Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 20, Issue 4, 2020
PRINT ISSN 2284-7995, E-ISSN 2285-3952

VARIATION OF THE MAIN AGRICULTURAL CROPS YIELD DUE TO DROUGHT IN ROMANIA AND DOBROGEA REGION IN THE PERIOD 2000-2019

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Abstract

The research was focused on yields dynamics of the main agricultural crops: wheat, maize, barley, oats, sunflower and rape recorded in Romania and especially in Dobrogea region in =order to identify in what measure they were affected by climate change, mainly by drought in two decades: 2000-2009 and 2010-2019. For this purpose, there were calculated the negative deviations of yield in each year from the average of each decade, and also the differences between the average decade yield in Dobrogea region and at the country level. The results proved substantial negative deviations for almost all the crops compared to the decade averages, and a smaller production performance in Dobrogea region versus yield level in Romania. All these differences were caused by the change in climate factors: the increased air temperature, low of lack of precipitations, low or lack of water resource into the soil, which characterize the severe and strong droughts with which Romania, and mainly Dobrogea region were facing during the last 20 years. In order to reduce the economic, social and environmental impact of droughts, the authorities have to develop sustainable strategies in order to support agriculture with irrigation systems and other measures of protection (financial aid to cover losses, tax exemption, extending the terms of repayment of the debts etc), and farmers have to continue their efforts for adapting the technologies cultivating high production potential varieties and hybrids resistant to drought, diseases and pests, choosing the right moment and depth for sowing, fertilization level and plant protection. Only in this way, farmers could obtain a production performance able to cover costs and assure profitableness of their business.

Key words**:** *agricultural crops, yields, climate change, drought impact, Dobrogea region, Romania*

INTRODUCTION

Crop production depends on a large range of factors among which the most important are: crop type, variety and hybrid, soil type and its fertility level and water reserve capacity, applied technologies systems (irrigated or not), climate factors.

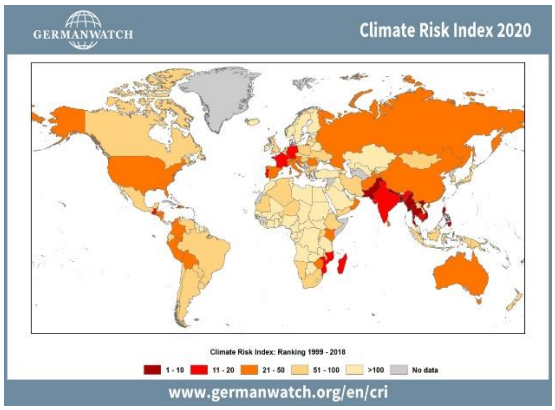
If all the technological factors are assured but weather conditions are not favorable, agricultural yield could register deviations from the crop potential with damages and losses for farmers' business.

If weather conditions are not suitable to each crop at the key moments of the year, they could affect plant development along various vegetation stages and production.

Heavy spring frosts at blossom time, spring and summer droughts of high intensity and length, heat waves, strong winds, strong storms, heavy rainfall, hail, and floods during the period of vegetation and harvesting could diminish or destroy agricultural production, produce damages and economic losses [10].

At the global level, climate change is more and more visible affecting both the emerging economies, and the developed ones, people's life and environment. The Global Climate Risk Index (CRI-2020) presents the actual situation of the countries where climate

extreme phenomena like heat waves, severe droughts, huge rainfalls and floods, storms and tornados etc have had a deep influence (Map 1) [4].



Map 1. Climate Risk Index 1999-2018
Source: [4].

That is why all the countries are interested to set up strategies with clear objectives, activities and measures destined to adapt to climate change, to reduce its negative economic, social and environment impact.

Grace to the technical progress in studying the weather events and providing forecasts, agro-meteorological information has become an useful tool to prevent farmers to adapt the agricultural technologies to climate change so that damages and losses to be at minimum or to be completely avoided [5].

By its geographical position, Romania is exposed to extreme weather conditions like heat waves, drought, floods, storms, hail etc which cause huge losses and damages in agriculture, but also in human life, affect vegetation and animal resources, ecosystems and seasons.

About 30-50% of agricultural production has been lost from 7 million ha representing 48% of 14.87 million ha agricultural land in Romania during the last decade [33, 5].

The most affected parts of Romania are South West Oltenia, South Muntenia, South East and East, where climate change, mainly droughts are strong and severe, and a trend of aridity and desertification has been noticed in many regions, but mainly in Oltenia and Dobrogea where the fluctuation of the climate factors has led to the variation of the agricultural production from a year to another.

During the last decades, high air temperatures, reduced rainfalls, a high deficit of water reserve into the soil in summer season and even in autumn have become more frequent, affecting the vegetation phases and crop productions, making farmers who have not irrigation systems to be aware that they will harvest a low output which will not cover costs by selling their products, and debts to banks and leasing companies. Also, the deficit of production will affect food security of the population and increase imports to cover the consumption needs [6].

The expectations for the future for Romania are similar to the forecast for Europe, that in 2020-2029 horizon, the deviation of temperature will range between $+0.5^0$C and 1.5^0C and for 2090-2099, it will vary between 2^0C and 5^0C [2].

Also, the precipitations are expected to decrease by 20% in the period 2090-2099 horizon compared to 1980-1990 [33, 6].

These scenarios are an "alarm bell" or a "red flag" for any country to set up strategies for adapting to climate change.

During the period 1901-2019, Romania was facing an increasing trend regarding the annual average temperature and a decreasing trend concerning the annual average precipitations, and this was noticed especially in the South, South East and East regions during the last 35 years.

The frequency of severe droughts and for longer periods has increased affecting almost year by year agricultural production performance.

The year 2015 was considered the warmest year with an increase of $+1.96^0$C compared to the average temperature during 1961-1990.

In the period 2000-2015, based on the average level of temperature, the hierarchy of the years with the highest temperature is the following one: 2015, 2007, 2014, 2012, 2013, 2009, 2008, 2000, 2002, 2010,2001, 2011, 2004, 2006, 2003 and 2005 [11].

The deviation of the average temperatures ranged between $+1.35^0$C, the lowest one, registered in the year 2002 and $+1.96^0$C, the highest one, recorded in the year 2015 (Table 1).

Table 1. The additional air temperature to the annual average temperature registered in the period 1901-2015 in Romania

	2015	2007	2014	2012	2013	2009	2008	2000	2002
Average air temperature ^{0}C	11.6	11.5	11.5	11.1	11.1	11.1	11.1	11.0	11.0
Deviation ^{0}C	+1.96	+1.87	+1.86	+1.54	+1.52	+1.48	+1.46	+1.39	+1.35

Source: [11].

The extreme droughts were registered in the following years of the period 2000-2020: 2000-2001, 2001-2002, 2002-2003, 2006-2007, 2008-2009, 2011-2012, 2014-2015, 2016, 2018, 2019 and 2020.

The year 2019 was completely different, and considered by the experts "the warmest year since measurements are made in Romania, that is during the last 140 years since 1900 till present" [11, 10, 12].

Agricultural drought is characterized by the increase of temperatures, the decline of rainfalls and by the deficit of soil water, this phenomenon lasting usually for a longer period than two weeks. However, the period of drought, the size of the affected surfaces, the temperature and precipitations level vary from a region to another, a country to another, In 2019, the drought started in spring and continued in summer and fall, and even in winter, then in spring, summer and autumn of the year 2020 as never before [12].

Dobrogea region has a high level of drought risk as in this part of Romania, the annual average temperature is over 11^{0}C and the rainfalls vary between 351 and 450 mm/year in average, while Moldova and Muntenia regions have a medium risk of drought as the rainfalls here vary between 451-600 mm/year. Oltenia, Crisana, Transilvania and Banat have a low risk of drought level as the precipitations range between 601-800 mm/year, while Maramures is the only region with the lowest risk of drought as here precipitations exceed 800 mm per year (Table 2).

Table 2. Annual average rainfalls and risk drought level in Dobrogea compared to other regions of Romania during the period 1981-2010 (mm)

Region	Average annual precipitations (mm)	Deviations in Dobrogea compared to the other regions		Precipitation level (mm)	Risk drought level
		(mm)	%		
Dobrogea	412	-	-	351-400	High level
Moldova	575.9	-163.9	-28.5	451-600	Medium level
Muntenia	575.7	-163.7	-28.5		
Oltenia	645.8	-233.8	-36.3	601-800	Low level
Crisana	668.4	-256.4	-38.4		
Transilvania	680	-268	-39.5		
Banat	737.8	-325.8	-44.2		
Maramures	829.1	-417.1	-50.4	Over 800	Very low

Source: Own calculations based on [11].

In this context, the paper objective was to analyze the evolution of agricultural yields during the last two decades, 2000-2009 and 2010-2019 and to identify the absolute deviation of production caused by climate change, especially by drought which is the main climate factor which affects agricultural production. The yield produced in each year of the chronological series was compared with the decade average to quantify the variation of production both at Romania's level and in Dobrogea region, which is the most affected area by drought in the country. Also, the average yields carried out in Dobrogea region for the two decades 2000-2009 and 2010-2019 for wheat, maize, barley and oats, as well as for sunflower and rape were compared to the average yields at the national level in order to assess the decrease or losses of production.

MATERIALS AND METHODS

The study is based on the available data picked up from the National Institute of Statistics, Tempo Online data base for the period 2000-2019, and also from the Statistical Divisions of Constanta and Tulcea Counties for the year 2018 available on their sites.

The period of research was chosen to include the warmest years as mentioned by [11, 12].

The main agricultural crops for which yield levels were studied in the warmest years have been: wheat, maize, barley, oats, sunflower and rape.

The main indicators calculated in this study have been the following ones:

(i) The average of crop yield for the decade 2000-2009 and 2010-2019 in Romania;

(ii) The average of crop yield for the decade 2000-2009 and 2010-2019 in Dobrogea region

(iii)The absolute difference between yield level in n year (n= 1,2,...10) and the average yield determined for the decade 2000-2009, and respectively for the decade 2010-2019 in Romania;

(iv)The absolute difference between yield level in n year (n= 1,2,...10) and the average yield determined for the decade 2000-2009, and respectively for the decade 2010-2019 in Dobrogea region;

(v)The difference between average yield registered in the decade 2010-2019 and in the decade 2000-2009 in Romania;

(vi) The difference between average yield registered in the decade 2010-2019 and in the decade 2000-2009 in Dobrogea region.

The formulas used in this study have been:

The average value of agricultural crop in each decade was determined based on the formula:

$\bar{y}=\frac{\sum_{t=1}^{n} yt}{n}$

Absolute differences between crop yield and the decade average, $\Delta = y_n - \bar{y}$

Mean at the decade level, $\bar{Y} = \frac{\sum_{1}^{n} y_i}{n}$

The differences between the average level of yield in the decade 2020-2019 and the average level of yield in the decade 20020-2009 were determined as follows:

$\bar{y} = \bar{y}decade\ 2020-2019 - \bar{y}\ decade\ 2009-2000$

The results were illustrated in tables and graphics, being accompanied by comments and finally the main conclusions have been drawn.

RESULTS AND DISCUSSIONS

Romania's agriculture - A brief statistical overview in 2019

Romania is situated in the Eastern part of Europe and has a harmonized territorial structure from a geographical point of view characterized by three relief forms with a shape of amphitheater distributed in the same proportionof 33% between mountains, hills and plains.

Romania's surface is 238,390 km^2, and its climate is a temperate continental one with a few Mediterranean influences.

Agricultural land is 14.63 million ha, representing 61.36% of the country surface, while an arable land which accounts for 8,737,275 ha representing 93,34% of the cultivated area.

The main agricultural crops cultivated in Romania are cereals, which occupy 5.57 million ha, representing 63.8% of the total cropped area, oil seeds plants which cover 1.80 million ha (20.5%), forage plants which are cultivated on 0.9 million ha (10.3%), vegetables are cultivated on 0.23 million ha (2.63%), leguminous plants on 0.12 million ha (1.36%) and other crops.

Romania produces a large variety of agricultural products both of vegetal and animal origin (from cattle, pigs, sheep, goats, poultry), but mainly cereals and oil seeds.

Of the 5.57 million ha cultivated with cereals, maize comes the 1st with 2.68 million ha (48.11%), followed by wheat with 2.17 million ha (38.95%), barley and two-row barley 0.45 million ha (8.07%), oats 0.16 million ha (2.87%) and the remaining others (Sorghum etc) [18, 21, 22, 25, 30].

Of the 1.8 million ha cropped with oil seeds plants, 1.28 million ha are represented by sunflower (71.11%), 0.35 million ha by rape

(19.44%) and 0.16 million ha by soybean (8.88%) [16, 17].

Agricultural production is mainly represented by cereals which achieved 30.41 million tons, of which maize grains 17.43 million tons (57.31%), wheat 10.3 million tons (33.87%), barley and two- row barley 1.88 million tons (6.18%) [26, 23].

Also, oil seeds production accounted for 3.57 million tons, of which sunflower seeds 3.57 million tons (74.53%), rape seeds 0.80 million tons (16.7%), and the remaining soybean seeds [27, 28, 29].

Also, Romania produced 3.53 million tons of vegetables.

In 2018, agricultural production value accounted for Lei 86,349 million, of which vegetal production Lei 61.22 million (70.89%) and animal production Lei 23.9 million (27.67%).

Of 8,634.7 thousand persons occupied population in Romania, 1,919.6 thousand are dealing with agriculture, forestry and fishing, representing 22.23% [19, 21].

Agriculture contribution to GDP was Lei 37 billion in 2017, meaning 4.3% of Romania's GDP (Lei 857.89 billion) [24, 13].

In 2019, Romania achieved Lei 1,059.9 billion GDP, to which agriculture contributed by 4.2% [15].

In 2019, Romania's GDP accounted for Euro 223 billion, contributing by 1.6% to the EU-27 GDP (Euro 13,900 billion), for which Romania comes on the 14th position among the members states [3].

Variation of yield for the main agricultural crops in Romania in the warmest years during the last two decades (2000-2019)

In the period 2000-2019, *wheat yield* registered the highest level of 4,888 kg/ha in the year 2017 and the lowest one of 1,429 kg/ha in 2003. However, in 2019, wheat yield was 4,749 kg/ha 2.07 times higher than in the year 2000. Looking at the chronological series, it is easily to identify the decline of yields in the years: 2003, 2007, 2002, 2000, 2009, 2012, 2010, the decreasing hierarchy of these years being established in accordance with the production deviation compared to the average yield in each decade, 2000-2009 and, respectively, 2010-2019. The decline of yield was considered due to climate change and especially to drought (Fig. 1).

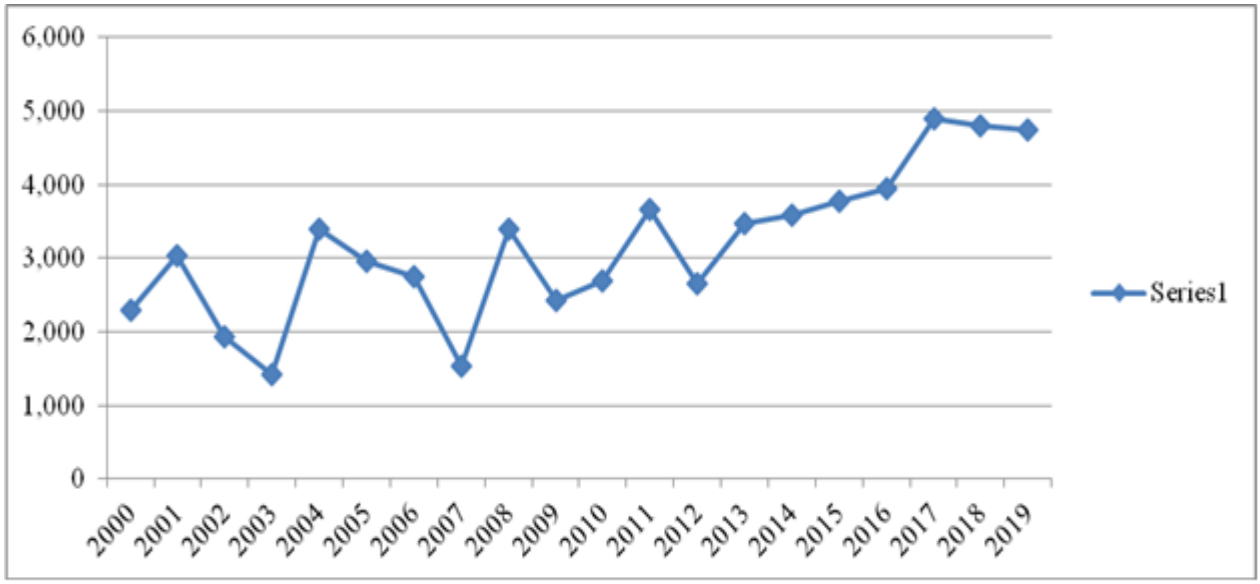


Fig. 1. Dynamics of wheat yield in Romania, 2000-2019 (kg/ha)
Source: Own design based on the data from [13].

In the analyzed interval, *barley and two-row barley yield* varied between 1,461 kg/ha in 2007, the lowest level, and 4,417 kg/ha in 2018, the highest level. In 2019, barley produced 4,188 kg/ha, that is 1.98 times more than in the year 2000. The years with the decline in barley yield according to the intensity and length of drought, in the

decreasing order of production decline, were: 2007, 2003, 2002, 2000, 2009, 2012, 2010 (Fig. 2).

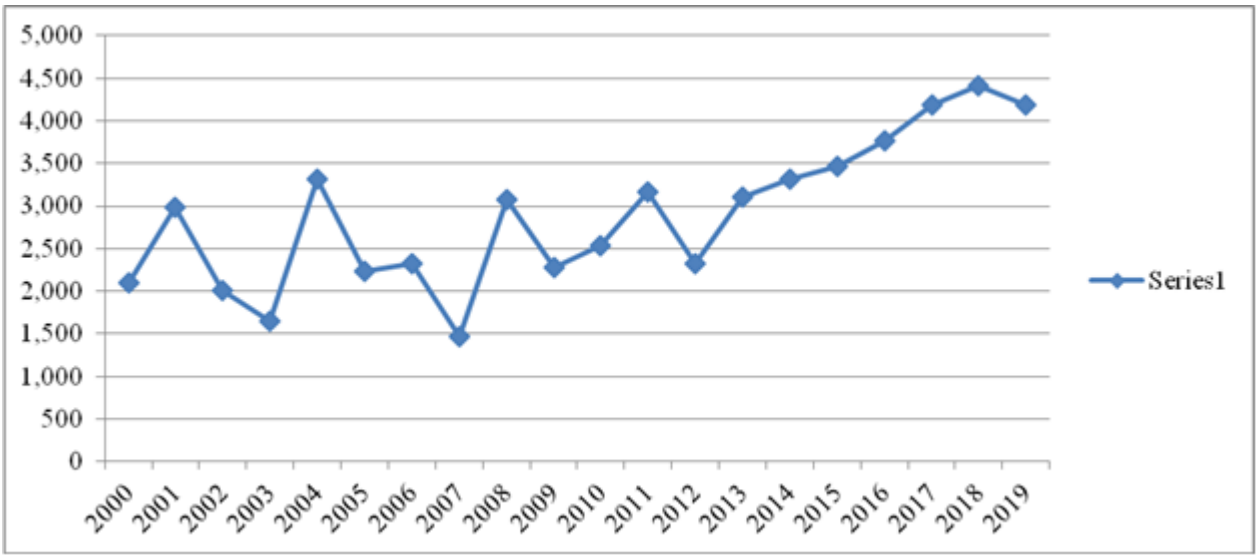


Fig. 2. Dynamics of barley and two-row barley yield in Romania, 2000-2019 (kg/ha)
Source: Own design based on the data from [13].

In case of *oats*, yield ranged between 1,050 kg/ha in the year 2000, the lowest level, and 2,460 kg/ha in the year 2017, the highest record. In 2019, oats yield accounted for 2,243 kg/ha, meaning 2.13 times more than in the year 2000. The most critical years when drought affected oats performance have been in the descending order: 2000, 2007, 2003, 2002, 2009, 2010 and 2015 corresponding to the ascending loss of production (Fig. 3).

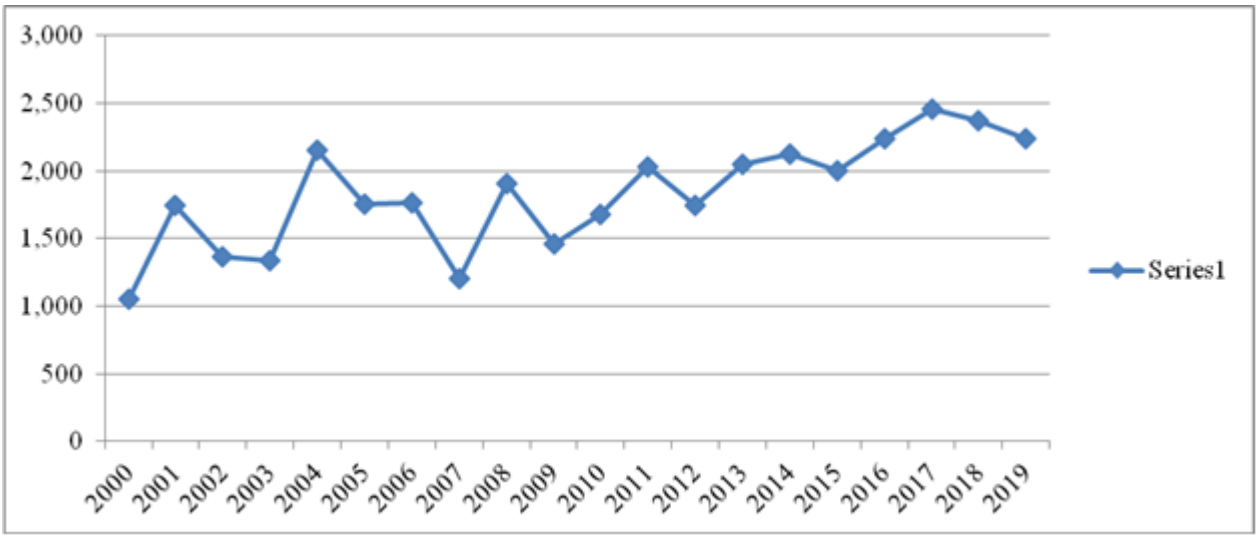


Fig. 3. Dynamics of oats yield in Romania, 2000-2019 (kg/ha)
Source: Own design based on the data from [13].

Maize registered the lowest yield, which accounted for 1,526 kg/ha in the year 2007, and the highest one of 7,644 kg/ha in 2018. But, in 2019, maize produced 6,502 kg/ha by 1,142 kg less than in the previous year, but 4.05 times more than in the year 2000. The most difficult years for maize crop, when drought caused a deep decline of production, were: 2007, 2000, 2012, 2002, 2003, 2015, 2019, the years being arranged in the increasing order of the yield loss (Fig. 4).

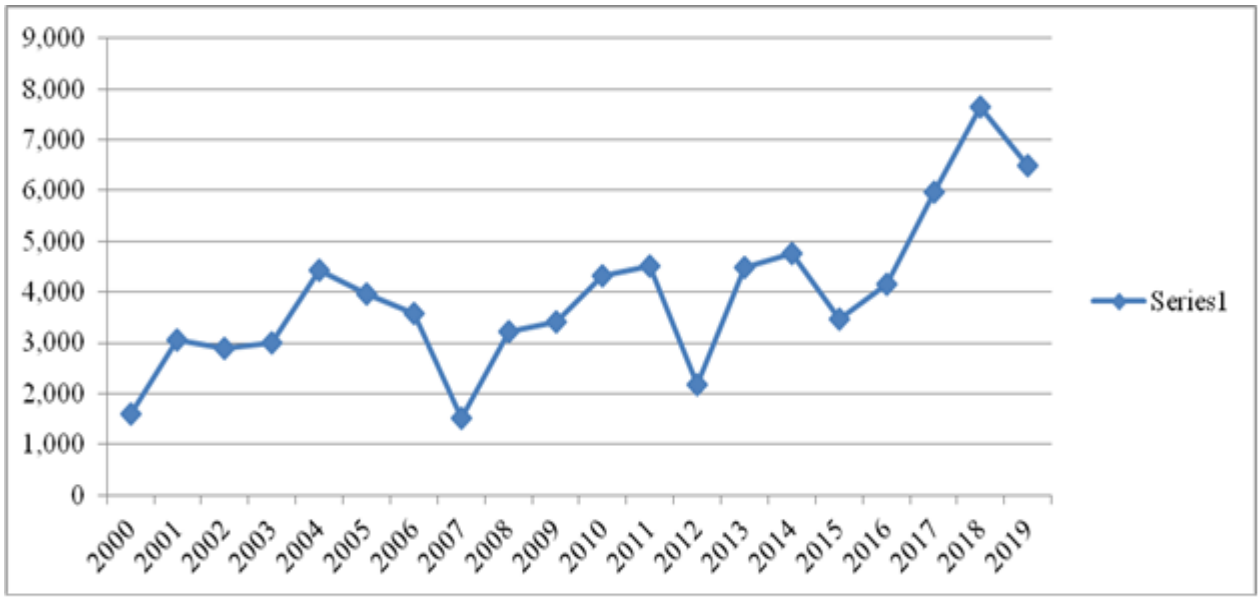


Fig. 4. Dynamics of maize yield in Romania, 2000-2019 (kg/ha)
Source: Own design based on the data from [13].

Sunflower registered the lowest production level per surface unit, 654 kg in the year 2007 and the highest one, accounting for 3,041 kg/ha in the year 2018. In 2019, sunflower yield was 2,783 kg/ha, 3.38 times higher than in the year 2000. The droughty years 2007, 2000, 2001, 2002, 2012, 2010, 2015 and 2019 were considered responsible for the loss of production (Fig. 5).

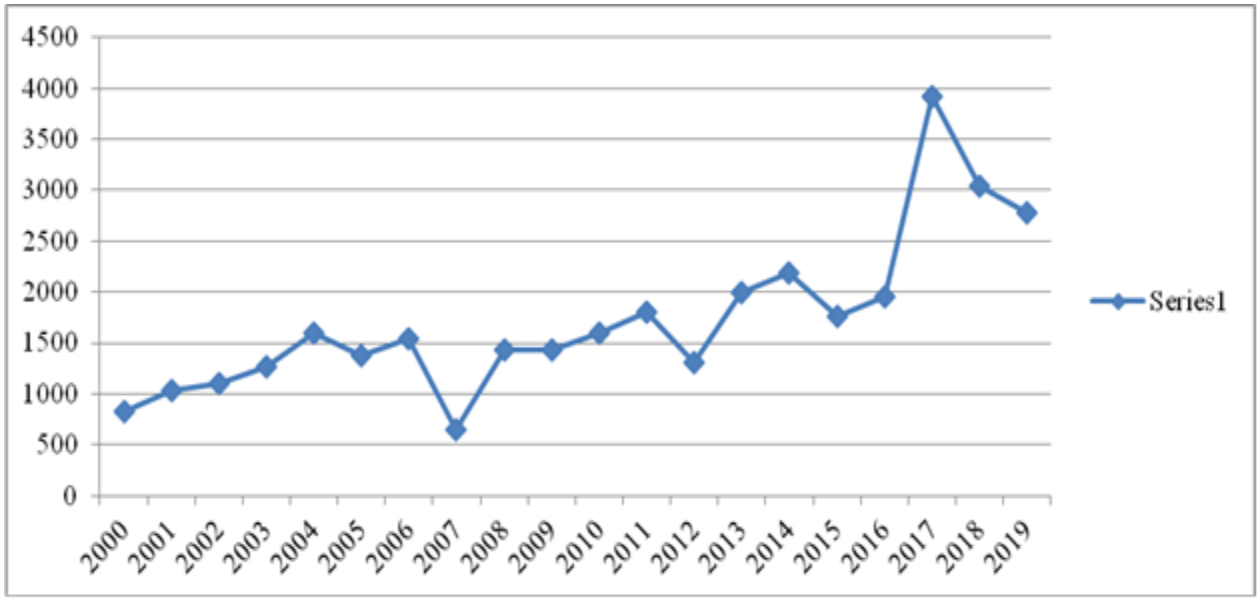


Fig. 5. Dynamics of sunflower yield in Romania, 2000-2019 (kg/ha)
Source: Own design based on the data from [13].

Rape yield ranged between 473 kg/ha, the minimum performance registered in 2003 and 2,835 kg/ha, the highest level recorded in the year 2016. In 2019, rape produced 2,264 kg/ha, 2.03 times more than at the beginning of the analyzed period, that is in the year 2000. The most droughty years for rape crop, arranged in the increasing order of the loss of production, were: 2003, 2002, 2007, 2000, 2012, 2010, 2019 and 2015 (Fig. 6).

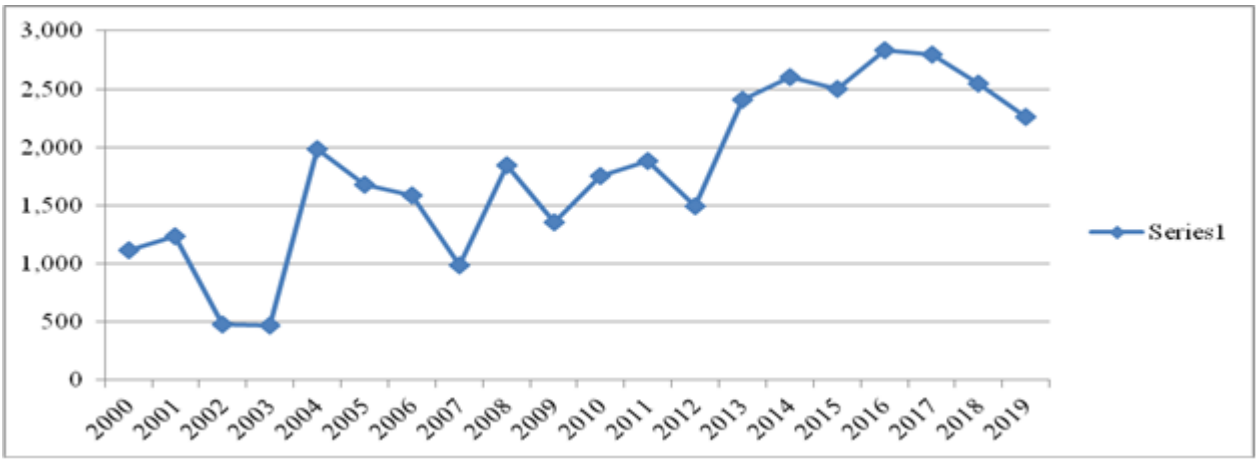


Fig. 6. Dynamics of rape yield in Romania, 2000-2019 (kg/ha)
Source: Own design based on the data from [13].

The evolution of yields and the losses of yields due to the droughts are presented in Table 3 and 4.

Table 3. The evolution of cereals yields and of the yield losses due to the droughts in Romania in the decades 2000-2009 and 2010-2019 (kg/ha)

Year	Yield (kg/ha)				Yield deviations from the average yield in the decade 2000-2009 (kg/ha)			
	Wheat	Barley and two-row barley	Oats	Maize	Wheat	Barley and two-row barley	Oats	Maize
2000	**2,286**	**2,105**	**1,050**	**1,603**	+12.5	-237.3	-524	-1,464.2
2001	3,038	2,988	1,743	3,066	+764.5	+645.7	+169	-1.2
2002	**1,924**	**2,005**	**1,368**	**2,902**	-349.5	-337.3	-206	-165.3
2003	**1,429**	**1,641**	**1,334**	**2,993**	-844.5	-701.3	-240	-74.2
2004	3,403	3,312	2,154	4,441	+1,129.5	+969.7	+580	+1,373
2005	2,965	**2,227**	1,757	3,952	+691.5	-115.3	+183	+884.8
2006	2,746	**2,331**	1,763	3,565	+472.5	-11.3	+189	+497.8
2007	**1,541**	**1,461**	**1,206**	**1,526**	-732.5	-881.3	-368	-1,541.2
2008	3,403	3,069	1,906	3,215	+1,129.5	+726.7	+332	+147.8
2009	2,421	**2,284**	**1459**	3,409	+147.5	-58.3	-115	+341.8
Average decade yield	**2,273.5**	**2,342.3**	**1,574**	**3,067.2**	-	-	-	-
	Yield (kg/ha)				Yield deviations from the average yield in the decade 2010-2019 (kg/ha)			
2010	**2,688**	**2,542**	**1,679**	4,309	-1,133.5	-907.2	-247.3	-490.8
2011	3,663	3,170	2,028	4,525	-158.5	-279.2	+101.7	-274.8
2012	**2,652**	**2,325**	**1,743**	**2,180**	-1,169.5	-1,124.2	-183.3	-2,619.8
2013	3,468	3,111	2,051	4,488	-353.5	-338.2	+124.7	-311.8
2014	3,590	3,319	2,124	4,770	-231.5	-130.2	+197.7	-29.8
2015	3,780	3,461	1,999	**3,462**	-41.5	+11.8	+72.7	-1,337.8
2016	3,944	3,773	2,239	**4,159**	+122.5	+323.8	+312.7	-640.8
2017	4,888	4,186	2,460	5,959	+1,066.5	+736.8	+533.7	+1,159.2
2018	4,793	4,417	2,376	7,644	+971.5	+967.8	+449.7	+2,844.2
2019	4,749	4,188	2,243	6,502	+927.5	+738.8	+316.7	+1,702.2
Average decade yield	**3,821.5**	**3,449.2**	**1,926.3**	**4,799.8**				

Source: Own calculation based on the data from [13].

Table 4. The evolution of oil seeds yields and of the yield losses due to the droughts in Romania in the decades 2000-2009 and 2010-2019 (kg/ha)

	Yield (kg/ha)		Yield deviations from the average yield in the decade 2000-2009 (kg/ha)	
	Sunflower	Rape	Sunflower	Rape
2000	**821**	**1,113**	-405.3	-161.9
2001	**1,029**	**1,235**	-197.3	-39.9
2002	**1,105**	**481**	-121.3	-793.9
2003	1,268	**473**	+41.7	-801.9
2004	1,595	1,984	+368.7	+709.1
2005	1,381	1,681	+154.7	+406.1
2006	1,540	1,590	+313.7	+315.1
2007	**654**	**991**	-572.3	-283.9
2008	1,437	1,844	+210.7	+569.1
2009	1,433	1,357	+206.7	+82.1
Average decade yield	**1,226.3**	**1,274.9**	-	-
	Yield (kg/ha)		Yield deviations from the average yield in the decade 2010-2019 (kg/ha)	
2010	**1,597**	**1,755**	-537.6	-553.7
2011	**1,798**	**1,882**	-336.6	-426.7
2012	**1,310**	**1,496**	-824.6	-817.7
2013	**1,993**	2,408	-141.6	+99.3
2014	2,187	2,604	+52.4	+295.3
2015	**1,765**	2,499	-369.5	+190.3
2016	**1,955**	2,835	-179.6	+526.3
2017	2,917	2,798	+782.4	+489.3
2018	3,041	2,546	+906.4	+237.3
2019	2,783	**2,264**	+648.4	-44.7
Average decade yield	**2,134.6**	**2,308.7**		

Source: Own calculation based on the data from [13].

However, in the last two decades, the general trend of the yields in case of all these crops is an ascending one at the country level, reflecting the positive impact of the strategies of agriculture development in Romania, mainly after its accession into the EU, and the EU support for sustaining this sector (Table 5).

Table 5. Comparison between the average yields for the main agricultural crops in the period 2010-2019 and the period 2000-2009 in Romania (kg/ha)

		Wheat	Maize	Barley	Oats	Sunflower	Rape
1	Average yield 2010-2019	3,821	4,799.8	3,449.2	1,926.3	2,134.6	2,308.7
2	Average yield 2009-2010	2,273.5	3,067.2	2,342.3	1,574	1,226.3	1,274.9
3	Difference 3= 1-2	+1,548	+1,732.6	+1,106.9	+352.3	+908.3	+1,033.8
4	2010-2019/ 2000-2009 (%)	+68	+56	+47.2	+22.3	+74	+81

Source: Own calculation.

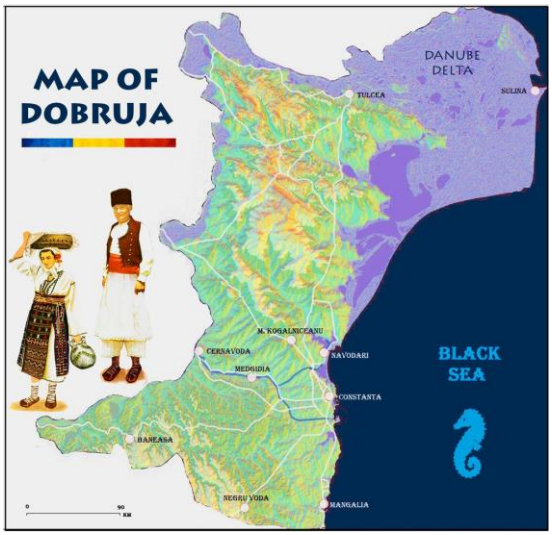
Dobrogea's agriculture - A brief statistical overview

Dobrogea region consists of two counties, Constanta and Tulcea. Its surface is 15,570 km^2, of which 7,071 km^2 (45.4%) Constanta County and 8,499 km^2 (54.6%) Tulcea County.

The population of the region was 997,792 inhabitants on January 1st, 2020, of which 763,549 inhabitants (76.5%) in Constanta

county and 234,243 inhabitants (23.5%) in Tulcea county.

The soils in Dobrogea are in general represented by chernozem, clay, sandy, and alluvial soils.



Map 2. Dobrogea map
Source: [1].

Dobrogea region is included in the warm and droughts 1st agro-climate zone, characterized by high temperatures and low precipitations compared to other regions of Romania.

Average annual temperature is over 11^0C, sun radiation ranges between 128-136 kcal/cm^2/year and the length of sunshine varies between 2,275-2,350 hours/year.

The amount of precipitations is low, usually varying between 350-400mm/year and their incidence is commonly noticed at the end of Spring and the beginning of Summer.

Dobrogea climate is an accentuated continental climate with hot and dried summers and winters with strong winds.

During the last decades, Dobrogea region is more and more affected by drought of high intensity and long length with a negative effect on agricultural productions. Even a tendency to aridity was also noticed during the last five decades [31, 32].

The year 2019 was characterized by a long period of drought which lasted from spring 2019 and continued along the whole year till late in autumn. The low precipitations in winter and spring season 2020 have led to an extreme pedological drought for the depth 0-100 cm into the soil. The water reserve in the soil layer of 0-20 cm was missing, so that winter crops were compromised in the farms lacked of irrigation systems. In the agricultural year 2019-2020, the pedological drought affected in different proportions cereals and other crops in this part of the country, but also at the national level [14].

Agriculture is one of the main economic sectors in Dobrogea region, grace to its surface suitable for this purpose, accounting for 922,145 ha, representing 59.2% of the region area. However, in Constanta County, agricultural land is 558,204 ha with a share of 78.9% in the county surface, while in Tulcea County, agricultural land is only 363,841 ha, representing 42.8% of its surface, as the county includes the Biosphere Reservation of the Danube Delta, the largest in Europe and belonging to the UNESCO patrimony.

The arable land in Dobrogea region is 778,991 ha, of which 484,103 ha in Constanta County (62.1%) and 294,888 ha (37.9%) in Tulcea County.

The cultivated surface is 741,538 ha at Dobrogea level, representing 95.1% of its total surface. In Constanta County, 474,343 ha and in Tulcea County 267,195 ha are cultivated.

The main crops are: cereals: wheat, maize for grains, barley and two-row barley, oats, oils seeds crops: sunflower, rape, soybean and their share in the cultivated area is 79.46% in Dobrogea region, 80.19% in Constanta County and 78,15% in Tulcea County (Table 6).

Cereals occupy the top position in agricultural production. In 2018, Dobrogea region achieved 2,722,333 million tons cereals, of which 66.18 in Contanta county and 33.82% in Tulcea county.

Wheat comes the first among cereals, its output accounting for 1,406,343 tons at Dobrogea level, of which 72.38% was registered in Constanta County and 27.62% in Tulcea County. Wheat has the highest share among cereals: 51.6% in Dobrogea, 56.5% in Constanta county and 42.17% in Tulcea county.

Maize for grains comes on the 2nd position as importance in Dobrogea region which obtained 887,220 tons, that is 32.52% of the total cereal production. In Constanta county, maize accounts for 25.37% in cereal production, while in Tulcea county for 46.71%.

Barley is ranked the third, contributing to cereal production of Dobrogea region by 14.57%, by 16.92% in Constanta county and by 9.96% in Tulcea county (Table 6).

Table 6. Dobrogea region- a brief statistics of agriculture

	Dobrogea region	Constanta County	Tulcea County	Share in Dobrogea region (%)	
Agricultural land (ha)	922,145	558,204	363,941	60.5	39.5
Arable land (ha)	778,991	484,103	294,888	62.1	37.9
Value of agricultural production (Lei Million), of which:	4,753,629	2,929,186	1,824,443	61.6	38.4
Value of vegetal production (Lei Million)	3,777,967	2,377,863	1,400,104	62.9	37.1
Share of vegetal production in agricultural production value (%)	79.5	81.1	76.4	-	-
Cultivated area (ha)	741,538	474,343	267,195	63.9	36.1
Share of cultivated area in agricultural land (%)	80.4	84.9	73.4	-	-
Cultivated area with the main crops (ha)					
Wheat (ha)	260,649	175,998	84,651	67.5	32.5
Barley (ha)	88,173	65,088	23,085	73.8	26.2
Maize (ha)	106,803	58,045	48,758	54.3	45.7
Sunflower (ha)	133,712	81,318	52,394	60.8	39.2
Share of the crops in the cultivated area (%)					
Wheat	35.14	37.10	31.68	-	-
Barley	11.89	13.72	8.63	-	-
Maize	14.40	12.23	18.24	-	-
Sunflower	19.03	17.14	19.60	-	-
Total crops	79.46%	80.19	78.15		
Crop production (tons)					
Cereals (tons)	2,722,333	1,801,684	920,649	66.18	33.82
- Wheat and rye	1,406,343 (51.6%)	1,018,032 (56.5%)	388,311 (42.17%0	72.38	27.62
-Barley and two-row barley	396,791 (14.57%)	305,018 (16.92%)	91,773 (9,96%)	76.87	23.13
-Oats	21,297 (0.80%)	18,184 (1.00%)	3,613 90.39%)	83.42	16.58
-Maize for grains	887,220 (32.52%)	457,152 (25.37%0	430,068 (46.71%)	51.52	48.48
-Sunflower	477,329	296,518	180,811	62.12	37.88
-Rape	164,462	102,463	61,999	62.30	37.70

Source: Own calculations based on the data from [34, 35].

Oats is ranked the 4th, its contribution to cereal production being small, just 0.80%.

Sunflower is the most important oil seeds crop, its production being 477,329 tons, of which 62.12% being produced in Constanta County and 37.88% in Tulcea County.

Rape production accounted for 164,462 tons at Dobrogea level, of which 62.3% in Constanta county and 37.7% in Tulcea county (Table 6).

Therefore, the share of the main crops cultivated area in Dobrogea in the cultivated area in Romania is: 12.31% for wheat, 4.37% for maize for grains, 20.82% for barley and 13.27% for sunflower.

The contribution of Dobrogea region to agricultural production in Romania is 13.86% for wheat and rye, 20.89% for barley and two-row barley, 4.75% for maize, 5.55% for oats, 15.58% for sunflower and 10.20% for rape,

and this reflects how important is Dobrogea region in Romania's agriculture.

Variation of crop yield in Dobrogea region in the warmest years in the period 2000-2019

Wheat yield varied between 296 kg/ha in 2003, the year which affected the most this crop in Dobrogea, and 3,477 kg/ha, the highest production level registered in the year 2008, which was the most favorable year in the decade 2000-2009.

Other decreases were recorded in 2007, 2009, 2001, 2002, years in which yields were below the average yield in this decade.

In the decade 2010-2019, compared to 3,713.4 kg/ha average yield recorded in this period, wheat yield achieved lower performances in 2012, 2010, 2013, 2014, considered the unfavorable years for this crop (Fig. 7).

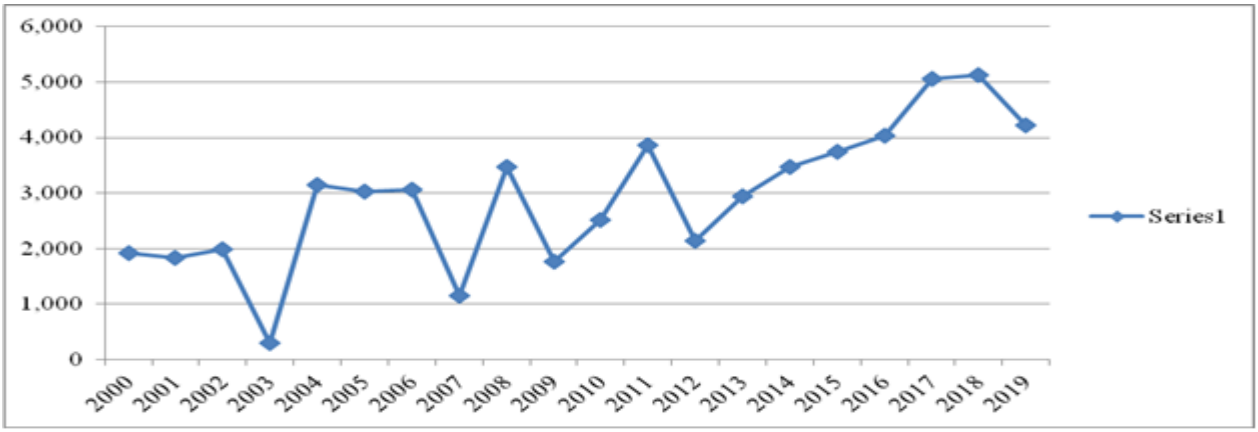


Fig. 7. Dynamics of wheat yield in Dobrogea region of Romania, 2000-2019 (kg/ha)
Source: Own design based on the data from [13].

Barley and two-row barley registered an average production of 1,952 kg/ha in the decade 2000-2009, yield levels ranging between 932 kg/ha in 2007, the smallest production, and 3,030 kg/ha in 2008, the highest one. The unfavorable years for this crop, taking into account the hierarchy of the losses, were 2007,2003,2005,2000.

In the decade 2010-2019, the average production was 3,281 kg/ha with variations between the lowest level, 1,651 kg/ha in 2012 and 4,366 kg/ha, the highest level, in 2018.

The highest decreases of yield were registered in the years 2012, 2010, 2013 and 2019 (Fig. 8).

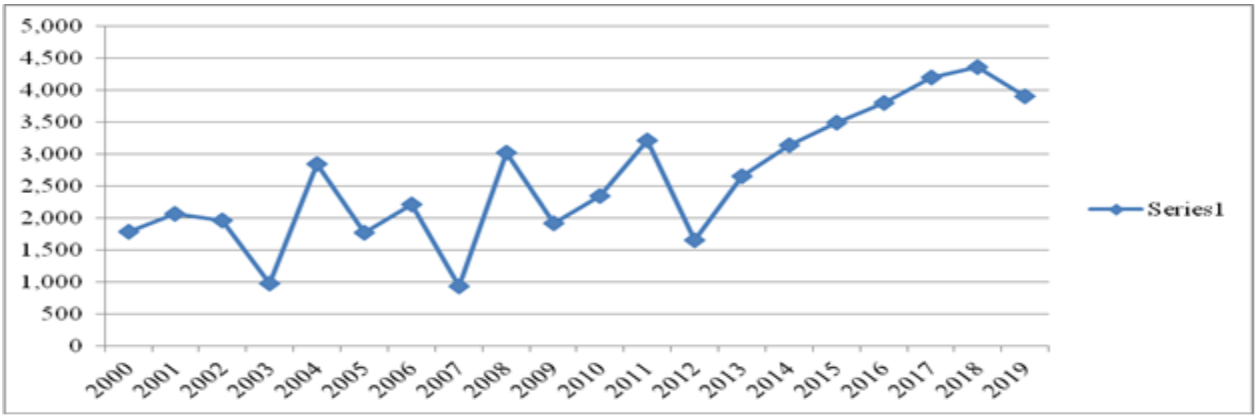


Fig. 8. Dynamics of barley and two-row barley yield in Dobrogea region of Romania, 2000-2019 (kg/ha)
Source: Own design based on the data from [13].

Oats yield accounted for 1,210.5 kg/ha as the decade 2000-2009 average. In this interval, it ranged between 474 kg/ha, the minimum yield, registered in 2007, and 1,681 kg/ha, the

maximum level, in the year 2008. The unfavorable years for this crop were 2007, 2003, 2000, 2009, 2002, 2001, when yield was lower than the decade mean.

In the decade 2010-2019, oats yield registered an average level of 1,950 kg/ha, the variation thresholds being 1,354 kg/ha in the year 2012, the lowest performance, and 2,438 kg/ha, the highest one, in 2019.

The most unfavorable years for oats crop in this decade were 2012, 2010, 2013, 2014 and 2015 when production was below the decade mean (Fig. 9).

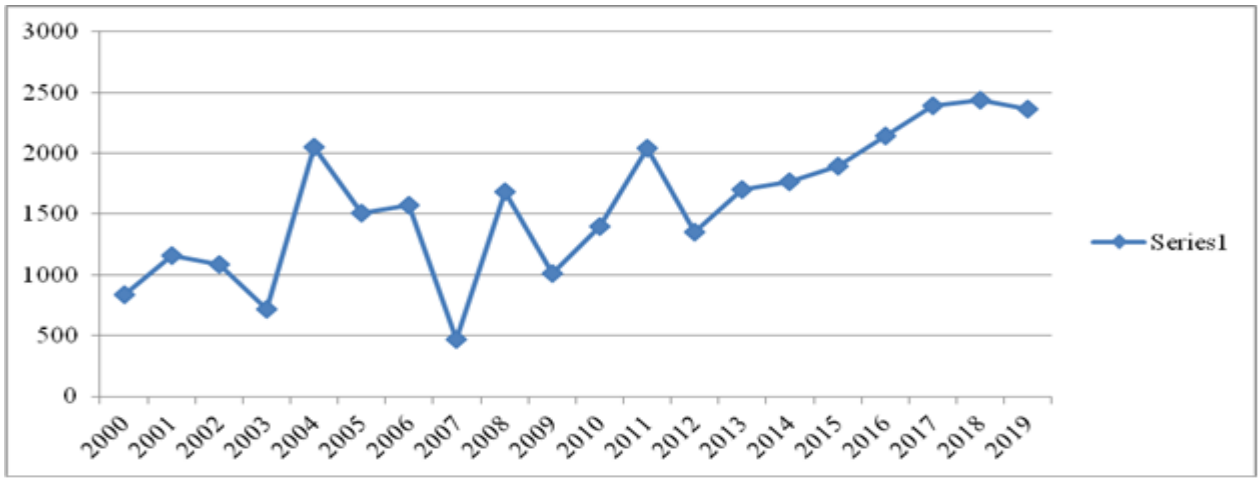


Fig. 9. Dynamics of oats yield in Dobrogea region of Romania, 2000-2019 (kg/ha)
Source: Own design based on the data from [13].

Maize for grains registered an average yield of 2,549 kg/ha in the decade 2000-2009. The highest performance was 3,881 kg/ha carried out in the year 2004, and the lowest one, 480 kg/ha, was noticed in the year 2007. The most unfavorable years for maize crop in this decade, when production decreased below the decade average were 2007, 2001, 2000 and 2002. In the second decade 2010-2019, maize yield registered a mean of 4,483.8 kg/ha. The performance ranged between 1,374 kg/ha, the minimum level in 2012, and 8,472 kg/ha, the maximum level achieved in the year 2018.

Maize yield registered levels below the decade average in the following years: 2012, 2015, 2016, 2013, 2014, 2010, 2019 which were considered unfavorable for this crop (Fig. 10, and Table 7).

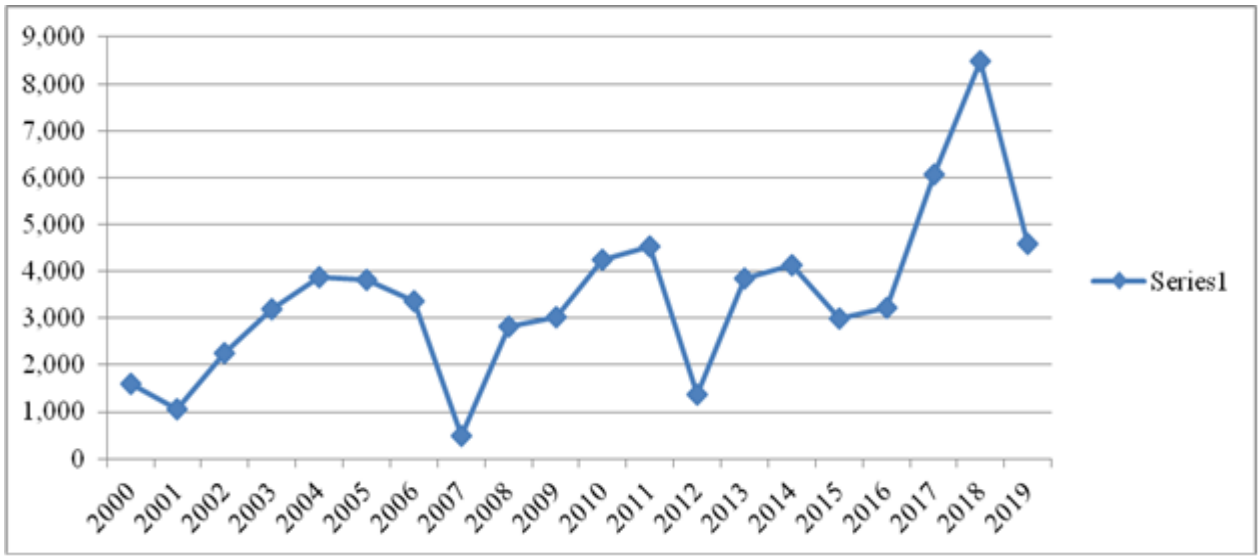


Fig. 10. Dynamics of maize yield in Dobrogea region of Romania, 2000-2019 (kg/ha)
Source: Own design based on the data from [13].

Table 7. The evolution of cereals yields and of the yield losses due to the droughts in Dobrogea region in the decades 2000-2009 and 2010-2019 (kg/ha)

Year	Yield (kg/ha)				Yield deviations from the average yield in the decade 2000-2009 (kg/ha)			
	Wheat	Barley and two-row barley	Oats	Maize	Wheat	Barley and two-row barley	Oats	Maize
2000	**1,914**	**1,784**	**840**	**1,596**	-251.7	-168.4	-370.5	-953
2001	**1,830**	2,064	**1,159**	**1,069**	-335.7	+ 111.6	-51.5	-1,480
2002	**1,977**	1,968	**1,088**	**2,239**	-188.7	+15.6	-122.5	-310
2003	**296**	**984**	**717**	3,204	-1,809.7	-968.4	-493.5	+65
2004	3,145	2,853	2,052	3,881	+979.3	+900.6	+641.5	+1,332
2005	3,024	**1,771**	1,509	3,829	+858.3	-181.4	+298.5	+1,280
2006	3,069	2,216	1,575	3,361	+903.3	+263.6	+364.5	+812
2007	**1,154**	**932**	**474**	**480**	-1,011.7	- 1, 020.4	-736.5	-2,069
2008	3,477	3,030	1,681	2,819	+1,311.3	+1,077.6	+470.5	+270
2009	**1,771**	**1,922**	**1,010**	3,012	-394.7	-30.4	-200.5	+463
Average decade yield	**2,165.7**	**1,952.4**	**1,210.5**	**2,549**	-	-	-	-
	Yield (kg/ha)				Yield deviations from the average yield in the decade 2010-2019 (kg/ha)			
2010	**2,518**	**2,343**	**1,397**	**4,237**	-1,195.4	-937	-553	-246.8
2011	3,860	3,224	2,042	4,541	+146.6	-57	+92	+57.2
2012	**2,133**	**1,651**	**1,354**	**1,374**	-1,580.4	-1,630	-59.6	-3,109.8
2013	**2,946**	**2,659**	**1,699**	**3,852**	-767.4	-622	-251	-631.8
2014	**3,468**	**3,145**	**1,768**	**4,132**	-245.4	-136	-182	-351.8
2015	3,752	3,502	**1,898**	**2,980**	+38.6	+221	-52	-1,503.8
2016	4,036	3,810	2,144	**3,211**	+322.6	+529	+194	-1,272.8
2017	5,060	4,206	2,394	6,065	+1,346.6	+925	+444	+1,561.2
2018	5,132	4,366	2,438	8,472	+1,418.6	+1,085	+488	+3,988.2
2019	4,229	3,904	2,366	4,600	+515.6	+623	+416	+116.2
Average decade yield	**3,713.4**	**3,281**	**1,950**	**4,483.8**				

Source: Own calculation based on the data from [13].

Sunflower seeds yield was 1,068.5 kg/ha in the decade 2000-2009, ranging between 470 kg/ha, the minimum level registered in 2001, and 1,428 kg/ha, the maximum level obtained in 2004. Comparing the yield level in this interval with the mean of the decade, the highest de creases of yield were registered in the years 2001, 2007, 2000, 2009, 2002, 2003. In the second decade, 2010-2019, the sunflower seeds yield accounted for 1,815.6 kg/ha, with variations between 1,315 kg/ha registered in 2010, the minimum level, and 3,583 kg/ha, the maximum level, achieved in the year 2018. Sunflower seeds yield was smaller than the average of this decade in the following years: 2012, 2010, 2013, 2015, 2016, 2014 (Fig.11).

In case of rape crop, the average yield of seeds obtained in the decade 2000-2009 was 1,291.8 kg/ha, ranging between 467 kg/ha in the year 2003, the minimum level, and 2,030 kg/ha, the maximum level recorded in the year 2004. The highest declines of yield compared to the average of this decade were noticed in the years 2003, 2002, 2001, 2000, 2009.

In the decade 2010-2019, rape produced 1,911.2 kg/ha in average, with variations between 1,182 kg/ha, the smallest yield in the year 2011 and the highest level 2,541 kg/ha achieved in 2016. The unfavorable years for rape crop in this second decade, when yield performance was below the average of this interval, were 2011, 2012, 2010, 2013, 2019 (Fig. 12 and Table 8).

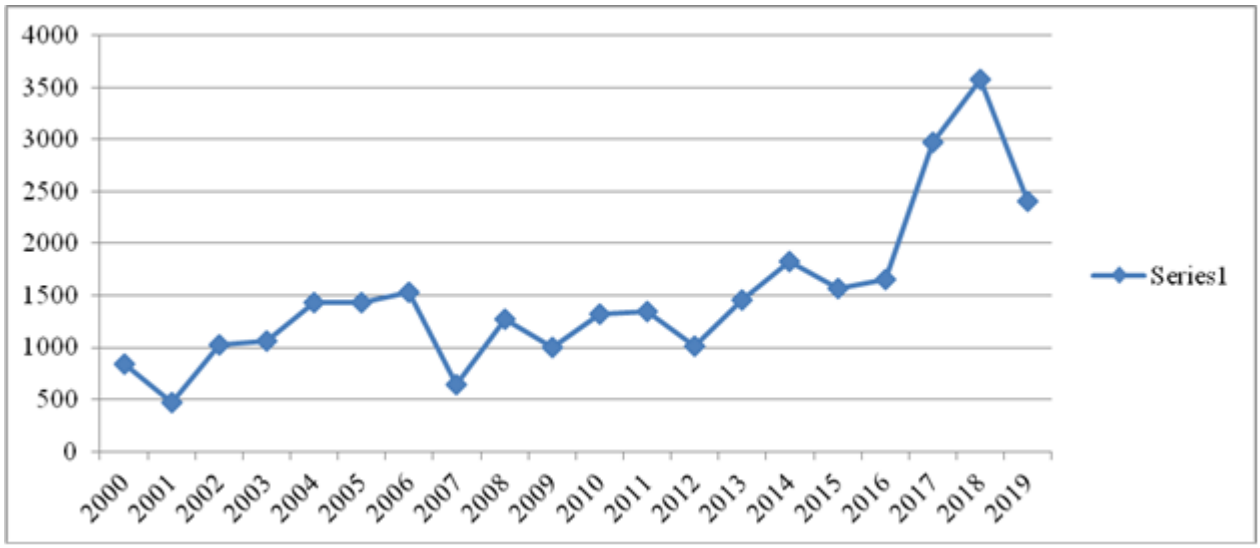


Fig. 11. Dynamics of sunflower yield in Dobrogea region of Romania, 2000-2019 (kg/ha)
Source: Own design based on the data from [13].

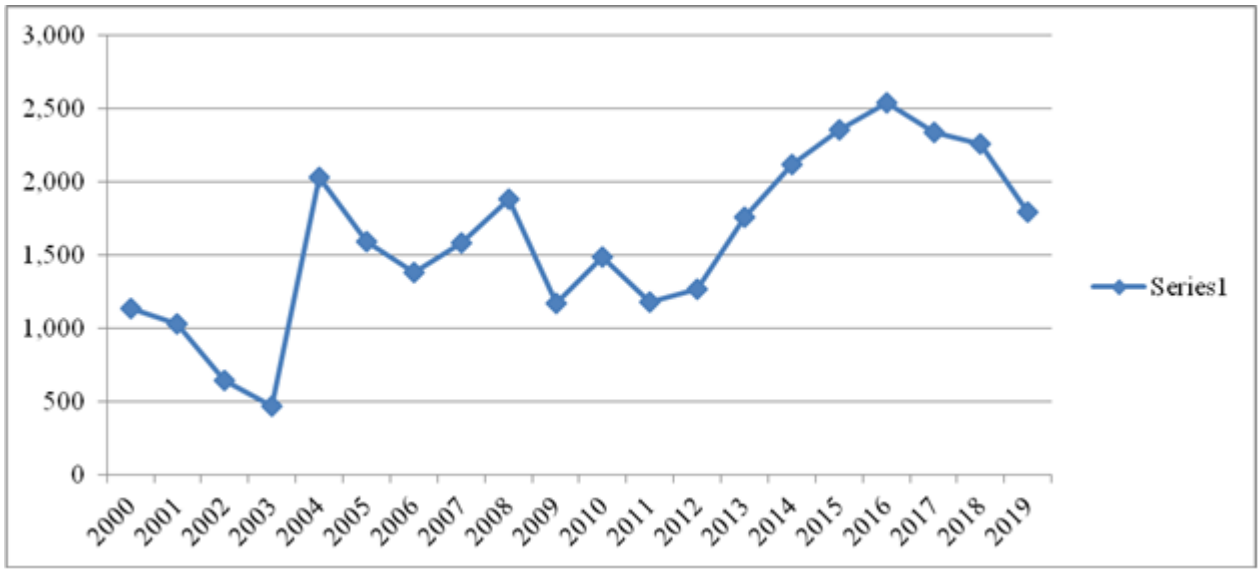


Fig. 12. Dynamics of rape yield in Dobrogea region of Romania, 2000-2019 (kg/ha)
Source: Own design based on the data from [13].

The negative deviation of yield for the main agricultural crops in Dobrogea region compared to the average yield in Romania in the two analyzed decades

Making the difference between the average achievements of yield for the studied agricultural crops in Dobrogea region and the average yield recorded in Romania in the decade 2000-2009, we may easily notice that almost all the crops registered losses of production as follows: - 518.2 kg/ha in case of maize, -389.9 kg/ha in case of barley, -363.5 kg/ha in case of oats, - 107.8 kg/ha in case of wheat and -157.8 kg/ha in case of sunflower. Rape is the only crop whose average in the decade 2000-2009 was by +16.9 kg/ha higher in Dobrogea region than the average production of rape seeds yield in Romania.

In the second decade, 2010-2019, Dobrogea region achieved lower yield levels compared to the average yield at the national level in case of almost agricultural crops, except oats.

The average losses of yield carried out in Dobrogea region accounted for: -316 kg/ha for maize, -168.2 kg/ha for barley, -108.1 kg/ha for wheat, -397.5 kg/ha for rape, -217 kg/ha for sunflower. Oats recorded an average surplus of +23.7 kg/ha in this decade compared to the mean yield at the country level.

All these losses of production are a proof that Dobrogea region was deeply affected by drought in the two analyzed decades, 2000-2009 and 2010-2019 (Table 9).

Table 8. The evolution of oil seeds yields and of the yield losses due to the droughts in Dobrogea region in the decades 2000-2009 and 2010-2019 (kg/ha)

	Yield (kg/ha)		Yield deviations from the average yield in the decade 2000-2009 (kg/ha)	
	Sunflower	Rape	Sunflower	Rape
2000	**834**	**1,136**	-234.5	-155.8
2001	**470**	**1,031**	-598.5	-260.8
2002	**1,030**	**640**	-38.5	-651.8
2003	**1,057**	**467**	-11.5	-824.8
2004	1,428	2,030	+359.5	+738.2
2005	1,430	1,590	+361.5	+298.2
2006	1,529	1,381	+460.5	+89.7
2007	**642**	1,582	-426.5	+290.2
2008	1,267	1,886	+198.5	+584.2
2009	**997**	**1,175**	-71.5	-116.8
Average decade yield	**1,068.5**	**1,291.8**	-	-
	Yield (kg/ha)		Yield deviations from the average yield in the decade 2010-2019 (kg/ha)	
2010	**1.315**	**1,485**	-600.6	-426.2
2011	**1.349**	**1,182**	-566.6	-729.2
2012	**1,010**	**1,268**	-905.6	-643.2
2013	**1,458**	**1,758**	-457.6	-153.2
2014	**1,832**	2,123	-83.6	+211.8
2015	**1,569**	2,362	-346.6	+450.8
2016	**1,656**	2,541	-259.6	+629.8
2017	2,976	2,336	+1,060.4	+424.8
2018	3,583	2,260	+1,667.4	+348.8
2019	2,408	**1,797**	+492.4	-114.2
Average decade yield	**1,915.6**	**1,911.2**		

Source: Own calculation based on the data from [13].

Table 9. Differences between the average yield produced in Dobrogea region versus the national average for the main agricultural crops in the period 2000-2019 (kg/ha)

		Wheat	Barley and two-row barley	Oats	Maize	Sunflower	Rape
		Decade 2000-2009					
1	National average yield	2,273.5	2,342.3	1,574	3,067.2	1,226.3	1,274.9
2	Dobrogea average yield	2,165.7	1,952.4	1,210.5	2,549	1,068.5	1,291.8
3	3 = 2-1	**-107.8**	**-389.9**	**-363.5**	**-518.2**	**-157.8**	+16.9
		Decade 2010-2019					
1	National average yield	3,821.5	3,449.2	1,926.3	4,799.8	2,184,6	2,308.7
2	Dobrogea average yield	3,713.4	3,281	1,950	4,483.8	1,915.6	1,911.2
3	3 = 2-1	**-108.1**	**-168.2**	+23.7	**-316**	**-219**	**-397.5**

Source: Own calculations.

However, in Dobrogea production performance in agriculture during the last decades recorded an ascending trend due to the efforts made by farmers and with the support from the EU and Romanian Government to improve production technologies. In this respect, many farmers from Dobrogea found new alternatives to the classical technologies being more and more oriented to varieties and hybrids not only of high production potential, but also resistant to drought, diseases and pests, to changes

regarding the sowing time and depth, fertilization level, and plant protection measures [7, 8, 9].

CONCLUSIONS

The research results have emphasized the dynamics of yields for the main agricultural crops: wheat, maize, barley and two-row barley, oats, sunflower and rape in the period 2000-2019 in Romania and also in the years when yield level declined due to drought.

Also, the yields for the same crops were analyzed in their evolution during the last two decades pointing out the decline of production in the warmest years when drought had a deep impact in Dobrogea region, which is the most affected part of the country by this climate factor.

Yields were analyzed in Dobrogea region in the studied period 2000-2019, and also in each year compared to the average yield registered in the decade 2000-2009 and 2010-2019.

The substantial yield negative deviations registered by all the cultivated crops: wheat, maize, barley, oats, sunflower and rape compared to the decade averages were due to the severe and strong intensity of drought with which Dobrogea region was facing during the last 20 years and not only.

Also, compared to the average performance of yield at the country level, Dobrogea region carried out smaller yield levels, which is a confirmation that this part of the country si not able to reach its production potential due to drought.

The occurrence of drought characterized by high air temperatures, deficit of precipitations, lack or unsufficient water resource into the soil, high evapo-transpiration had a deep negative impact on agricultural production in Romania, but especially in Dobrogea region. This has affected farmers' harvests, incomes and profit, and put them in a difficult situation not to be able to pay their debts to the banks or leasing companies.

This must be a "red flag" for the authorities who have the responsibility to restore, improve and invest in irrigation systems in Dobrogea region, and also for farmers who have to continue their efforts to adapt the technologies to the change of the climate factors and mainly to drought.

Only using varieties and hybrids of high performance, well adapted and resistant to drought and to the attack of various pathogen agents, identifying the right moment for sowing, choosing the corresponding sowing depth, the corresponding fertilization level and treatments for assuring plant protection, applying agricultural works at the right moment and of high quality, farmers could obtain production which could cover the costs and assure profitableness of their business.

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