. Marshall, Jean-Baptiste Say, etc., each of the mentioned explained/developed some notions of it in their own field of research.

There are many definitions/explanations of "production theory", so it was decided to

choose the one from the well-known encyclopedia Britannica, which sounds "theory of production, in economics, an effort to explain the principles by which a business firm decides how much of each commodity that it sells (its "outputs" or "products") it will produce, and how much of each kind of labour, raw material, fixed capital good, etc., that it employs (its "inputs" or "factors of production") it will use" (Dorfman, 2022).

So, the resources used in production are called the factors of production, also known as inputs. The main factors of production are natural resources (land, water, soil, rainfall), labour and capital (Debertin, 2012).

Factors of production "circulate" in their markets according to the rules similar to those for the markets for consumer goods, having supply and demand, determining wage rates, land rents, interest rates, and profits (Samuelson and Nordhaus, 2010).

Taking into consideration everything stated above, it should be noted, that, being considered a primary factor of production, land can take on various forms—from raw property to commercial real estate (Indeed, 2023) as it is not just an area required for production, but it also includes all the free gifts of nature like water, air, natural resources etc. which affect production (Toppr, n.d.).

Land and natural resources are extremely important for a country's economy as they provide the footing and fuel for any economy as we derive output or satisfaction from their services (Samuelson and Nordhaus, 2010), because land is used for residential, commercial, industrial, recreational, agricultural, and transportational purposes (Chen, 2023).

In general, land is considered one of the most important production factors in agriculture, "competing" with climatic conditions and labour. A characteristic feature of land, if applied to its use in agriculture, is the fact that it is a part of nature used for plant production but at the same time it is not a product of human labour, so it cannot be replaced by a different means of production or its area cannot be increased infinitely (Stręk and Noga, 2020). Land is also said to be a passive production factor, being useless without the human efforts application (ClassNotes.ng, 2020).

2. Literature Review

In the course of the research, among the scientists' publications on land as a production factor, the following ones seem to be close enough to the researched topic, that is Kui Yang *et al.* (2020) concentrate themselves on the measurement of the urban land use efficiency, using the Malmquist index approach to measure and decompose urban land use total factor productivity and a panel vector autoregressive model (PVAR) to investigate the interactions among urban land use total factor productivity, technological progress, pure technical efficiency, and scale efficiency

in China from 2003 to 2016 (Kui Yang *et al.*, 2020).

It should also be stressed here, that there are rather many publications of Chinese authors concerning the land use efficiency, among them the one by Jing Liu *et al.* proposing a new analytical framework of land use efficiency in food-economy-ecology, analysing the impact of land use efficiency on land use planning and management (Jing Liu *et al.*, 2020).

Haibin Han and Xiaoyu Zhang, having used MinDS-U and MinDS-U-M models to measure China's cultivated land use efficiency, identifying significant differences in cultivated land use technical efficiency between regions (Haibin Han and Xiaoyu Zhang, 2020), etc.

In addition, Adenuga *et al.* (2021) with a group of co-authors provide a comprehensive and systematic review exploring the benefits of longer-term land leasing with a particular focus on developed countries and some selected developing countries in the context of commercial farming with more formal arrangements (Adenuga *et al.*, 2021).

Another group of authors, researching land leasing issues are Sholih Mu'adi with the co-authors, having made an attempt to research the impact of marginalization caused by the activities of agricultural land conversion in Indonesia (Sholih Mu'adi *et al.*, 2020). Authors, headed by Cláudia M. Viana, did the agricultural land systems research, stating, among the others, its importance for food security (Viana *et al.*, 2022).

Hualou Long *et al.* attempted to provide scientific support for sustainable land use and environmental management, giving systematic analysis of the overall picture, development trends, key fields and hot topics of land use transition research in the past two decades from a comprehensive perspective (Hualou Long *et al.*, 2021). Xiukang Wang researched the role of agricultural land in food production to sustainably feed a human population (Xiukang Wang, 2022).

The analysis and measurement of agricultural land suitability in Turkey was made by T. Everest, A. Sungur and H. Özcan, using an analytic hierarchy process (Everest *et al.*, 2020). There are also rather many publications, in which the urban land use efficiency is researched, though land as a production factor either isn't considered at all or such a fact was just mentioned in passing in the scientific works more or less close to the topic.

Working through the research works describing different issues of land use in Ukraine, the following ones seem to be interesting for the specialists involved, that is the research made by Viktoriya Onegina and Yurii Vitkovskiy having made an attempt to identify trends and factors of investment into the agriculture of Ukraine in the period 2014–2019 and the impact of land reform, expected liberalization of the

trade of agricultural land on the investment into agriculture (Onegina and Vitkovskyy, 2020).

A group of authors headed by Shmatkovska Tetiana O. substantiate, that, because the soils ploughing level in Ukraine has not changed for a long time, soil depletion is growing every year and, as a result of the formed culture tendencies, every year the productivity of the said lands will lower, decreasing systematically the efficiency of agricultural enterprises management (Shmatkovska *et al.*, 2020).

Petrychenko Vasyl and co-authors researched the main ecological challenges of agricultural production of Ukraine in conditions of European integration, providing the benchmarking analysis of the security and efficiency of land use in Ukraine among the EU-28 countries, suggesting the formation of a program to protect the soil resources of Ukraine from degradation and their effective use, with respect to social needs and environmental risks (Petrychenko *et al.*, 2022).

Martyn Andrii with the co-authors show that the traditional forms of state regulation of the agricultural land market of Ukraine are currently losing their effectiveness with the land right acquisition to be more often fulfilled not by buying land plots but through acquiring corporate rights for the companies that own or use land nominally, substantiating the directions of control improvement over economic concentration of land resources in agriculture of Ukraine (Martyn *et al.*, 2020).

Kucher Anatolii and co-authors made an attempt to determinate the economic loss due to crop productivity loss caused by soil erosion in Ukraine as well as to present the results of the econometric modelling of soil erosion impact on the efficiency crop production at the regional and district level (Kucher *et al.*, 2021).

Malashevskyy Mykola with his co-authors considered the tendencies of the land fund change during the last years, presenting an analysis of a number of normative documents to highlight the main problems in modern land use, having investigated the dynamics of changes in the areas of agricultural land and arable land in their composition, as well as pastures, hayfields, deposits, and perennial plantations (Malashevskyy *et al.*, 2020).

Sodoma Ruslana with co-authorship assessed the effectiveness of the management of land resources for agricultural enterprises with the use of the suggested factors affecting the market for agricultural products, which, in turn, integrates a system of environmental, economic and social indicators, describing the main theoretical aspects of the land resource management for the agricultural enterprises of Ukraine (Sodoma *et al.*, 2021).

A group of authors lead by Dziamulych Mykola analysed resources management of an agricultural enterprise in Ukraine, having proved that the resource potential of agricultural enterprises is a necessary element of the management system pointing

out the need for strategic management of resource potential, being determined by the fact that in modern conditions, inefficient use of resources reduces the competitiveness of enterprises and makes their activities irrational (Dziamulych *et al.*, 2023).

Yue Ma with co-authors developed a framework for analyzing the spatiotemporal distribution of agricultural land and assessing the impact of the Ukraine–Russia war on agricultural management in Ukraine using remote sensing (RS) and geographic information system (GIS) technology, demonstrating, that fallowed and abandoned croplands could be successfully and effectively identified through the said methods (Yue Ma *et al.*, 2022).

Shvorak Anatoliy analysed in co-authorship the preventive measures during proceedings of land market in the countries of Europe, Argentine and the existing state of land relations in Ukraine, substantiating, that the emergence of agroholdings in Ukraine is connected with the imperfection and failures in the economy functioning, the lack of necessary institutional and legal conditions for the effective business conduction as well as inadequate policy of the state, in particular lack of the full market farmland (Shvorak *et al.*, 2020).

So, taking into account everything stated above, despite the availability of scientific works on the land use in Ukraine, a scientific gap of the publications on the land as a production factor, specifically used in agriculture, with the simultaneous analysis for the crop production, important for its exports, was identified, being perfectly filled in by the research presented in the given article, drawing conclusions about the influence of the war on the said production amounts.

3. Research Methodology

The agro production state of matters, its values and trends research, aiming at gathering and analysing information on the content of production related issues, is gaining in its importance immensely. The data to be analysed in the presented article were taken from the official web page of the State Statistics Service of Ukraine, mostly from the statistical yearbook “Agriculture of Ukraine”.

The notion “agricultural land” is used in the sense of the land, which is systematically used to produce agricultural products (State Statistic Service of Ukraine, 2023). To be added, the assumption “arable land” denotes a kind of land plots that is permanently cultivated and used for agricultural crops, including permanent grasses and clean fallow, areas of hothouses and greenhouses (State Statistic Service of Ukraine, 2023).

The concept “agricultural products at constant prices” means the cost of the agricultural products, produced during a certain period of time, at constant prices (State Statistic Service of Ukraine, 2023). At the same time, “constant prices” are the

weighted average prices of the year, accepted as the basis for comparison as they are calculated as average weighted prices for agricultural commodity output and agricultural non-commodity output (State Statistic Service of Ukraine, 2023).

The data on the agricultural land area of Ukraine has the analysed time frame from the year 2000 to 2020 included. The year 2000 was taken as it is the earliest year of the data available, being an interesting point for the data comparison. At the same time, the year 2020 is the last year with the available data and, as the said data were taken from the State Statistics Service of Ukraine, there were no data on the topic under research available in the statistical publications, issued in 2022 and 2023, because of the war going on in the country.

The timeframe for the data on the agricultural production value of Ukraine is from the year 2010 to 2022 included. The year 2010 was taken as it is the earliest year of the data available and it is the year before the first attack of Russia on Ukraine, so the data from the said year were taken for the comparison purposes. The year 2015 was taken as it is the year after the years 2013-2014, when part of the Ukrainian territory was annexed by its neighbouring country, so comparison of the data before and after the said invasion is of great scientific interest.

Similar intentions were the motivation of the author for the inclusion of the data from the years 2019 and 2022 into the analysis. The data on the production of agricultural products important for Ukraine's exports were analysed in the time frame from 2010 to 2022 included to be comparative to those for the agricultural production value of Ukraine.

Such methods of scientific research as empirical and comparative analyses, time series analysis, modelling and forecasting, method of trends as well as textual and tabular methods added by bar charts for better data presentation and comparison were used while conducting the research presented in the given paper. The trend lines were built either to show the dynamics for the production of agricultural products important for Ukraine's exports or to see the possible projection values of the said production for the year 2022 under the conditions unchanged.

Figures 5 and 6 also include bar charts of the mentioned data but with the real – time production amounts for the said agro products in the year 2022. The aim for such a common figure composition was to present the comparison results of the projected and real – time data for the production amount of the agro products under research.

In order to better present the data analysis results, both formulae and R^2 coefficient values were placed on the bar charts with the depicted trend lines. The mentioned trend lines were built with the help of an appropriate function, which was chosen from the exponential, linear, logarithmic, polynomial, and power ones. The exponential function, used for the trend lines building, was the one, having the following formula:

$$f(x) = a^x \quad (1)$$

where 'a' > 0 and not equal to 1,
'x' is any real number (BYJU'S, n.d.).

A linear function is a function that represents a straight line on the coordinate plane (CueMath, n.d.) with the following formula:

$$y = mx + b \quad (2)$$

where 'y' – the dependent variable,
'm' – the slope of the line,
'b' – the y-intercept of the line, and
'x' – the independent variable (CueMath, n.d.).

The trend line built, with the help of the logarithmic function, means, that the formula given below was used for it:

$$y = b \times \ln(x) + c \quad (3)$$

where 'y' is the dependent variable, 'x' is the independent variable, while 'b' is the slope and 'c' – the intercept (XcelanZ, 2018).

As most of the data under research are rather changeable, a simple linear regression model would not capture all the peculiarities of the said data in order to build an adequate trend line. In such a case, a polynomial function is said to be most useful to catch major ups and downs of the fluctuating data sets.

Therefore, for the purposes mentioned before, the so-called quadratic trinomials were used for the research, the generally accepted formula of which is:

$$y = ax^2 + bx + c \quad (4)$$

where 'y' is the dependent variable, 'a' and 'b' are coefficients, 'x' – the independent variable, and 'c' is the constant (Vedantu, 2024). The trend lines built with the help of a power function, used the following formula:

$$y = ax^b \quad (5)$$

where 'y' is the dependent variable, 'x' – the independent variable, and 'a' and 'b' are the parameters of the function, in other words function coefficients or constants, found by the least squares method (Officetooltips, 2023).

The appropriate functions for the mentioned trend lines building were chosen

judging by the R^2 coefficient values as the mentioned coefficient measures the trendline reliability (Microsoft, 2022). Despite its limitations, R^2 is one of the goodness-of-fit statistics, used for assessing the chosen model's robustness.

As the presented article is not dedicated to the statistical analysis only, the mentioned trend lines were built with the help of the functions, chosen on the basis of the R^2 coefficient values, as it was noted before. Using the said functions, the trend lines for the production of agricultural products important for Ukraine's exports were built with the amount for the year 2022 as the projected value.

Only one following period, in the given case – a year, was taken for the projection making for the purpose to compare the projected and the real – time values of the agro products production amount in the year of the war begin, taking into account, that the said terrible event was one of the most strong factor having influenced the change for the mentioned production amount in 2022.

4. Research Results and Discussion

Known as the granary of Europe, Ukraine has highly developed agricultural production that accounted for more than 10% of its gross domestic production (GDP) in 2021 (Faqin Lin *et al.*, 2023).

Having all the conditions for the intensive development of agricultural economy sector, i.e., availability of fertile soil, favourable geographical location, appropriate climatic conditions, long traditions of farming, etc., Ukraine occupies one of the leading places among the world's greatest producers and exporters of many agricultural products without even being on the list of the largest territorial countries on the global scale but, nevertheless, being the second largest territory in Europe (as of 2020).

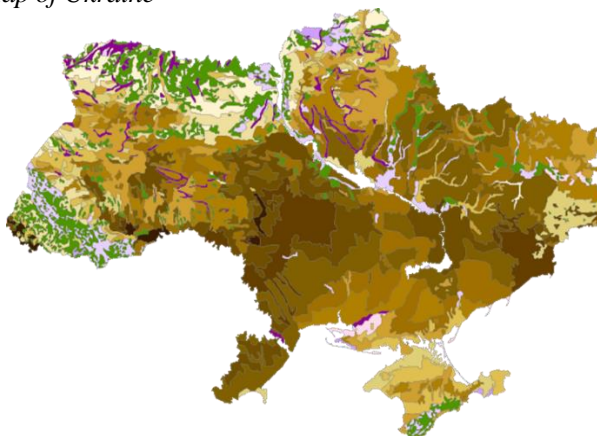
The agricultural economy sector is important not only for Ukraine itself, but for the insurance of food security in the world as well (Shahini Ermir *et al.*, 2023). But, before the analysis starts, let's remember some basic facts about Ukraine, which will add to the understanding of the country's agricultural economy sector development. It is a unitary state located in Eastern Europe.

Ukraine borders on Belarus, Poland, Slovakia, Hungary, Romania, Moldova and the Russian Federation. The country also has exits to the Black Sea and the Sea of Azov. Nowadays, Ukraine is written about on the first pages of major newspapers and talked of on the sidelines of the highest ranked summits.

But, such great interest the global economic and political players show in Ukraine is not due to the country's mountains, rivers or lakes. Or rather, not only to them. The country's main wealth is surely its soils (Figure 1).

As it can be observed in the map given above, from the northwest to the southeast the soils of Ukraine can be divided into three main zones: a zone of sandy podzolic soils, a central belt composed of black, extremely fertile Ukrainian chernozems, and a zone of chestnut and saline soils.

Figure 1. Soils Map of Ukraine



Most Fertile		Good		Medium		Infertile		Especially infertile		Other Land Types	
	94 -100		80-87		59 - 66		38 - 45		17 - 24		Forests
	87-94		73-80		52 - 59		31 - 38		till 17		Peatlands
			66-73		45 - 52		24 - 31				Sands

Source: (Hrachov Andriy n.d.).

In other words, about 50% of the country's territory is covered with chernozems, containing up to 9% humus with a layer thickness of 40 centimetres to even one meter, considered to be one of the most fertile in the world, another 14% of the territory - chestnut soils with 3 - 4% humus and layer thickness of about half a meter.

It should be added, that most agricultural land is located in the chernozem belt, stretching from the Ternopil Oblast, through the central part of Ukraine, to the eastern border (Matuszak, 2021). To deeper analyse either the structure of the agricultural land in Ukraine or the changes both in the said structure and the land area used in different years, the agricultural land area of Ukraine with its differences from the year 2000 to 2020 included is presented in the table given below (Table 1).

Having analysed the data provided in the table given above, it should be noted that the general area of Ukraine's agricultural land decreased during the whole analysed time period. Consequently, the biggest area of the country's agricultural land could be observed in the year 2000 while the smallest one – in 2020.

A different situation is noted while analysing the dynamics of the country's arable land area, meaning it decreased in the timeframe from 2000 to 2010 included, having changed its dynamics direction from that on to the final year of the analysed timeframe.

Table 1. Agricultural Land Area of Ukraine (as of the year beginning), thsd ha.

	2000	2005	2010	2015	2017	2018	2019	2020	Difference of 2020 to 2000		Difference of 2020 to 2015	
									thsd ha.	%	thsd ha.	%
Agricultural Land	41 829,5	41 763,8	41 596,4	41 511,7	41 504,9	41 489,3	41 329,0	41 310,9	-518,6	▼1,2	-200,8	▼0,5
including												
Arable Land	32 669,9	32 482,2	32 478,4	32 531,1	32 543,4	32 544,3	32 698,5	32 757,3	87,4	▲0,3	226,2	▲0,7
Pastures	5 501,6	5 530,1	5 489,7	5 441,0	5 430,9	5 421,5	5 282,6	5 250,3	-251,3	▼4,6	-190,7	▼3,5
Hayfields	2 336,4	2 438,0	2 409,8	2 407,3	2 402,9	2 399,4	2 294,4	2 283,9	-52,5	▼2,2	-123,4	▼5,1
Perennial Plantations	945,2	903,8	897,7	892,9	897,1	894,8	863,0	852,7	-92,5	▼9,8	-40,2	▼4,5
Conversions	376,4	409,7	320,8	239,4	230,6	229,3	190,5	166,7	-209,7	▼55,7	-72,7	▼30,4

Source: Authors' elaborations on the basis of the data from (State Statistic Service of Ukraine, 2023).

The biggest positive change of the said land kind could be seen in 2019, while the smallest one – in 2018. The situation, different from the mentioned above, can be observed while analysing the dynamics of Ukraine's pastures area as it increased in 2005, comparing to the area in 2000, and was decreasing through the whole rest time period till the final year included. As it follows from the mentioned above, the biggest positive change of the pasture's area, and its only one, was in 2005.

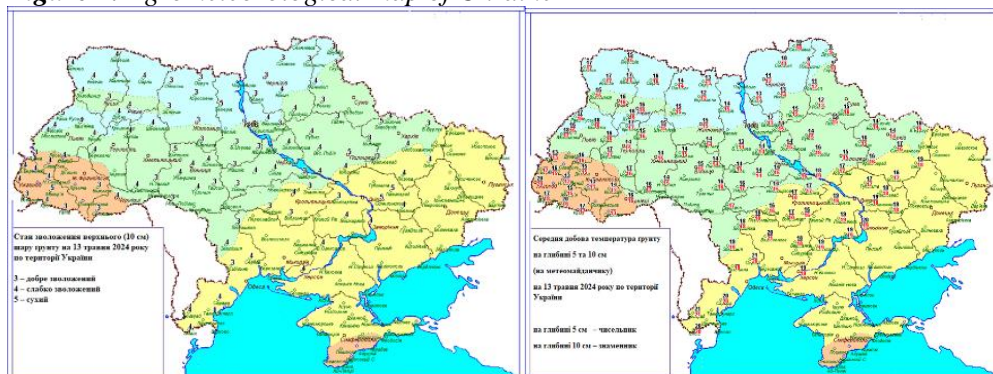
At the same time, the biggest negative change of the said land kind was observed in 2019 with the smallest one – in 2018, which, in turn, is the change opposite to that of the arable land. The dynamics of hay fields area through the analysed timeframe is similar to that of Ukraine's pastures, that is the increase in 2005 with the following decrease lasting to the end of the researched period.

The perennial plantations area dynamics is, again, different from those analysed above, that is it decreased to the year 2015 included, then increased in 2017, being the only year of its positive change, changing its direction to the negative one afterwards, lasting this negative tendency to the end of the analysed period. The dynamics of conversions area during the timeframe under research is similar to that of hayfields, meaning the only positive change is observed in 2005 with the sequence of negative changes lasting to the end of the analysed time period.

While analysing the overall changes of all the land kinds, presented in the table given above, their similarity is the item, that falls into one's eye, meaning the changes of all but one land kinds in 2020 either compared to 2000 or to 2015 are negative, with the exception of the arable land area, which increased in 2020 if compared both to 2000 and 2015, that, in turn, can be an explanation of the decrease of all the other analysed land kinds.

The availability alone as well as the amount of fertile soils are an important prerequisite of successive agricultural production, but, nevertheless, is not the only one required, that is the climatic conditions are also quite important for big harvests and stable animal production. So, according to the level of warmth and moisture, the territory of Ukraine can be divided into the agrometeorological zones as presented in the figure given below (Figure 2).

Figure 2. Agrometeorological map of Ukraine



*Moistening of the arable layer of the soil
(May 13, 2024)*

*Warming of the arable layer of the soil
(May 13, 2024)*

Source: Ukrainian Hydrometeorological Centre, 2024.

As you can see from the figure presented above, the territory of Ukraine can be divided into the following agrometeorological zones, that is the one with moderate level of warmth and sufficient or excessive moisture, the one with moderate level of warmth and stable level of moisture, the very warm and dry one as well as a hot very dry one.

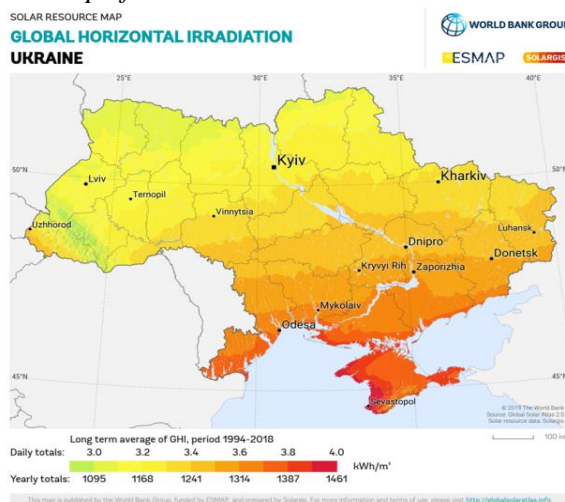
In addition, after considering the fact, that the territory of Ukraine lies in the temperate-continental region of the temperate climate zone, the air temperature varies depending on solar radiation and therefore decreases from south to north (Figure 3).

Judging by the data visualised in the figure given above as well as taking into account the information of the Ukrainian Hydrometeorological Centre, it can be stated that the average annual air temperature in Ukraine ranges from +11°C... +13°C in the south to +5°C... +7°C in the north.

The average temperature of the coldest month (January) ranges from -7°C... -8°C in the north-east of the country to +2°C... +4°C on the southern coast of the Crimea. In the warmest month (July), the average monthly temperature ranges from +17°C... +19°C in the north and northwest of the country to +22°C... +23°C in the southern regions.

So, taking into account everything stated above, both geographical location and climatic conditions contribute to the successive development of agriculture in Ukraine.

Figure 3. Irradiation Map of Ukraine



Source: The World Bank Group, 2024³.

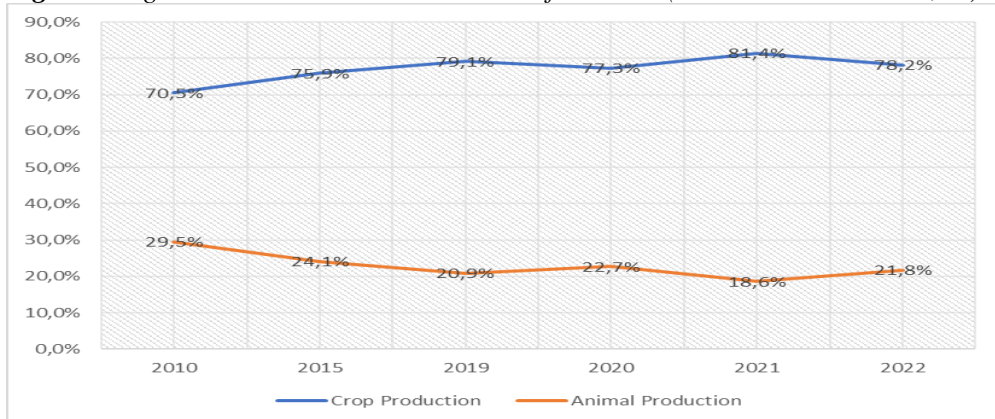
Consequently, the abundant fertile land, suitable climatic conditions, and a relatively favourable investment climate have made Ukraine able not only to feed itself, but also to provide food for millions of people in Asia, Africa, the Middle East, and other countries (Mamonova *et al.*, 2023).

In order to better understand the essence of the Ukrainian agricultural production, the agricultural production structure of the country on the yearly basis from 2010 to 2022 included is visualised in Figure 4.

Analysing the structure for agricultural production of Ukraine, the following fact should be paid a special attention at, meaning the reduction in the share of animal production from 29% in 2010 to 24% in 2015 and 19% in 2021, with its subsequent increase to 22% in the following year.

We observe quite opposite tendency in the case of the crop production share in Ukraine during the analysed period, that is, we see an increase in the share of the mentioned production from 71% in 2010 to 76% in 2015 and 81% in 2021, with its further decrease to 78% in 2022.

³The map was obtained from the "Global Solar Atlas 2.0, a free, web-based application is developed and operated by the company Solargis s.r.o. on behalf of the World Bank Group, utilizing Solargis data, with funding provided by the Energy Sector Management Assistance Program (ESMAP).

Figure 4. Agricultural Production Structure of Ukraine (Constant Prices 2016, %)

Source: Authors' elaborations on the basis of the data from (State Statistic Service of Ukraine, 2023).

The change of the agricultural production of Ukraine in 2022 was a little bit surprising as the country is considered to specialise in the plant production rather than the animal one. The possible explanation of such a surprising change for the agricultural production of the country under research, that is one of the factors, having influenced the said change, was the war impact in general and all its "peculiarities", like the occupation of the lands, on which the crops were grown, by the aggressor-country, the extraction of a definite amount of land from the agricultural production, because the war actions are being held on them, a certain amount of lands, which became unsuitable for the agricultural production because of mines, etc.

Of course, the change of the structure doesn't necessarily mean the appropriate change of the production amount as it is, because the change of the overall agricultural production has also its impact on the mentioned structural change. As it is obvious from the data presented in Table 2, the value of both crop and animal production in Ukraine decreased in 2022, if compared to 2021, but the decrease of the crop one was 146 534,2 mln UAH bigger than that of the animal one.

It should also be added, that the biggest share of the crop production was observed in 2021, while the smallest one – in 2010. More than that, in 2015 crop production share increased the most in the analysed time frame with the smallest increase in 2019. The decrease of the said production occurred twice during the time frame under analysis with the biggest one in 2022 and the smallest one in 2020.

Talking about the animal production of Ukraine changes, it could be observed, that the positive changes of its amount through the analysed time period were noted in the years 2020 and 2022 with the biggest one in 2022 and the smallest one in 2020. Adding to the analysis, the biggest negative change of the animal production share

was in 2015 and the smallest one in 2019. To indulge deeper into the analysis of the agricultural production structure of Ukraine, the data for the main kinds of the Ukrainian agriculture values in the researched time frame are given in Table 2.

Before making a detailed analysis of the data presented in the given table, let's take a look at the value of the overall agricultural production of Ukraine. It has an upward tendency from the beginning of the analysed period to the year 2019 included, having changed its direction to the opposite one in the next year. It should also be added, that the biggest value of Ukraine's agricultural production was in 2021, while the smallest one – in 2010. More than that, we observe the decrease of the mentioned production only in two years, that is in 2020 and 2022.

During the rest of the years under research the increase of Ukraine's agricultural production was noted, with the biggest one in 2015 and the smallest one – in 2019. The crop production of Ukraine development has the same tendency as the overall agricultural production of the country, that is the increase period from the beginning of the analysed period to the year 2019 included with the consequent drop of the said production in the next year, followed by the production increase in 2021 and its decrease in 2022.

The biggest value of the mentioned production can be observed in the year 2021, while the smallest one – in 2010. During the rest of the years under analysis the increase of the country's crop production was observed with the biggest one in 2015 and the smallest one – in 2019. The list of the produced crops as of their production value would look almost similar to that it is presented in Table 2, if we make the said list according to the mentioned value in 2010, except for the last position.

At the same time, the said list would look exactly the same as it is presented in Table 2, without any exceptions, if we make it according to the values as of 2022 in the descending order.

The animal production of Ukraine analysis allows us state, that its dynamics differs from that of the country's crop production, that is we observe the increase of the said production in 2015, if compared to 2010, with the consequent decrease period, lasting from the year 2019 to the end of the analysed time frame. The years of the biggest/smallest values of Ukraine's animal production differs from that of the crop one as well, meaning – we observe the biggest value of the animal production in 2015 and the smallest one – in 2022.

As the increase of the animal production occurred only once through the analysed period, that is in the year 2015, consequently, the rest of the years experienced its decrease, with the biggest one in 2022 and the smallest one – in 2019. If we make the animal products list either according to the values of 2010 or 2022, it would look almost similar to that presented in Table 2 with the exception of the last position.

The differences of either overall agricultural production or crop and animal production of Ukraine as of 2022 compared to 2010 can be divided into two groups according to their positivity/negativity. The first group, containing positive changes for the said values, include those of overall agricultural production, crop production, grain and leguminous crops, industrial crops (including sunflower and sugar beets), potatoes, vegetables, cucurbits crops as well as fruits, berries, grapes.

The rest belong to the second group, containing the negative changes of the analysed values. The division of the differences for the analysed values as of 2022 compared to 2021 into two groups is, theoretically possible, though, it would sound a little bit odd, meaning – all the changes of the values under research as of 2022 compared to 2021 are negative with a single exception of the production group “other crop production”, the value of which increased of almost 49%.

The interdependency of agricultural production and exports seems to be obvious as the more agricultural products are produced in a country, the bigger amount it exports, willing to take advantage of all the preferences an excessive exports give, like foreign currency inflow, access to the foreign markets with a bigger demand and prices levels, etc.

According to the data from (World Integrated Trade Solution) WITS-Comtrade database, ten agricultural and food products, which are most important for the exports of Ukraine, according to the data as of 2022, contain maize (corn); sunflower seed, safflower or cottonseed oils and their fractions, whether or not refined, but not chemically modified; wheat and meslin; rapeseeds, whether or not broken; sunflower seeds, whether or not broken; soya beans, whether or not broken; meat and edible meat offal of poultry of heading 0105, fresh, chilled or frozen; cake and other solid residues, whether or not ground or in the form of pellets, resulting from the extraction of vegetable fats or oils; barley and soybean oil and its fractions, whether or not refined, but not chemically modified.

As it is consequent from the analysis made above, Ukraine’s agriculture is specialised on crop production (amounting of about 70 – 80% for the overall agricultural production of the country), the production of crop products, important for the exports of Ukraine, during the time frame from 2010 to 2022 included was analysed and presented in the table given below (Table 3).

Table 2. *Agricultural Production of Ukraine by Kinds (in Constant Prices of 2016, mln UAH)*

	2010	2015	2019	2020	2021		2022		Difference of 2022 to 2010		Difference of 2022 to 2021	
					mln UAH	%	mln UAH	%	mln UAH	%	mln UAH	%
Agricultural Production	467 474,7	596 832,8	680 982,4	612 121,5	712 566,3	100	534 380,3	100	66 905,6	▲14,3	-178 186,0	▼25,0
Crop Production	329 646,3	453 016,9	538 705,6	473 377,0	580 267,7	81,4	417 907,6	78,2	88 261,3	▲26,8	-162 360,1	▼28,0
grain and leguminous crops	126 803,3	193 390,3	239 728,2	207 778,6	274 271,9	38,5	172 463,5	32,3	45 660,2	▲36,0	-101 808,4	▼37,1
industrial	98 164,6	149 263,1	194 847,6	162 374,8	199 836,0	28,0	160 400,4	30,0	62 235,8		-39 435,6	▼19,7

crops (including sunflower and sugar beets)												▲63,4	
potatoes, vegetables, cucurbits crops	67 679,7	77 346,2	77 753,1	78 861,4	80 747,7	11,3	69 413,6	13,0	1 733,9		▲2,6	-11 334,1	▼14,0
fruits, berries, grapes	12 757,9	14 799,3	14 564,1	13 410,0	14 366,9	2,0	13 011,5	2,4	253,6		▲2,0	-1 355,4	▼9,4
fodder crops	11 048,0	10 103,6	8 618,2	8 128,9	8 064,4	1,1	7 045,0	1,3	-4 003,0		▼36,2	-1 019,4	▼12,6
other crop production	13 192,8	8 114,4	3 194,4	2 823,3	2 980,8	0,4	4 426,4	0,8	-8 766,4		▼66,4	1 445,6	▲48,5
Animal Production	137 828,4	143 815,9	142 276,8	138 744,5	132 298,6	18,6	116 472,7	21,8	-21 355,7		▼15,5	-15 825,9	▼12,0
agricultural animals (breeding)	64 717,5	70 153,8	74 165,4	73 409,7	71 663,4	10,1	63 767,1	11,9	-950,4		▼1,5	-7 896,3	▼11,0
milk	50 104,2	47 320,7	42 978,0	41 199,6	38 766,3	5,4	34 543,9	6,5	-15 560,3		▼31,1	-4 222,4	▼10,9
eggs	19 797,5	19 498,0	19 362,7	18 770,2	16 337,0	2,3	13 841,3	2,6	-5 956,2		▼30,1	-2 495,7	▼15,3
wool	103,0	55,0	42,6	38,8	36,7	0,0	30,4	0,0	-72,6		▼70,5	-6,3	▼17,2
other animal production	3 106,2	6 788,4	5 728,1	5 326,2	5 495,2	2,7	4 290,0	0,8	1 183,8		▲38,1	-1 205,2	▼21,9

Source: Authors' elaborations on the basis of the data from (State Statistic Service of Ukraine, 2023).

Table 3. Production of Agricultural Products Important for Ukraine's Exports, thsd tons

	2010	2015	2019	2020	2021	2022	Difference of 2022 to 2010		Difference of 2022 to 2021	
							thsd tons	%	thsd tons	%
Maize (Corn)	11 953,0	23 327,6	35 880,1	30 290,3	42 109,9	26 186,9	14 233,9	▲119,1	-15 923,0	▼37,8
Wheat and Meslin	16 851,3	26 532,1	28 327,9	24 877,4	32 151,0	20 729,2	3 877,9	▲23,0	-11 421,8	▼35,5
Rapeseeds	1 469,7	1 737,6	3 280,3	2 557,2	2 938,9	3 318,0	1 848,3	▲125,8	379,1	▲12,9
Sunflower Seeds	6 771,5	11 181,1	15 254,1	13 110,4	16 392,4	11 328,8	4 557,3	▲67,3	-5 063,6	▼30,9
Soybeans	1 680,2	3 930,6	3 698,7	2 797,7	3 493,2	3 443,8	1 763,6	▲105,0	-49,4	▼1,4
Barley	8 484,9	8 288,4	8 916,8	7 636,3	9 437,0	5 608,2	-2 876,7	▼33,9	-3 828,8	▼40,6

Source: Authors' elaborations on the basis of the data from (State Statistic Service of Ukraine, 2023).

The dynamics of maize (corn) production is rather changeable with the upward tendency from the beginning of the researched time period to 2019 included, being changed afterwards to the opposite one in the next year, having changed once more in 2021 – this time its increase was noted with the following production decrease in the year 2022. The biggest amount of maize was produced in 2021, while the smallest one – in 2010.

Wheat and meslin production changed the same way through the time frame under research as maize did. The biggest amount of wheat and meslin was also produced in 2021 and the smallest one in 2010 as well as the previous agricultural product.

The negative changes of wheat and meslin production correspond to those of maize ones, that, in turn, ceases the similarity between the agricultural products, taking the first two places in the agro exports of Ukraine.

The matter is, that the biggest positive change of wheat and meslin production occurred in 2015, while the smallest one – in 2019, unlike the situation with the previous agro product amount changes. The agricultural product, which takes the third place among the exported agro products of Ukraine, is rapeseeds.

Its production dynamics differs a little bit from two previous ones as we observe an upward tendency in its production amount from the first analysed year to 2019 included, with another period of upward dynamics lasting to the end of the researched time frame. In addition, the biggest amount of rapeseeds was produced in 2022, while the smallest one – in 2010. As it was stated above, the only negative change of rapeseeds production occurred in 2020.

So, during all the rest analysed years its increase was noted, with the biggest one in 2019 and the smallest one – 2015. The dynamics of sunflower seeds production is similar to those of maize and wheat, being upward from the beginning of the analysed time frame to the year 2019 included, having changed to the opposite one next year, noting increase in 2021 with the subsequent decrease in 2022.

The greatest amount of sunflower seeds was produced in 2021, while the smallest product amount was noted in 2010. The sunflower seeds production decreased twice during the analysed time period, meaning in 2020 and 2022. During the rest of the time periods under research the increase of sunflower seeds production was noted, with the biggest one in 2015 and the smallest one in 2021.

The production of soybeans dynamics is rather changeable, noting increase in 2015 with the following decrease periods in 2019 and 2020. The increase of soybeans production, observed in 2021 didn't last for another year as in 2022 another decrease of the said agro product was observed. The biggest amount of soybeans was produced in 2015, while the smallest one – in 2010.

Unlike maize, wheat and sunflower seeds, noting two periods of the production decrease during the analysed time frame, soybeans production decreased three times during the researched period, meaning in 2019, 2020 and 2022, with the biggest one in 2020.

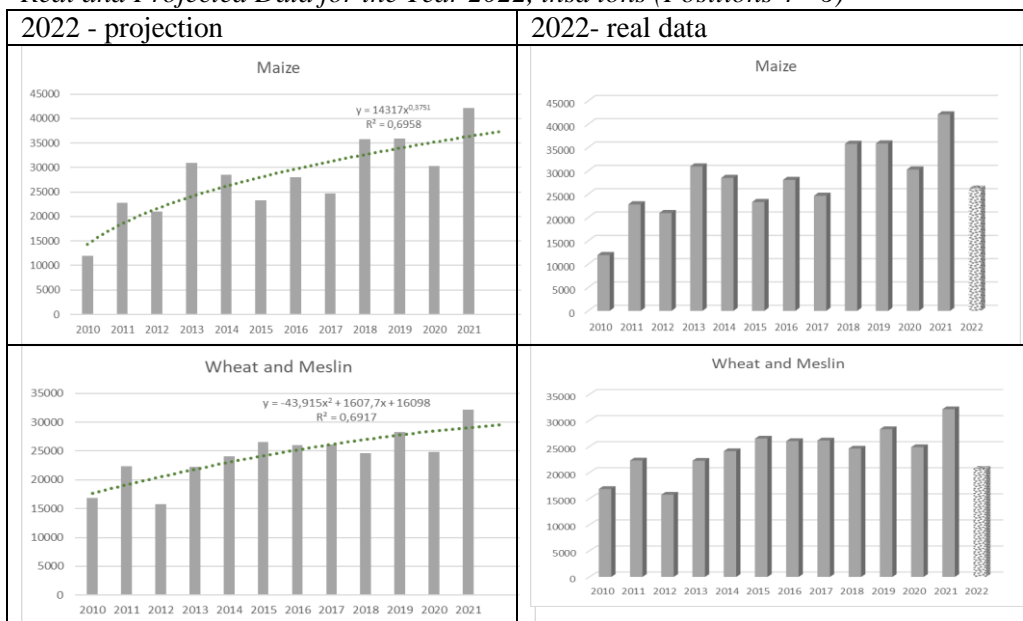
The most changeable of all the production dynamics is the one of barley as its decrease was noted every second analysed period. The biggest amount of barley was

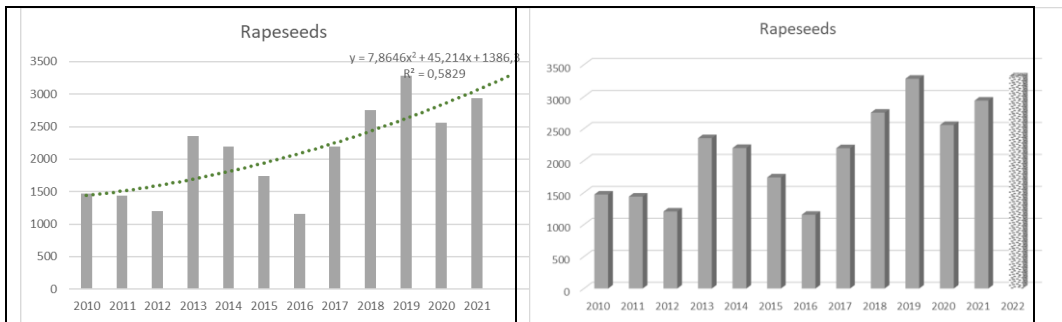
produced in 2021, while the smallest – in 2022. The production of barley decreased three times through the analysed time period, that is in 2015, 2020 and 2022.

Consequently, the increase of the said production can be observed in 2019 and 2021. In addition, it should be noted, that all the products presented in the table given above recorded an increase of their production in 2022 if compared to 2010, except barley, which recorded its decrease by 2,876.7 thsd tons. But, if we compare the production amount as of 2022 to 2021, a different situation is being observed, namely a reduction in the production of all the crop products mentioned, except for rapeseeds. As agriculture is vitally important for the survival of the humanity as a whole and every single human being in particular, its production amount is under the influence, direct or indirect, of many factors, sometimes those, which are not supposed to impact it at all.

A war is a horrible event/process for everybody and anything, that influences all the spheres of any country's activity, the agricultural production amount as well. In order to assess how big such a shock as a war was for the Ukrainian agro production, the production dynamics of six crop products, which are most important for the Ukrainian exports, without the real time production data as of 2022 and with the ones are visualised in the figures given below (Figures 5, 6).

Figure 5. Production of Agricultural Products Important for Ukraine's Exports with Real and Projected Data for the Year 2022, thsd tons (Positions 4 - 6)





Source: Authors' elaborations on the basis of the data from (State Statistic Service of Ukraine, 2023).

Having observed the data visualised in Figure 5, it should be noted, that, despite the fact, that the trend line for the maize production amount, made with the help of the power function, is upward through the whole analysed time frame as well as during one more following period, in this case the year 2022, the projected production amount for the year 2022 is supposed to be a little bit smaller than that of the year 2021.

After having compared the mentioned projected amount with the real time one, presented in the right part of the figure given above, we see, that the real production amount is much smaller, than the projected one. Both the direction and the outline for the trend line of wheat and meslin production are similar to those of maize, but the trend line as well as the projection for the next one period of time were made with the help of the polynomial function.

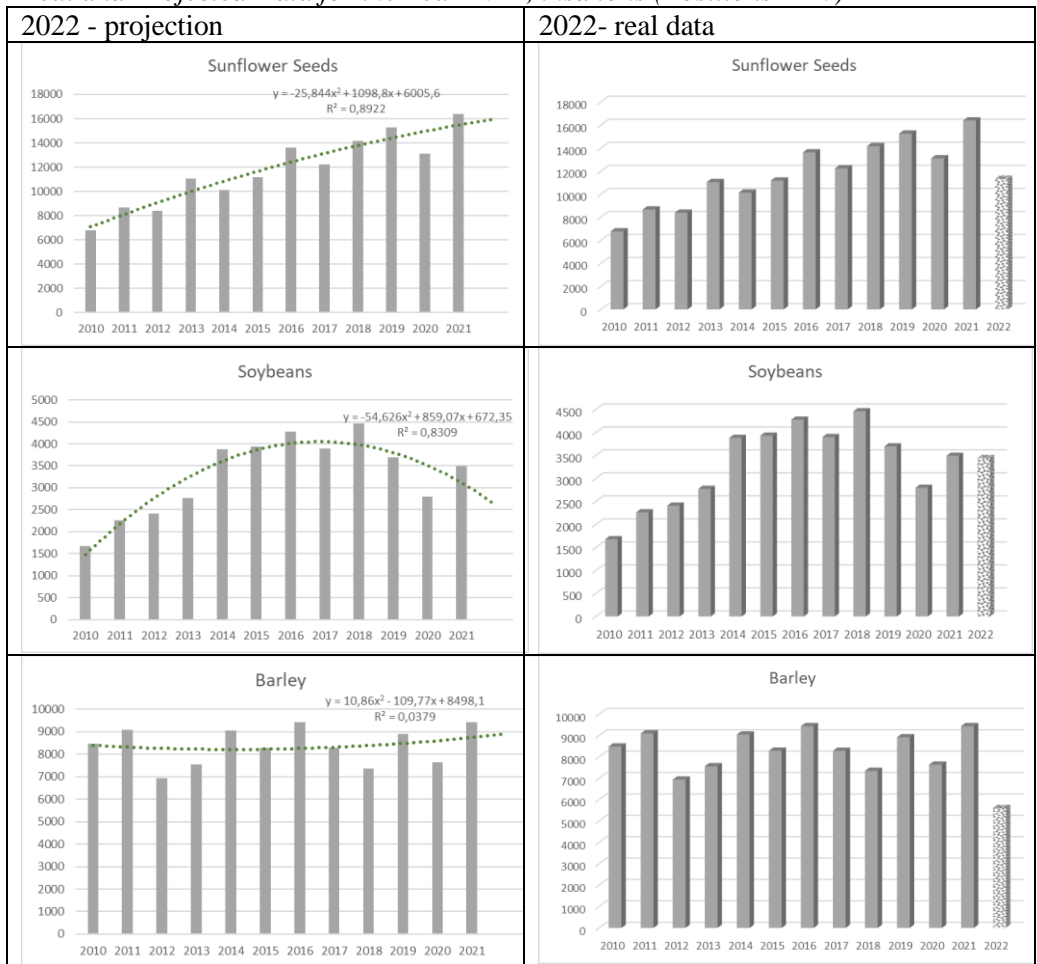
The wheat and meslin production amount for the year 2022 is projected to be smaller than that of 2021. Though, having compared the projected with the real time production data, we see, that the real time production value is smaller than that of the projected one.

Although the trend line for the rapeseeds production amount was made with the help of the polynomial function, just like in the case of wheat and meslin, its outline differs from that of the agro products mentioned above, though being also upward.

Another interesting observation, connected with rapeseeds production amount, is the similarity of its projected and real time data. The data for the production amounts of the next three agro products from the list of the most important ones for the agro exports of Ukraine, is presented in the figure given below (Figure 6).

The third trend line, that was built with the help of the polynomial function, is the one for the sunflower seeds production amount. It's upward through the whole analysed time frame and its outline is very much like the one for wheat and meslin production. The projection for the year 2022 is a small decrease in the sunflower seeds production, despite the upward direction of its trend line.

Figure 6. Production of Agricultural Products Important for Ukraine's Exports with Real and Projected Data for the Year 2022, thsd tons (Positions 4 - 6)



Source: Authors' elaborations on the basis of the data from (State Statistic Service of Ukraine, 2023).

Although the real time amount for sunflower seeds production in 2022 is smaller than that of the projected one. The trend line, standing out from the presented ones, is the one for soybeans production. It was made with the help of a polynomial function, but, unlike the trend lines for all the data mentioned before, is downward after the year 2007.

Another peculiarity of the soybeans production dynamics is that it is the only agro product, which production amount decreased in the year 2019 as all the other analysed agro products noted the increase of their production in the said year. It should also be stated, that the projected amount of soybeans production is smaller than the real time one. The outline of barley production trend line differs from all the

other ones built in the given research, though being also built with the help of polynomial function.

It is upward, like the most of the built trend lines in this research, though its slope is more delicate, than those of the other ones. According to the said trend line, the projected amount of barley production should be a little bit smaller, than that of the year 2021, though the real time one is much smaller than the projected amount.

So, agricultural production of Ukraine is rather important not only for the country alone, but for all its trade partners and the whole world as well. That's why the research made on both its present state of matters as well as its future perspectives are to be carried on in order to preserve its continuity not to be interrupted.

Among the ways of the said research continuation, one should mention the research on the impact of the agricultural land area or the total territory area change, caused by the war, on the agricultural production of Ukraine, including the amount of the plant as well as animal production of the country.

The other way of the eventual research continuation is the deep analysis of the soils kinds, that the occupied territories of Ukraine contain, what agricultural products have been produced on them, whether plant or animal, and what percentage of the mentioned production have been lost due to their fallout from the production circle because of the invasion.

Another way of the research continuation, started in the given paper, is the attempt to assess how much of agricultural land was damaged by the mines and rockets, how much of it is impossible to be cultivated because of the possible location of mines and how strongly the fall out of the said land will influence the present/future agricultural production amount, etc.

The eventual ways of the research, presented in the given paper, continuation, mentioned previously are not abridged to the said only, but, showing the field for the research continuation, they themselves imply the limitations of the said research.

The mentioned research continuation directions could be followed using different scenarios and simulations techniques, which will give decision makers another perspective options on the country/region/industry development. Among the ones, mentioned in the previous sentence, one should mention, among the others, the uncertainty caused by the war.

The uncertainty, in this case, means the unpredictability of everything connected with the said event, that is the unpredictability of the time the said war will be going on, the riskiness to start anything because of the said unpredictability of the war development or the finishing results, the delay in the statistical information publication as well as the impossibility to get some statistical information, and so on.

But, despite all the limitations mentioned above as well as those, possible to arise, the research presented in the paper proves to be important enough to be continued and expanded.

5. Conclusions

A country's agricultural production depends on many factors, like geographical location, climatic conditions, soils fertility, availability of water resources, sufficient and skilled workforce, and so on. However, a lot more impact factors come into play if we talk about the said production of the country, which is being invaded by its neighbour, in particular, if the country is one of the world's greatest agro producers and exporters.

Ukraine's agricultural production is in a very good state, thanks to a good geographical location, favourable climatic conditions, availability of sufficient amount of water, attainability of skilled relatively cheap workforce, accessibility of modern agricultural machinery as well as best practices and techniques of doing agriculture, etc. Ukrainian chernozems, which comprise about 50% of the country's territory, are among the most fertile soils in the world.

Either the general area of Ukraine's agricultural land or all its kinds noted decrease of their area in 2020 if compared both to the year 2000 and 2015. The exception from this rule is the arable land of the country, whose area increased in 2020 if compared both to 2000 and 2015.

If talking about the agricultural production structure of Ukraine, it should be noted, that the crop production had an upward tendency from the beginning of the time frame under analysis to the year 2021 included with the sharp decrease in 2022, while the animal production has the opposite dynamics.

The list of either crop or animal production of Ukraine made either according to the data as of 2010 or 2022 in the descending order would look similar, that, in turn means the structure of both crop and animal production of the country, made according to the products groups presented in Table 2, didn't change a lot since 2010.

When grouping the agricultural production of Ukraine as for its change in 2022 compared to 2010, the following kinds noted its increase, meaning agricultural production in general, including crop production, containing grain and leguminous crops, industrial crops (including sunflower and sugar beets), potatoes, vegetables, cucurbits crops, fruits, berries, grapes and other animal production. The rest noted decrease of its production in 2022 compared to 2010. The similar grouping as of the change in the said production in 2022 if compared to 2021 looks absolutely different, that is only one agro production kind, meaning – other crop production, increased in 2022 compared to 2021, when all the rest decreased.

Maize, wheat and sunflower seeds have similar dynamics as well as their biggest and smallest amounts were produced in the same years. The most changeable of all the production dynamics is the one of barley as the decrease of its production amount was noted every second analysed period.

Barley is the only researched agro product, whose production amount was the smallest in 2022 through the whole time period under research. It is also the only crop, that had a negative change in its production amount in 2022 if compared to that of 2010, while rapeseeds is the only crop, whose production amount increased in 2022 if compared to that of 2021, when those of the rest decreased.

Comparing the trends and projected production values of the agro products important for the Ukrainian exports, we see, that in the cases of maize, wheat, rapeseeds, sunflower seeds and barley the general projection trends for the year 2022 coincide with the ones of the real – time data, though the changes of the real – time data are bigger than those implied by the projected trend lines values. The exception is the soybeans production, whose projection trend line doesn't coincide with the real – time data.

The difference between the projected and real – time data values are especially big in the cases of maize, wheat, sunflower seeds and barley, implying, that the war has influenced tremendously the production amounts of the agro products under research in a negative way, nevertheless it was one of the factors impacted the said production as it cannot be stated, that only one single factor has a sole impact on the agro production amount of the country under analysis, it's rather the combination of different factors influenced the production amount under research, with the war being the most powerful one among them.

The war's impact on the researched production factor land contain, amidst the others, the decrease of the overall Ukraine's territory of about 20% and, as it is implied, the agricultural land as well, the less amount of the land suitable for agricultural production because of mines danger, real or potential, as well as because of its pollution, caused by different weapons kinds used and their use consequences, etc.

In the presented research it was attempted to make a general analysis for the agro production of Ukraine starting from its natural and climatic conditions description through the soils availability research to the agricultural production of Ukraine by kinds in general and the ones important for the agro exports of Ukraine in particular, attempting to compare the projected trends and values for the said production amounts with the real – time ones, which, in turn, can be considered the novelty approach of the research presented in the given paper. The research, presented in the given paper, is the first part of a bigger research of a production potential of Ukraine's agriculture as one production factor, meaning – land availability, was researched in it.

The all-encompassing analysis approach applied in the conducted research would be useful for the scientists in general and researchers interested in similar topics in particular, while the information and data presented in the article would be useful for educators of all the levels as a helping tool in their lessons/lectures/seminars conduction.

The presented research is also interesting and useful for big and small agricultural companies, including family farmers, administrative bodies officials connected either with agriculture or agro products trade, big and small firms indulged in international trade in general and agro products one in particular, politicians and decision makers, academic community representatives as well as beginners and experienced statisticians and data analysts.

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