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THE IMPACT OF CLIMATE CHANGES ON THE DEVELOPMENT OF AGRICULTURE AND FOOD SECURITY (CASE OF UKRAINE AND SLOVAKIA)

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Abstract

The purpose of the paper was to assess the impact of climate changes on agricultural development and food security in Ukraine and Slovakia using statistical data from Statistical Office of the Slovak Republic, State Statistics Service of Ukraine, Eurostat, Food and Agriculture Organization and other sources. The comparison method was used to evaluate changes in agricultural development indicators, as well as climate changes in 1998-2021 in Ukraine and Slovakia. The main indicators of agricultural development used in the research were agricultural raw materials exports(%), agricultural raw materials imports (%), agriculture value added (% of GDP), agriculture value added (annual % growth), agriculture value added (current US$), cereal production (metric tons), cereal yield (kg per hectare), crop production index, food production index. Correlation and regression equations were used to establish the relationship between climatic factors and agricultural development indicators. The multiple correlations between air temperature and indicators of agricultural development was r=0.75 for Ukraine, r=0.69 for Slovakia. Using neuromodeling tools, the indicators of cereal production volumes and cereals yields in Ukraine and Slovakia in 2024-2033 were predicted. Tables were used to summarize the results. In conclusion, it should be noted that climatic conditions should be analyzed in each sector of crop production, and measures should be taken to adapt technologies for the gradual expansion of obligations for the production and export of agricultural products to world markets.

Key words**:** *agriculture, climate change, food security, agricultural development indicators, Ukraine, Slovakia.*

INTRODUCTION

The relevance of the issue of the impact on the development of agriculture and food security of global climate changes lies in the fact that the last decades in many countries of the world have been characterized by noticeable climate changes, which are manifested in the increase in the average annual temperature, in the rise in the level of the oceans, in the increase in the number of natural disasters, in such phenomena, such as desertification, landslides, hurricanes, floods, floods, heavy downpours, hail, droughts, etc. Therefore, climate change affects food production, the food environment and socio-economic conditions, affects the quality of food and the degree of malnutrition, that is, global food security. The global system of food production is forced to adapt to the growth of the planet's population and climate change. Due to unpredictable changes in the weather, agriculture, namely food production, which is an important feature for the normal functioning of mankind, is at risk.

Sun et al. emphasize that in the coming decades, due to global warming, the productivity of agriculture will decrease by 17%. Instead, the need for agricultural production will increase by 70% by 2050 to meet the food shortage due to the increase in the number of the global population [22].

Birgani et al. examine in detail the issue of providing food to the population and note that climate change is a key problem for the development of agriculture in the world. In the case of climate change, the yield of certain agricultural crops may decrease in certain regions, which is the reason for the increase in food prices, and, in turn, affects the diet and level of consumption, and, accordingly, food security. The increase in average temperature and uneven distribution of precipitation caused by global climate changes can lead to the transformation of climatic and agricultural zones [4]. Demyanjuk claims that the climate changes taking place can affect the redistribution of natural resources among different states and cause a conflict of their interests [8]. Fuglie summarizes that today one of the main areas of the economy is agriculture, which guarantees food security and the production of quality food products. Climate change has a significant negative impact on agriculture, primarily on crop yields, quantity and quality of food products [14]. Seppelt et al. emphasize that extremely high temperatures, droughts, excessive intense precipitation, or their absence, disruption of the rhythm and duration of seasonal weather changes have a significant impact not only on production, but also on the use of food [19].

Chandio et al. explain that in connection with the fact that agriculture is one of the main branches of the economy of many countries of the world, the share of GDP of which is a significant specific weight, there is a need to improve existing models of agricultural production and optimize methods of managing agricultural systems in accordance with climate changes [6]. Climate change is a global and long-term phenomenon that requires global coordination and a forward-looking approach according to Kompas et al. [17].

Abbade defines that food products are the main and indispensable in the full functioning of a person. Based on this, the development of the food industry and agricultural products, which are the basis of nutrition, act as a demographic factor, that is, they are key to the realization of basic human needs. Food security is characterized as a state of the economy and belongs to one of the factors of national security, which contributes to the sustainable development of society. That is, it is considered as the state of food production in the state, which has the opportunity to fully realize the needs for quality food products of every citizen, provided that it is balanced and available to the extent necessary for maintaining human health and working capacity [1].

Allen & Prosperi conclude that solving the country's food security problem is impossible without ensuring the quality and safety of food products. The main directions of achieving food safety are clear compliance and control of sanitary and hygienic requirements, technological instructions, recipes, modes of processing, storage, transportation, sale of raw materials and finished products [3]. Climate change has an impact on crop yields, micronutrient deficiencies, rising food prices, shortages of quality food products, and a decrease in food security (according to research by Burke et al.) [5]. Affoh et al. point out that already 821 million people on the planet suffer from hunger, and more than 2 billion people suffer from micronutrient deficiencies, including iron and zinc, which are a major cause of death and disease. And this situation tends to worsen. Low- and middle-income countries are already on the brink of nutrient deficiencies. Deficiency of trace elements has negative consequences for the health of the population [2].

Stoicea et al. say in their research that climate change will cause drought in more than 60% of the areas where wheat, an important source of food and energy, is grown. The growing of leguminous crops is becoming more difficult due to increased drought. Such climate changes threaten the loss of such foods as durum wheat pasta, coffee, cocoa beans, nuts, and some vegetables and fruits [21].

Adaptation to climate change is a key challenge for managing the impacts of climate change on food security, the food environment and human health. Preventive actions are very important in this direction, as climate change reduces the opportunities for successful adaptation and increases the associated costs.

Strategies aimed at minimizing the impact of the results of climate change are focused on stable production of necessary food products, healthy nutrition and reduction of food waste (according to the research of Radin Firdaus and others) [11]. The trends observed in agrarian business require constant monitoring, evaluation and management decisions to prevent a food crisis. In the long run, food security depends on how successfully it will be possible to adapt agricultural systems to climatic phenomena, taking into account a comprehensive understanding of production systems, logistics, food consumption and social and economic characteristics of the countries of the world [11].

However, the impact of rising average temperatures, changing precipitation regimes, and the growth of extreme weather events affecting the world's crop production and livestock production in the world is uneven. In the southern countries, the changes will be very negative, which will affect them in reducing the yield of agricultural crops. However, warming will have a positive effect on agriculture in countries located in northern latitudes [9]. Forecasts indicate that the negative consequences of climate change will have the most negative impact on agriculture in India, sub-Saharan Africa and South Asia [12]. However, global warming will have a beneficial effect on North America, some areas of South America (for example, Chile), Eastern Europe and Central Asia [13]. That is, the international export of agricultural products will change. There will be a concentration of international agricultural markets, that is, the main volume of exports will fall on a smaller number of countries. In this connection, the comparative advantages and the level of competitiveness of agriculture in different countries will change. Some countries will benefit from climate change, and some will lose. The problem of global warming is one of the most important problems of the world economy. Damages to the world economy are estimated at hundreds of billions of dollars per year, and in the future, by 2100, they may reach 20% of the global gross product [18]. The economic consequences of global warming affect both the growth and the quality of agricultural products with high economic value. The negative impact on the agricultural sector will increase the level of poverty in rural areas [7].

Among the main indicators used by scientists when analysing the impact of climate change on the development of agriculture are the trend of temperature changes and changes in the amount of precipitation. At the same time, each of the models has its own characteristics. The temperature level affects the growth rate of per capita production only temporarily [15]. Macroeconomic climate-economics models almost always assume that temperature is a level effect [16].

Therefore, the strategy of adaptation to climate change is aimed at strengthening the ability to continue agribusiness in the conditions of climate change, responding to natural challenges at the micro and macro levels. The purpose of the research is to assess the impact of temperature changes and the amount of precipitation on the economic indicators of agricultural development, namely the level of export and import of agricultural raw materials, the increase in the added value of agriculture, the production and yield of grain crops, the index of crop production and the index of food production, as well as determination of the nature of fluctuations of these indicators in Ukraine and Slovakia under the influence of changes in climatic conditions and forecasting future trends in the economic development of agriculture in the countries.

MATERIALS AND METHODS

The research work is based on a large amount of information, including empirical data from the State Statistics Service of Ukraine, the Office of Statistics of the Slovak Republic, Eurostat and other sources [23, 20, 10, 24]. The main indicators used in this study were indicators for Ukraine and Slovakia, namely Agricultural raw materials exports (% of merchandise exports) (Var1), Agricultural raw materials imports (% of merchandise imports) (Var2), Agriculture, value added (% of GDP) (Var3), Agriculture, value added (annual % growth) (Var4), Agriculture, value added (current US$) (Var5), Cereal production (metric tons) (Var6), Cereal yield (kg per hectare) (Var7), Crop production index (Var8), Food production index (Var9), Average precipitation, Average annual temperature. The study period is 24 years (from 1998 to 2021). Correlation coefficients were calculated between economic indicators of agricultural development and temperature, as well as precipitation. Regression equations were used to assess the dependence of economic indicators of agricultural development on the level of temperatures and precipitation. Using neuromodeling tools, the indicators of cereal production volumes and cereal yields in Ukraine and Slovakia in 2024-2033 were predicted. Tables were used to summarize the results. The conclusions present the main ideas drawn from this research.

RESULTS AND DISCUSSIONS

Consider the impact of climate change on the development of agriculture using the examples of Slovakia and Ukraine. Annual data for 1998-2021 are used for calculations. Table 1 presents dynamics of indicators of the development of agriculture in Ukraine, as well as average temperature and average precipitation in 1998-2021.

The data in Table 1 show that for 24 years, agriculture accounted for 7-13% of the GDP of Ukraine, starting from 2002 (except for 2008).

Also, the export of agricultural products exceeded the import, the grain yield increased more than 2 times from 1998 to 2021.

Table 1. Dynamics of agricultural development indicators in Ukraine, as well as average temperature and average precipitation in 1998-2021

Year	Agricultural raw materials exports (% of merchandise exports)	Agricultural raw materials imports (% of merchandise imports)	Agriculture, value added (% of GDP)	Agriculture, value added (annual growth%)	Agriculture, value added (current US$)	Cereal production (metric tons)	Cereal yield (kg per hectare)	Crop production index	Food production index	Average precipitation (in mm)	Average annual temperature (°C)
1998	1.09	1.95	12.07	-11.18	5054414941.57	25699039.30	2,109.40	44.3	59.6	599.88	8.62
1999	1.61	1.67	11.88	-3.95	3750204275.98	23960468.59	2,002.90	40.7	56.5	546.34	9.63
2000	1.69	1.50	13.95	12.10	4516901848.57	23814123.87	1,950.80	49.2	61.8	520.39	9.48
2001	1.49	1.53	13.98	10.02	5493940916.96	38886120.16	2,729.50	55.4	66.2	629.94	9.01
2002	1.81	1.32	12.60	1.91	5539905662.59	37984706.45	2,752.20	55.5	68	543.15	9.45
2003	1.85	1.33	10.50	-11.12	5460847921.30	27493983.59	2,278.40	52.8	66	519.64	8.36
2004	1.55	1.35	10.44	19.71	7015792442.19	40996700.00	2,845.20	63.1	72.7	642.54	8.92
2005	1.47	1.32	8.88	0.28	7920223684.02	37258000.00	2,623.00	63.1	72.6	598.85	9.06
2006	1.36	1.17	7.24	1.66	8099405940.59	33518621.59	2,427.70	62.6	72.8	555.95	8.68
2007	1.29	1.02	6.28	-6.17	9344950495.05	28945257.88	2,206.70	56.5	67.6	532.89	10.22
2008	0.87	0.89	6.54	16.87	12293768360.51	52747334.16	3,486.90	79.6	84.2	549.99	9.72
2009	1.18	1.09	6.91	-2.00	8393657133.15	45413410.45	3,003.80	74.2	80.1	565.94	9.67
2010	1.15	1.08	7.40	0.21	10452591863.71	38685986.74	2,726.60	70.2	77.6	665.72	9.46
2011	1.07	0.99	8.15	19.57	13801083505.73	56263263.02	3,753.70	91.9	94	456.03	9.08
2012	0.99	0.96	7.76	-4.00	14171515993.27	45750171.09	3,156.80	83.7	88.1	563.63	9.53
2013	1.27	0.99	8.69	12.64	16558738896.53	62687581.61	4,030.80	99.6	101.2	574	9.76
2014	1.77	1.09	10.15	-0.68	13556794583.86	63388560.00	4,400.20	100.1	101.1	521.01	9.75
2015	2.15	1.14	12.06	-4.38	10977766896.18	59627180.00	4,140.90	96.1	96.8	492.5	10.36
2016	2.11	1.24	11.73	6.33	10946629977.24	65217850.00	4,651.60	103.8	102.1	639.33	9.71
2017	1.74	1.18	10.18	-2.52	11408184810.41	60689783.33	4,311.30	100.8	100.1	526.29	9.84
2018	2.02	1.06	10.14	8.18	13271745069.03	69112267.78	4,847.30	111.1	107.3	549.6	9.88
2019	1.74	0.97	8.97	1.00	13795893581.74	74443852.37	4,975.80	112.8	108.9	462.25	10.67
2020	1,71	1,05	9,31	-10,7	14581346358.46	64343120.16	4,293.40	100.9	99.3	497.11	10.86
2021	1.57	1.02	10.89	15.13	21746055913.64	85338631.18	5,453.10	96.50	92.10	623.82	9.38

Source: Statistical information of Ukraine [23].

The index crop production increased more than twice from 1998 to 2019, the downward trend of this indicator can be traced in 2020-2021, the same situation with the food production index. Regarding climatic conditions, the average annual temperature has increased by 2 degrees Celsius over 24 years and there is no direct trend in the average amount of precipitation.

In order to compare the trends of the indicators, similar initial data for the Slovak Republic were formed. Table 2 presents dynamics of agricultural development indicators in Slovakia, as well as temperature and precipitation in 1998-2021.

Table 2. Dynamics of agricultural development in Slovakia, as well as temperature and precipitation in 1998-2021

Year	Agricultural raw materials exports (%)	Agricultural raw materials imports (%)	Agriculture, value added (% of GDP)	Agriculture, value added (annual growth%)	Agriculture, value added (current US$)	Cereal production (metric tons)	Cereal yield (kg per hectare)	Crop production index	Food production index	Average annual temperature (°C)	Average precipitation (in mm)
1998	2.32	1.74	2.12	-0.39	634341648.95	3485707.64	4,054.90	96.7	127.7	8.35	822
1999	2.49	1.75	1.64	-23.84	500855247.02	2829922.00	3,857.40	89.7	121.5	8.65	765
2000	2.18	1.85	1.71	14.65	500137118.91	2202543.00	2,709.90	72.9	102.5	9.46	845
2001	2.07	1.63	2.12	32.50	652577168.89	3212188.00	3,889.70	88.4	110.6	8.35	841
2002	1.90	1.61	2.04	5.75	721098305.35	3197881.00	3,899.70	87.7	113.7	9.12	573
2003	1.57	1.51	1.81	4.69	849431322.57	2490571.00	3,136.00	74.3	104.3	8.51	851
2004	1.53	1.38	1.67	1.01	957758759.40	3797352.00	4,641.80	98.1	116.3	8.26	938
2005	1.78	1.27	1.62	6.11	1016738995.55	3585251.00	4,511.80	92.7	113.2	7.95	776
2006	1.31	1.15	1.85	22.49	1307989940.04	2928803.00	3,996.30	82.7	105.1	8.42	894
2007	1.07	1.19	2.30	26.35	1987506996.33	2793485.00	3,561.20	76.3	100.5	9.44	873
2008	0.95	1.03	2.53	20.01	2555490574.15	4137019.00	5,175.30	100.9	114.3	9.45	890
2009	1.25	1.14	2.09	-3.19	1864094626.84	3332824.00	4,331.50	87.2	101.2	9.12	1,255
2010	1.29	1.41	1.57	-22.59	1429781447.85	2554376.00	3,737.30	69.1	87.2	8.10	656
2011	1.06	1.49	1.88	17.81	1879983116.32	3714041.00	5,009.00	89.6	99,00	8.84	747
2012	1.06	1.44	1.90	-1.45	1799615055.79	3035809.80	3,829.10	70.2	85.4	9.01	864
2013	0.99	1.41	2.22	22.63	2198643632.96	3411961.00	4,490.40	82.1	93.5	8.94	934
2014	0.96	1.10	2.75	32.96	2788252132.11	4707654.80	6,038.70	105.00	104.7	10.07	719
2015	0.92	1.02	2.20	-16.15	1952156864.69	3805712.00	5,079.60	86.7	89.6	9.82	924
2016	0.87	0.97	2.24	8.74	2017081869.95	4847544.00	6,430.40	108.3	105.7	9.2	827
2017	0.84	1.07	2.09	-6.02	1999441918.82	3484061.00	4,856.00	87.5	91.9	9.08	674
2018	0.87	1.05	2.15	13.59	2276713780.32	4020160.00	5,409.70	96.8	97.9	10.05	848
2019	0.81	1.08	1.67	-18.34	1764047782.01	4104050.00	5,336.00	93.5	97.9	10.14	886
2020	0.83	1.06	1.73	5.55	1847134419.08	4580900.00	6,129.80	101.1	101.3	9.93	761
2021	0.99	1.21	1.78	-1.34	2108828338.35	4289470.00	5,976.80	99.8	97.4	8.78	822

Source: Statistical Office of the Slovak Republic [20] and Eurostat [10].

From 1998 to 2006, as well as in 2008-2009, there was an excess of export of agricultural products over import in Slovakia, during the last decade, import of agricultural products was greater than export. The specific weight of GDP from agriculture fluctuates for 24 years at the level of 2%. The grain yield is constantly fluctuating, but in general there is an almost 2-fold increase. There are no clear trends for crop production and food production indices, the values have approximately the same dynamics. There is no significant change in climatic indicators.

The assessment of the impact of changes in average temperature and average precipitation on economic indicators in the agriculture of the countries under consideration, namely Ukraine and Slovakia, is carried out with the help of correlation-regression analysis tools, using the STATISTICA 13.5.

Table 3 presents results of the regression analysis of the dependence of the agricultural development indicators of Ukraine on changes in climatic conditions.

Table 3. Results of the regression analysis of the dependence of the agricultural development indicators of Ukraine on climate change

	b* coefficient	**Std. Err. - of b* Standard error**	**t statistics**	**p-value**
Intercept	12.91766	3.732659	3.46071	0.003822
Var1	-0.01638	0.428632	-0.03821	0.970059
Var2	-0.53130	0.533450	-0.99596	0.336173
Var3	0.36755	0.446027	0.82405	0.423729
Var4	-0.43999	0.238892	-1.84178	0.086789
Var5	-0.47869	0.589395	-0.81217	0.430286
Var6	1.86204	2.488206	0.74835	0.466637
Var7	-2.25903	2.777485	-0.81334	0.429642
Var8	4.38580	4.316815	1.01598	0.326876
Var9	-3.21244	3.612327	-0.88930	0.388867

Source: Own calculation on the basis of data from Statistical information of Ukraine [23].

The results of multiple regression show the impact of changes in temperature and precipitation on indicators of the efficiency of agriculture in Ukraine. The most significant is the dependence on climate change of the indicators of cereal production, their productivity and indexes of crop production and food production.

The multiple correlation coefficient (Multiple R = 0.74627918) testifies to the high closeness of the connection between the change in temperature and indicators of the efficiency of agricultural development in Ukraine. The coefficient of determination (R^2= 0.55693262) shows that a significant part of the variability of the variable can be explained with the help of the built model, that is, the value of the coefficient of determination determines the significant share of changes due to the influence of factor characteristics in the overall variability of the resulting characteristic. The coefficients of the multiple regression model are given in column 1. The most statistically significant are highlighted in red.

The results of the regression analysis of the dependence of indicators of the agricultural economy of Ukraine on changes in the amount of precipitation showed a high degree of correlation between indicators of the effectiveness of agricultural development.

The multiple correlation coefficient (Multiple R = 0.74627918) testifies to the high closeness of the connection between the indicators of the development of agribusiness in Ukraine and the change in the average annual temperature. At the same time, the coefficient of determination (R^2= 0.55693262) indicates that a significant part of the variability of the variable can be explained by the constructed multiple regression model.

Table 4 presents the results of a regression analysis of the dependence of the agricultural development indicators of Slovakia on changes in the average annual temperature.

The results of the regression analysis indicate the significant dependence of Slovakia's agriculture on climate change. The values of the coefficients indicate the dependence between such indicators as grain yield, grain production volume, crop production index, food index and increase in average annual temperature. The same trends are taking place in the agricultural market of Ukraine.

Table 4. Results of the regression analysis of the dependence of the agricultural development indicators of Slovakia on climate change

	b* coefficient	**Std.Err. - of b* Standard error**	**t statistics**	**p-value**
Intercept	9.431189	3.057398	3.08471	0.008074
Var1	-0.29521	0.948842	-0.31113	0.760288
Var2	0.10064	0.507005	0.19849	0.845512
Var3	0.26588	0.413372	0.64319	0.530498
Var4	-0.18881	0.259655	-0.72714	0.479123
Var5	0.11514	0.756507	0.15220	0.881199
Var6	0.59929	1.353204	0.44287	0.664628
Var7	-1.76363	1.773285	-0.99456	0.336832
Var8	1.51799	1.576221	0.96306	0.351860
Var9	-0.96213	0.809968	-1.18787	0.254648

Source: Own calculation on the basis of data from Statistical Office of the Slovak Republic [20] and Eurostat [10].

The multiple correlation coefficient (Multiple R = 0.68744870) testifies to the high closeness of the connection between the indicators of the development of agrarian business in Slovakia and the increase in temperature in this country. At the same time, the coefficient of determination (R^2= 0.47258572), which is less than the similar one in Ukraine, means that the variability of the variable can be explained with the help of the constructed regression model.

The results of the dependence of indicators of the agricultural economy of Slovakia on changes in the amount of precipitation showed a low degree of correlation with indicators of the effectiveness of agricultural development, but a significant one in general.

The multiple correlation coefficient (Multiple R = 0.46845539) indicates a moderate closeness of the relationship between the change in the amount of precipitation and indicators of the efficiency of agricultural development in Slovakia. The coefficient of determination (R^2= 0.21945045) shows that a small part of the variability of the variable can be explained by the constructed multiple regression model. According to the obtained values and interdependencies, using neuromodeling tools in STATISTICA 13.5, it is possible to forecast such indicators as Cereal production (metric tons) and Cereal yield (kg per hectare) for 2024-2033 for Ukraine and Slovakia. The dynamics of economic indicators within the framework of the researched process act as input information for the neural network, that is, the data on which it learns. In the process of applying the neuromodeling toolkit, typical regularities of the dynamics of changes in agribusiness development indicators are formed in order to assess the development of the time series, which will be recognized by the Kohonen layer. These images are the examples for neural network training. In this case, the studied image is the dynamics of agricultural development indicators over a certain period of time, and the task of the neural network is to recognize this image and establish the class to which it corresponds. To predict the dynamics of indicators of agricultural development, a neural network of counterpropagation is built based on the combination of layers of Kohonen and Grossberg neurons. Model parameters are calculated during network setup.

Tables 5 and 6 present the results of forecasting indicators of the development of agriculture in Ukraine and Slovakia.

Table 5. Predictions for cereal production (metric tons) and cereal yield (kg per hectare) in Ukraine

Year	**Cereal production (metric tons)**			**Cereal yield (kg per hectare)**		
	Pessimistic prediction	**Most probable prediction**	**Optimistic prediction**	**Pessimistic prediction**	**Most probable prediction**	**Optimistic prediction**
2024	25699039	46950800	46933312	2,109.400	3,331.660	3,427.934
2025	23960469	46676412	46872449	2,002.900	3,311.817	3,427.089
2026	23814124	46464254	46863456	1,950.800	3,307.404	3,424.084
2027	38886120	47230434	46935438	2,729.500	3,335.049	3,432.178
2028	37984706	46629114	46877374	2,752.200	3,312.501	3,426.105
2029	27493984	46328742	46897766	2,278.400	3,316.968	3,419.382
2030	37258000	46998407	46919473	2,623.000	3,327.727	3,429.645
2031	33518622	46629613	46909316	2,427.700	3,321.649	3,424.185
2032	52747334	46715795	46870978	3,486.900	3,311.941	3,427.764
2033	38685987	47574065	46935122	2,726.600	3,339.797	3,436.967

Source: Own calculation on the basis of data from Statistical information of Ukraine [23]

Table 6. Predictions for cereal production (metric tons) and cereal yield (kg per hectare) in Slovakia

Year	**Cereal production (metric tons)**			**Cereal yield (kg per hectare)**		
	Pessimistic prediction	**Most probable prediction**	**Optimistic prediction**	**Pessimistic prediction**	**Most probable prediction**	**Optimistic prediction**
2024	3485708	3479775	3509363	4,054.900	4,516.091	4,554.566
2025	2829922	3477262	3509526	3,857.400	4,513.660	4,554.569
2026	2202543	3476316	3509967	2,709.900	4,515.767	4,554.732
2027	3212188	3477528	3509363	3,889.700	4,512.722	4,554.504
2028	3197881	3471986	3509781	3,899.700	4,507.811	4,554.536
2029	2490571	3501067	3509454	3,136.000	4,548.714	4,555.178
2030	3585251	3472396	3509143	4,511.800	4,503.213	4,554.264
2031	2928803	3483196	3509402	3,996.300	4,521.535	4,554.676
2032	4137019	3466677	3509960	5,175.300	4,501.275	4,554.466
2033	2554376	3443531	3509219	4,054.900	4,516.091	4,554.566

Source: Own calculation on the basis of data from Statistical Office of the Slovak Republic [20] and Eurostat [10].

Forecast indicators of cereal production (metric tons) and cereal yield (kg per hectare) in Slovakia and Ukraine in 2024-2033 indicate that the increase in temperature and changes in the amount of precipitation will not lead to a decrease in the volume of cereal production and their yield, there will be a tendency to the growth of relevant indicators, which will allow to increase exports.

CONCLUSIONS

Thus, the results of regression analysis and neuroforecasting regarding the development of agribusiness in Ukraine and Slovakia indicate that climate change affects the performance indicators in the agriculture of these countries. Forecasting the effectiveness of some indicators of agricultural development in Ukraine and Slovakia shows that climate change in these countries will have a positive impact on the development of the agricultural sector. Therefore, in the future, Slovakia and Ukraine can gradually increase the volume of production and export of agricultural products to world markets.

As a result of climate change, Ukraine and Slovakia are likely to be among those who will benefit from global warming. Accordingly, the agricultural export of these countries will become a means of supplying food to regions affected by global warming, and this will be a solution to the problems of the decline in agricultural production in these countries.

Therefore, in order to increase the production of agricultural crops and agricultural exports, the main task for the near future is to prepare not to lose the chance provided by global climate change, and to carry out reforms in the agricultural sector in order to be able to increase production volumes, reduce costs, stimulating development of agribusiness, family farms, to implement the latest innovative methods.

Food shortages associated with warming, with a growing population and rising food prices, will increase the number of players and supply of agricultural products in global agribusiness. One of the priority directions of the agrarian business development strategy of Ukraine and Slovakia should be the creation of conditions for investments in innovation in agriculture, as well as tax benefits to stimulate investments of agrarian companies.

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