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The Effect of Drought on Yield in Agriculture: 2020 Year Fatidic for Romania

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Abstract

In this paper we want to identify the effect that the severe drought registered in Romania in the agricultural year 2019-2020 had on the yield losses in agriculture. To develop this analysis, data on average yields per hectare extracted from national databases were used, as well as data on the level of precipitation extracted from international databases. Thus, following the analysis of the dynamics of average yields per hectare, precipitation and testing of hypotheses according to which the level recorded in 2020 is statistically significantly lower than in previous years. Thus, it was found that in the regions where the level of precipitation was higher, there were also increases in yields per hectare. Finally, following the running of the simple linear regression model, for the sunflower crop it was found that an increase in precipitation level by one unit will lead to an increase in yield by one kilogram and 260 grams of sunflower.

Keywords: drought, yield, agriculture, Romania, 2020.

Introduction

The agricultural year 2019-2020 was a difficult one in agriculture in Romania, given the health situation that caused the declaration of a state of emergency and the closure of activities in March 2020, but fortunately the agricultural activities, production, were an exception, the population having the opportunity to move in this direction. Unfortunately, over this situation that was pressing the sector, there was a severe lack of rainfall, therefore a drought with exponential character and influence since the fall of 2019. In the southern part of the country there were significant precipitations during the winter and after, compared to the previous period.

These extreme situations led to a decrease in total production, influenced by the decrease in average yield per hectare, so the main purpose of the study is to effectively identify the impact of drought on average yields per hectare in agriculture in Romania, for developing regions (NUTS2).

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Literature Review

According to Yu et al (2020), dry land covers 40% of the global land area and this area is expected to grow by 4-8% by 2100. Therefore, as mentioned in Leng and Hall's (2019) work, various simulations were performed on various crop models, indicating an increase in crop yield losses caused by drought by 2100.

Feeding the world's population and thus ensuring food security are restricted using water in agriculture, this sector being the largest single user of fresh water, comprising over 70% of the total use of fresh water worldwide (Wallace, 2000).

Drought and lack of water are severe constraints that restrict the sustainable development of agriculture (Tan, et al. 2020). It has been found that the use of modern irrigation technologies has the potential to reduce the risk of drought by providing efficient water use, which reduces rural poverty and would promote changes in agricultural sustainability (Koundouri et al., 2006) .

However, practically the multiple advantages of modern irrigation technology not only have a low success rate with a slow promotion process but have also contributed to a substantial heterogeneity in the process of adopting different agricultural technologies (Genius et al., 2013).

Currently, low yields in agricultural systems, for which the main source of water supply is rain, are partly caused by recurrent droughts and this has contributed in part to a high incidence of poverty in some parts of the globe (Kanchebe Derbile, 2013).

As it is known, in general, the climate of Romania is of "moderate continental" type, but there is a rather great variability from this classification, both zonal and from one year to another. The very large variation of the total amount of precipitation from one year to another, but also of their distribution during the year, determines water deficits during the vegetation of agricultural crops, in almost all areas of the country (Petcu, 2008).

Material and Method

The present research aims to identify the effect that the drought of the agricultural year 2020, difficult to test from this point of view can have on production and average yields per hectare, so for this we used data provided by the National Institute of Statistics on to the average production per hectare, as well as data on the level of precipitation provided by Raspisaniye Pogodi.

The data analysis will be performed on the development regions of Romania (NUTS2 according to Eurostat, 2021), thus, the dynamics of yields for the main crops exploited in Romania will be analyzed, as well as the determination of the relative differences between the last year and the previous years. To determine the level of significance of the differences between these periods, the student t test will be used to compare the means of a sample. Subsequently, the correlation coefficients between the precipitation level and the average yields per hectare will be identified, to identify very tight variables to elaborate the simple linear regression model. These instruments will be applied to identify the value of the influence of drought on the average production per hectare.

Results and Discussions

Table 1: Dynamics of average yields per hectare for the main agricultural crops in Romania (kg / ha)

The main cultures	2015	2016	2017	2018	2019	2020	2020 / average of the last 5 years	2020/2019
Grain cereals	3535	3965	5225	5999	5458	3402	-29.7%	-37.7%
Wheat and rye	3774	3937	4879	4784	4740	2984	-32.5%	-37.0%
Wheat - total	3780	3944	4888	4793	4749	2987	-32.6%	-37.1%
Barley and barley	3461	3773	4186	4417	4188	2562	-36.0%	-38.8%
Hop	996	809	546	860	866	989	21.3%	14.2%
Oat	1999	2239	2460	2376	2243	1942	-14.2%	-13.4%
Corn grain	3462	4159	5959	7644	6502	3963	-28.5%	-39.0%

Rice	4482	4625	4746	5254	5384	4207	-14.1%	-21.9%
Hemp for fiber	4719	5651	1546	1900	2205	2506	-21.8%	13.7%
Sunflower	1765	1955	2917	3041	2783	1883	-24.4%	-32.3%
Rape	2499	2835	2798	2546	2264	2124	-17.9%	-6.2%
Soy beans	2045	2070	2383	2748	2630	1857	-21.8%	-29.4%
In for oil	1670	1644	1675	1536	2011	1198	-29.8%	-40.4%
Sugar beet	39135	40611	41643	38031	40351	33416	-16.4%	-17.2%
Tobacco	1448	1788	1522	1375	1354	1308	-12.6%	-3.4%
Potatoes - total	13866	14551	18393	17629	15223	15063	-5.5%	-1.1%

Source: author processing based on NIS data, accessed (14th September, 2021)

Table one shows the dynamics of average yields per hectare for the main agricultural crops in Romania expressed in kilograms per hectare from 2015-2020. In order to determine the differences between 2020 and the rest of the time period, the relative differences between the last year and the average of 2015-2019 were established, as well as the relative differences between 2020 and 2019.

Regarding the differences between the last year and the average of the last five years, it is observed that the group of crops most affected was that of grain cereals where there was a decrease in average production per hectare of 29.7 percent. Analysis from the point of view of a single crop, the most affected, in 2020, was that of barley and barley, where the average production per hectare decreased by up to 36 percent. Among the analyzed crops there is only one exception, namely the hop crop whose average yield per hectare increased during the analyzed period by 21.3 percent, given the fact that this crop is quite rare in Romania, with declining areas, but in recent years it is on an upward trend and this can be seen in the average yield per hectare. On average in 2020 compared to the average of the last five years, respectively 2015-2019, the average yield per hectare for the entire range of crops decreased by about 19.8 percent.

The next proposed analysis was the one between the last two years, respectively 2020 compared to 2019, where there is an even sharper decrease in yields, given that 2019 was a very rich year from an agricultural point of view, one of the most prosperous years of the last decade. In this analysis it is observed that the yield of cereals decreased in the last year compared to the previous one by 37.7 percent, and the most affected crop was flax for oil whose yield decreased by up to 40 percent. Hop cultivation has a higher yield in 2020, compared to 2019, but lower than the average of the last five years, with an increase of only 13.7 percent. On average, reporting the last year, 2020, which was a fateful year from an agricultural point of view, in Romania, in the previous year and 2019, respectively, it can be considered that the yields for the entire structure of crops in Romania decreased by 20.4 percent.

Table 2: Statistical analysis of the difference between yields - t test

	Average of the last 5 years	***2020***
Mean	6310.525	5149.4375
Variance	92409689.54	67620327.6
Observations	16	16
Pearson Correlation	0.997467333	
Hypothesized Mean Difference	0	
df	15	
t Stat	3.041270826	
P(T<=t) one-tail	0.004124509	
t Critical one-tail	1.753050356	
P(T<=t) two-tail	0.008249018	
t Critical two-tail	2.131449546	

Source: author calculations using spreadsheet

To be able to demonstrate from a statistical point of view these differences and the fact that in 2020 there was a much lower yield per hectare than in 2019 or compared to the last five years, a statistical analysis of the difference between

averages was performed using the T test. Given that crop yields are kilograms per hectare as a unit of measurement, the average value in the previous table cannot be compared because two different crops cannot be added or overlapped, even if they are expressed in the same unit of measurement. However, the T test and the value of the parameter t State can be used compared to the value of the parameter t Critical in order to compare the averages and to validate or not the research hypotheses. It can be observed that the value t State of 3.04 is higher than the value C Ctritical of 2.15 corresponding to the 15 degrees of freedom, therefore it can be rejected with certainty the null hypothesis, namely the one in which the value of the averages would be equal. It is therefore demonstrated that there is a statistically significant difference between the two averages.

To identify the differences in yield over the main crops and between the main development regions of Romania (NUTS2) according to Eurostat, it was proposed to make a comparison between the average period 2015-2019 and 2020 for the most exploited crops in the last agricultural year table three.

Table 3: Determination of yield differences by main crops, by development regions (NUTS 2)

Crops	*Potatoes*			*Grain cereals*			*Sunflower*			*Rape*			*Soybeans*		
NUTS 2 (RO)	**Avrg. 2015-2019**	**2020**	**2020/ Avrg.**	**Avrg. 2015-2019**	**2020**	**2020/ Avrg.**	**Avrg. 2015-2019**	**2020**	**2020/ Avrg.**	**Avrg. 2015-2019**	**2020**	**2020/ Avrg.**	**Avrg. 2015-2019**	**2020**	**2020/ Avrg.**
BUCHAREST - ILFOV	10631	11443	7.6%	4701	3364	-28.4%	2207	2057	-6.8%	2289	2228	-2.7%	1485	3372	127.0%
CENTRU	21398	21565	0.8%	4615	4742	2.8%	2524	2365	-6.3%	2717	2560	-5.8%	2214	2004	-9.5%
NORD-EST	14488	12528	-13.5%	4496	3199	-28.9%	2327	1790	-23.1%	2151	1843	-14.3%	1799	1465	-18.6%
NORD-VEST	14897	14939	0.3%	4602	4870	5.8%	2469	2397	-2.9%	2400	2698	12.4%	2339	2255	-3.6%
SUD-EST	13536	12003	-11.3%	4794	1703	-64.5%	2467	1366	-44.6%	2399	1362	-43.2%	3106	2158	-30.5%
SUD-MUNTENIA	16007	17451	9.0%	5091	3075	-39.6%	2556	1977	-22.6%	2776	2181	-21.4%	2823	1696	-39.9%
SUD-VEST OLTENIA	13636	12091	-11.3%	4494	4080	-9.2%	2495	2209	-11.4%	2418	2502	3.5%	2022	1247	-38.3%
VEST	12512	11295	-9.7%	5484	4948	-9.8%	2712	2435	-10.2%	2850	2878	1.0%	2016	2115	4.9%

Source: author calculations based on NIS data, accessed (14th September, 2021)

Regarding the potato crop, comparing the yield registered in 2020, with the average of the period 2015-2019, oscillating differences can be observed between regions, depending on the geographical area, the level of precipitation and the climate related to the respective agricultural year. Of the eight development regions, four of them saw declines in yields, and four of them saw increases in yields. The Nord-Est region differs with the most significant decrease for the average potato production per hectare, registering a decrease of 13.5 percent in 2020, compared to 2015-2019, and the Sud-Muntenia region is notable for the increase in yield in 2020, compared to the average of the last five years, with an increase of 9 percent. On average, at national level, analyzing the eight development regions, the yield of potato cultivation in 2020 registered a decrease compared to the average of the last five years by 3.5 percent.

Regarding the grain cereals group, comparing the yield registered in 2020 with the average of the period 2015-2019, quite oscillating differences can be observed between the development regions, the dynamics being as follows. Of the eight development regions, six have a decrease in cereal yields, and two regions have seen an increase in average productivity per hectare. The most significant decrease is registered in the south-eastern region, for which the average production per hectare of grain cereals decreased by 64.5 percent. There is also a decrease in yield in the Sud-Muntenia region of almost 40 percent of the yield per hectare. In the Nord-Vest, there is an increase in grain yield of 5.8 percent. On average, at national level, analyzing the eight development regions, the yield of grain cereals in 2020, decreased by the average of the last five years by 21.5 percent.

For sunflower cultivation it is observed that in each of the eight development regions the yield in 2020, compared to the average period 2015-2019 decreased, with weights ranging from -2.9% to -44% in the southern region east, a region severely affected by pedoclimatic conditions. Carrying out a national average according to the eight development regions, it can be seen that the yield for sunflower cultivation has decreased in 2020, compared to the average of the last five years, by an average of 16 percent.

For rapeseed cultivation, out of the 8 development regions for five of them there is a decrease in yield per hectare in 2020 compared to the average of the period 2015-2019, and for three development regions there is an increase in yield. The Sud-Est region is noticeable with a decrease in yield for rapeseed cultivation of 43 percent, as well as the Sud-Muntenia region with a decrease in yield of 21.4 percent. Among the regions where there is an increase in yield, we mention the northwest region, where in 2020 there was an increase compared to the average of the last five years, of the production per hectare of rapeseed by 12 percent. On average at national level, there is a decrease in rapeseed production for all eight development regions of about 8.8 percent.

In terms of soybean cultivation, there has been a decline in yields in six of the eight development regions, and two regions have seen increases in yields. The most affected region was the Sud-Muntenia region where there was a decrease in yield by almost 40 percent in 2020 compared to the average of the last five years, and in terms of increasing yields the Vest region achieved a yield increase of 4.9 percent, but the Bucharest Ilfov region, due to certain irrigation systems and the fact that its surface is quite small and can be managed much easier, there was a very large sport doubling the production per hectare.

Table 4: Statistical analysis of the difference between yields, by development regions - t test

	Potatoes		***Grain cereals***		***Sunflower***		***Rape***		***Soy beans***	
	Avrg. 2015-2019	*2020*	*Avrg. 2015-2019*	*2020*	*Avrg. 2015-2019*	*2020*	*Avrg. 2015-2019*	*2020*	*Avrg. 2015-2019*	*2020*
Mean	14638	14164	4785	3748	2469	2075	2500	2282	2226	2039
Variance	10065387	13351220	117158	1268708	22702	132739	62790	243742	280062	417014
Observations	8	8	8	8	8	8	8	8	8	8
Pearson Correlation	0.942		0.124		0.377		0.507		-0.281	
Hypothesized Mean Difference	0		0		0		0		0	
df	7		7		7		7		7	
t Stat	1.06715		2.58203		3.30713		1.45204		0.55966	
P(T<=t) one-tail	0.16066		0.01818		0.00650		0.09490		0.29658	
t Critical one-tail	1.89458		1.89458		1.89458		1.89458		1.89458	
P(T<=t) two-tail	0.32132		0.03636		0.01299		0.18979		0.59316	
t Critical two-tail	2.36462		2.36462		2.36462		2.36462		2.36462	

Source: author calculations using spreadsheet

In order to study from a statistical point of view the level of significance of the differences between the yield averages in the 8 development regions, the student T tests were performed to identify for the eight development regions and for the five cultures taken into analysis, the value of the parameter t Stat.

Therefore, as can be seen from the previous table of the five crops analyzed only for two, the value of the parameter t Stat exceeds the t critical value, namely for sunflower crops and grain group for grains.

For the group of cereals for grains, a value of the parameter t Stat of 2.58 is registered, being higher than the value of the critical parameter t of 2.36 afferent to the 7 degrees of freedom, thus it can be established that between the average of the development regions from 2020 for cereal production and the average of the last five years for the eight regions there are statistically significant differences excluding the null hypothesis, namely that the averages may be the same.

In a similar case for the sunflower crop there is a value of the parameter t Stat 3.30 being higher than the value of the t critical parameter of 2.36 which means that the average of the development regions for the production of sunflower in 2020 is statistically significantly different from the average of the development regions for the last five years of analysis, thus excluding the null hypothesis that the differences between the averages would be zero.

Table 5: Precipitation dynamics by development regions in the last two agricultural years (mm)

Development regions	2018-2019	2019-2020
BUCURESTI - ILFOV	842.2	626
CENTRU	1137.6	758.1
NORD-EST	889.4	871.05
NORD-VEST	1446.9	943.75
SUD-EST	819.4	480
SUD-MUNTENIA	1083.25	682.75
SUD-VEST OLTENIA	1426.95	1078.3
VEST	935.5	947.65

Source: authors processing based on data http://rp5.co.uk, accessed (15th September, 2021)

To study the influence of precipitation on the average production per hectare for the main crops taken in analysis, it is necessary to statistically analyze the level of precipitation in the last two agricultural years, respectively 2018-2019 and 2019-2020, the year starting in October and ending in September.

From the analysis of the level of precipitation in these two years, for the eight development regions, it is observed that the level of precipitation was different as it is natural depending on the geographical area, relief, climatic conditions in that area, so for the year 2018-2019 precipitation varied between 842 mm per year (in the Bucharest Ilfov region) and 1427 mm per year in the Sud-Vest region. For the year 2019-2020, the precipitations in the eight development regions varied from 626 mm in the Bucharest Ilfov region to 1078 mm in the Sud-Vest region.

Table 6: Statistical analysis of the difference between precipitation, pre development regions - t test

	2018-2019	***2019-2020***
Mean	1072.65	798.45
Variance	62793.695	39017.64714
Observations	8	8
Pearson Correlation	0.682000338	
Hypothesized Mean Difference	0	
df	7	
t Stat	4.187852423	
P(T<=t) one-tail	0.002048497	
t Critical one-tail	1.894578605	
P(T<=t) two-tail	0.004096993	
t Critical two-tail	2.364624252	

Source: author calculations using spreadsheet

In order to study the difference between the levels of precipitation in 2019-2020 compared to 2018-2019, we used the analysis of the T test on the difference between the averages. It can be seen from the previous table that the value of the parameter t Stat is much higher than the value of the parameter t Critical so it can be seen that there are significant differences between the two averages, the difference between them cannot be zero, thus excluding the null hypothesis. Realizing a relative difference, it can be appreciated that, at national level, the difference between 2020 and 2019 was in fact a decrease in the level of precipitation by 25.6 percent.

Table 7: Analysis of the correlation coefficients (Pearson) between the precipitation level and the average yields per hectare

	2018-2019	*2019-2020*
2018-2019	1	
2019-2020	0.682000338	1
Potatoes 2019	0.211715841	x
Potatoes 2020	x	-0.106066423

Grains 2019	-0.170208897	x
Grains 2020	x	0.738605557
Sunflower 2019	0.323216987	x
Sunflower 2020	x	0.686490822
Rape 2019	0.247009805	x
Rape 2020	x	0.705813209
Soya 2019	-0.005506143	x
Soya 2020	x	-0.500910178

Source: author calculations using spreadsheet

The previous table determined the Person correlation coefficients between the level of precipitation and the level of average yield per hectare for the main agricultural crops sown in Romania in the last two agricultural years. Having previously established that the yields that have changed in the last year, statistically significant compared to the previous period were for cereals and sunflower crops, for which there was a correlation coefficient between -0.17 and 0, 73, and for sunflower cultivation 0.32 and 0.68. Therefore, it can be considered that in the agricultural year 2019-2020, for both cereals and sunflower crops, a correlation coefficient is significantly higher than 0.5, so the degree of influence between precipitation and production obtained is significant. We can consider the fact that the precipitation level and the average yield per hectare for these two crops are directly proportional in the reference year 2019-2020 for the eight development regions of Romania, when one of the values increases, the other will increase.

Table 8: Linear regression model between sunflower crop yield and precipitation level

Regression Statistics								
Multiple R	0.686491							
R Square	0.47127							
Adjusted R Square	0.383148							
Standard Error	286.1472							
Observations	8							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	437890.6	437890.6	5.347939	0.060058			
Residual	6	491281.4	81880.24					
Total	7	929172						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1063.5	448.7306	2.37002	0.055519	-34.5037	2161.504605	-34.50369004	2161.505
2019-2020	1.266203	0.547533	2.312561	0.060058	-0.07356	2.605966741	-0.073561349	2.605967

Source: author calculations using spreadsheet

In order to identify the degree to which the two variables increase, the previous table representing the linear regression model between the dependent variable was taken into account: average yield per hectare for sunflower culture and the independent variable: precipitation level in 2019-2020. Carrying out a similar model for the variables, the level of precipitation and the yield of cereals per hectare did not meet all the statistical criteria for the model to be representative.

Analyzing the first indicators in the model, the correlation coefficient is 0.68, a coefficient that describes the relationship between variables as tight to very tight, and R Sqare, respectively the coefficient of determination is 0.47, so the dependent variable is explained by the variable 47% independent.

The Anova table shows a value of parameter f of 5.34 slightly below the critical level f which leads to a significance f of 0.06 slightly exceeding the threshold of 0.05.

However, the value of the free land is very close to falling within the confidence interval, the value of P value being 0.55 very little above the critical value of 0.05, and the value of P value of the coefficient of X is 0.06 slightly above the standard value of 0.05.

The value of the coefficient of the dependent variable or the average production per hectare of sunflower is 1.266, so it can be considered that in 2020 in regions where the level of rainfall would increase by one unit the volume of agricultural production per hectare sunflower would increase by 1.26 units, in other words for a 1 mm increase in rainfall there would be an increase of 1.26 kilograms per hectare of sunflower.

Conclusions

We consider that the agricultural year 2019-2020 was a very challenging one for the Romanian agriculture, on the one hand starting the sanitary crisis, but with less important effects for the production sector, but registering an extreme drought in the southern part of the country, which greatly influenced the level of production per hectare.

Thus, in the present research we wanted to identify this influence of drought on average yields per hectare. Studying the dynamics of the latter, it can be seen that in 2020 there were lower productions by about 20% on average per hectare compared to previous periods, which is also demonstrated from a statistical point of view.

Analyzing at the level of development regions in Romania (NUTS2) and depending on the crops, there is a decrease in yields differently between depending on the geographical areas, but at the national level for all crops there was a decrease in yields. From a statistical point of view, it was shown that there were significant differences in yields between the last and penultimate year analyzed only for sunflower crops and the cereal group for grains.

Studying the level of precipitation in the last two agricultural years, a statistically significant difference could be noticed, in the last year registering an average of precipitation lower by 25% compared to the average of precipitation from the previous year.

Correlating the variables, respectively the precipitation level and the average yields, strong correlations were identified in the last year, by development regions, between the precipitation level and the yields for cereals and sunflower. Thus, when there were increases in rainfall in certain areas, there was also a higher yield of these crops in those areas.

Realizing the linear regression model between the precipitation level and the sunflower culture, it was possible to determine that the precipitation level influenced this crop in certain development regions, at national level establishing that if the precipitation level increases in certain regions by one unit the volume of production per hectare in those regions would also increase by 1.26 units.

Regarding the research limit, it should be noted that the linear regression model has a research limit, namely that in which the level of significance exceeds the accepted threshold of 0.05, thus, there is the possibility that at some point passing through the entire range reliable, the coefficient of the equation to have the value zero.

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