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# CLIMATE CHANGE AND ITS IMPACT ON WHEAT, MAIZE AND SUNFLOWER YIELD IN ROMANIA IN THE PERIOD 2017-2021

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***Abstract***

*The paper purpose was to assess the impact of climate change on wheat, maize and sunflower yield in the period 2017-2021, using statistical data from National Institute of Statistics (NIS) and National Administration of Meteorology (NAM) and other sources. Comparison method was used to evaluate the deviations between the registered air temperatures and precipitations and the 1981-2010 climatological norm. Graphic method reflected the dynamics of monthly air temperatures and rainfalls in each year. Descriptive statistics for mean, standard deviation and coefficient of variation reflected an more comprehensive image upon air temperature, precipitations and yield. Correlations and regression equations were used to establish the intensity of the kinks between climate factors and yield. The highest average air temperature In Romania was 12.13$^0$C in 2019. In the period 2017-2020, the average annual temperatures exceeded the climatological norm 1981-2010 accounting for 9.1$^0$C. The lowest rainfalls, 614.2 mm, were recorded in 2019, being below of 633.1 mm the norm for the period 1981-2010. The high temperatures associated with drought and low precipitations have deeply affected yield of many agricultural crops, including maize, wheat and sunflower. The highest wheat yield 4,888 kg/ha was achieved in 2017, and the lowest one, 2,966 kg/ha in 2020. Maize registered the highest performance of 7,644 kg/ha in 2018, and the lowest one, 3,977 kg/ha in 2020. Sunflower carried out the high performance 3,041 kg/ha in 2018, and the lowest one, 1,858 kg/ha in 2020. The worst agricultural years for these three crops was 2020, but 2017 favored wheat, while 2018 favored maize and sunflower. The correlation coefficient had in general small values between average temperature and yield, but a higher link with precipitations level. The multiple correlation between yield, air temperatures and precipitations was: r= 0.817 for wheat, r = 0.116 for maize and r = 0.504 for sunflower. In the South Eastern Dobrogea, the driest area in Romania, the rainfalls declined by 65% in the period 2018-2020 having a deep negative impact on sunflower seeds yield, which decreased from 4,282 kg/ha in 2018, to 1,503 kg/ha in 2020. The correlation between precipitations and sunflower yield positive and very strong (r = 0.737). As a conclusion, the climate conditions should be analyzed in each farm and farmers have to take measure to adapt the technologies for sustaining production.*

***Key words***: *climate change features, wheat, maize, sunflower, yield, Romania*

## INTRODUCTION

Romania is an important country in the EU agriculture, both as producer and exporter of agricultural products and food.

Of the 8.3 million cultivated area, the highest share is kept by three crops: maize 30.8% and wheat 26.3%, summing 57.1% and sunflower 13.6%, all together accounting for 70.7% [24, 33, 36, 37].

In 2020, of the 18.1 million tonnes cereals carried out in Romania, wheat represented 6.4 million tonnes and maize 10.9 million tonnes, all together 17.3 million tonnes (95.5%) [32, 34, 38, 40].

Since 2015, Romania's sunflower production of seeds is on the top position in the EU. In 2020, Romania contributed to the EU sunflower output by 2.1 million tonnes (34%) [33, 35, 41, 42, 44].

The exports raised both quantitatively and as values. In 2020, Romania exported 4.4 million tonnes wheat and rye, 5.8 million tonnes maize and 1.6 million tonnes sunflower seeds, at the same time assuring the availabilities for internal consumption which accounted for 3.9 million tonnes, 6.6 million tonnes and, respectively for 1.3 million tonnes [33, 39, 41, 46].

During the last decade, the yield and production performance were due to the efforts made by farmers to modernize production technologies and increase economic efficiency in wheat, maize and sunflower cropping. However, this performance would have been higher if the climate change has not been intensified during the last decade, climate factors being the main environmental items influencing the evolution of the development of agricultural crops and productivity.

Climate factors are considered of high risk for agriculture, taking into account the monthly, annual and multiannual deviations of temperature and precipitations from the climatological norms [3].

Any deviation from the optimal requirements in thermal, rainfalls regime, wind and air humidity along each phenological stage could affect yield and harvest, farmers' income and profit [8].

Despite that the effects of climate change are more and more visible, there are still not enough studies which approach the climate impact on yield.

In Europe, in the last decade, it was noticed a higher temperature, an elevated $CO_2$ concentration in the atmosphere, low rainfalls and extreme hazards. In consequence, sunflower was deeply affected by heat stress and drought during its growing cycle leading to a loss of yield, oil content and fatty acids [7].

In the EU, it was noticed a relevant progress in wheat and barley, and it was affirmed that a temperature growth by $1^0$C could increase yield by +0.33 T $ha^{-1}$. At the global level, in the recent years, warming has led to a stagnation yield progress.

To adapt to higher temperatures, a mix between genetic performance, crop cycle duration, drought tolerance, sowing moment and smart irrigation could be a useful recommendation [15].

In France, maize and wheat yield is highly challenging due to climate change in the opinion of [4].

In Spain, the impact of climate change on wheat and barley was studied using regression models like EURO-CORDEX regional climate model RCM simulation combining maximum and minimum air temperature with monthly precipitations [2].

Rain fed and irrigated sunflower yield was studied in connection with climate change in Turkey and it was found that an increase of temperature will cause a shortening of plant growth cycles [13].

In Serbia, there were found positive correlations between precipitations in July and August sand maize and sunflower yield, and also that the temperatures registered in March, August and September are the most responsive of crop yield level [25].

[50] used regression models and correlations, and found that wheat yield is strongly influenced by rainfall in January-March.

In Hungary, 75% of the area cultivated with sunflower is affected by drought and as a result it is was noticed a loss of yield [14].

In Romania, during the last decade, climate is characterized by the following aspects:

-the shift of the seasons;

-mild winters with a thin snow layer or even missing in some parts of the country; late frosts; low precipitations and even absent across the year in the period of vegetation of the plants;

-an increased air temperature, heat waves and a scorching heat for a longer period of time, severe drought in many regions and pedological drought on the surfaces situated in the South, East and South-Eastern part of the country;

-the appearance of desertification in the traditional zones for cultivating wheat, maize, barley, sunflower and also other crops and plants;

-extreme phenomena like: huge rainfalls, floods, storms, hail [1].

The largest agricultural surfaces have a moderate regime of precipitations, a moderate and dried regime. In the period 1961-2010 it was noticed a general decreasing trends in

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precipitations, especially in the South, South East and Eastern part of the country.

In the period 2001-2010, the average annual temperature increased by + 0.4...+0.6 degrees compared to each decade since 1961 till present when it reached 9.3$^0$C [49].

In the last 40 years, the average annual temperature increased by +2$^0$C in Romania [5].

All these aspects have had a deep impact on crop development, production level per surface unit, seeds quality and their destinations, selling price at the farm gate, farmers' income and profit, especially in South and South-East Muntenia, Dobrogea, South West Oltenia, West, North-West Transilvania and Moldova regions.

Also, demand/supply ratio on the domestic market, price volatility, seeds trade on the domestic market and Romania's external trade were also disturbed due to lower yields and productions in wheat, maize and sunflower and other crops [37, 47, 48].

Theses aspects were studied by researchers who pointed out the impact of climate change on agricultural crops in Romania.

In this respect, it was attested that wheat cultivated in the West part of Romania is extremely vulnerable to meteorological hazards [21].

Studying the physiological feed-back of winter wheat and maize to climate change, using CERES simulation crop models, it was concluded that "interaction between double $CO_2$ concentrations and higher temperatures, under irrigated maize in South of Romania had a negative response to climate change" and it was suggested the use of a longer maturity hybrid, sown in the last week of April, for diminishing the impact of climate change on maize yield [6].

In Transilvania, it was found that using an optimal combination between fertilization and crop protection in conservation agriculture system could be an alternative for maize [9] and also for wheat yield compared to conventional agriculture [11].

The No-tillage system and fertilization could increase wheat production and also protein and gluten content in grains [10, 12].

The extreme meteorological phenomena obliged the farmers to adapt crop technologies to diminish the negative impact of climate change on yield [22, 23].

Dobrogea, South East Romania, is the region with the lowest precipitations accounting for less than 200 l/year during the last years and combined with higher and higher temperatures, heat waves and pedological drought, production per surface unit in many crops, and especially in sunflower was diminished [43, 45].

In such a situation, to sustain yield, farmers proceeded to adapt sunflower technology selecting the hybrids with high yield performance and resistant to drought and also changed the sowing moment and plant protection scheme [16, 17, 18].

In this context, the aim of the paper was to analyze the impact of climate change in Romania, in terms of temperatures and precipitations, on wheat, maize and sunflower yield in the period 2017-2021, using correlations and regression models between yield and climate factors.

## MATERIALS AND METHODS

The research work is based on a large source of information, including empirical data from National Institute of Statistics- NIS, National Administration of Meteorology-NAM and other sources [18, 19, 20].

The main climate indicators used in this study were:

-air temperatures, maximum, minimum, average at the level of each year and also by month in Romania;

-rainfalls, maximum, minimum, average per year and also per month in Romania.

Wheat, maize and sunflower yields were studied in the period 2017-2021;

Correlation coefficients were calculated between yield and temperatures and rainfalls.

Regression equations were used to evaluate the dependence of yield on the level of temperatures and precipitations.

A study case regarding the impact of the decrease in precipitations in South Eastern Dobrogea on sunflower yield was included to point out that climate factors have to be

studied locally and in consequence farmers have to adapt the technology to sustain production.
Tables and graphics were used to synthesize the results.
Finally, the conclusions presented the main ideas drawn from this research work.

## RESULTS AND DISCUSSIONS

### Climate characteristics in the period 2017-2021

The last decade 2012-2021 has reflected more than ever an alarming climate change with a negative economic, social and environmental impact.
The temperatures proved a warming process year by year, exceeding the value of 9.1$^0$C, representing the climatological norm in the period 1981-2010 ( Fig. 1) [27].
The figures show that the years 2019 and 2020 are the warmest years in the history, and the experts consider that "the decade 2012-2021 is the warmest interval of 10 consecutive years with positive thermal deviations since the meteorological measurements have been made in Romania" [1]. The analyzed period is characterized by extreme meteorological phenomena like: high air temperatures, heats waves, scorching heat, low precipitations and unevenly distributed in the territory of the country, strong and prolonged drought, pedological drought, torrential rains followed by devastating floods, storms and hail, which caused damages to the households and agricultural crops.

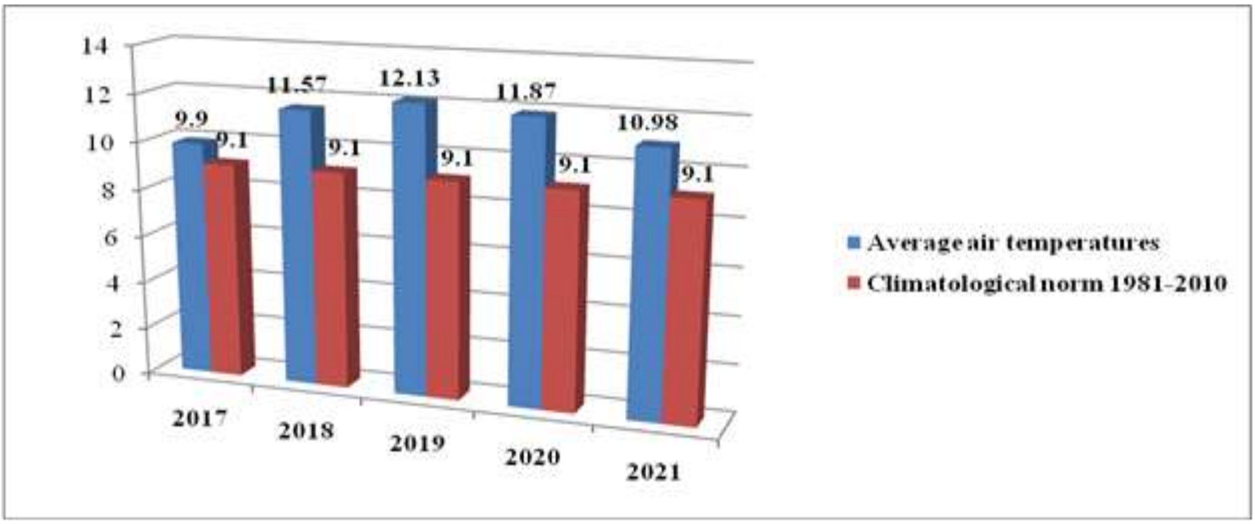


Fig. 1. Air temperatures in Romania, 2017-2021 compared to climatological norm 1981-2010 ($^0$C)
Source: Own design based on the data from [27, 28, 29, 30, 31].

Annual precipitations varied from a year to another with a general decreasing trend in Romania from 791.5 mm in the year 2016 to 648.2 mm in the year 2021, meaning a reduction by -143.3 mm.
Taking into account the climatological norm 1981-2021 of 633.1 mm, it is obviously that in the years 2017, 2018, 2020, 2021, precipitation level was higher, but in the year 2019 it was registered 614.2 mm, by -18.9 mm less (-3%) (Fig. 2).
***The year 2017*** recorded 9.9$^0$C average air temperature by +0.8$^0$C more than the climatological norm of 9.1$^0$C. The deviations of temperatures varied between 0.3$^0$C in the month of May and 3.9$^0$C in January, but in the other 9 months between 0.1$^0$C in October and 3.4$^0$C in March [31].
The annual precipitations accounted for 673.5 mm, with a deviation of 40.4 mm (+6.1%) compared to the multiannual norm 1981-2010 whose value was 633.1 mm [31].
The average monthly precipitations in 2017 were 56.1 mm, with variations between the maximum level 84.7 mm in the month of May and 27 mm in January.

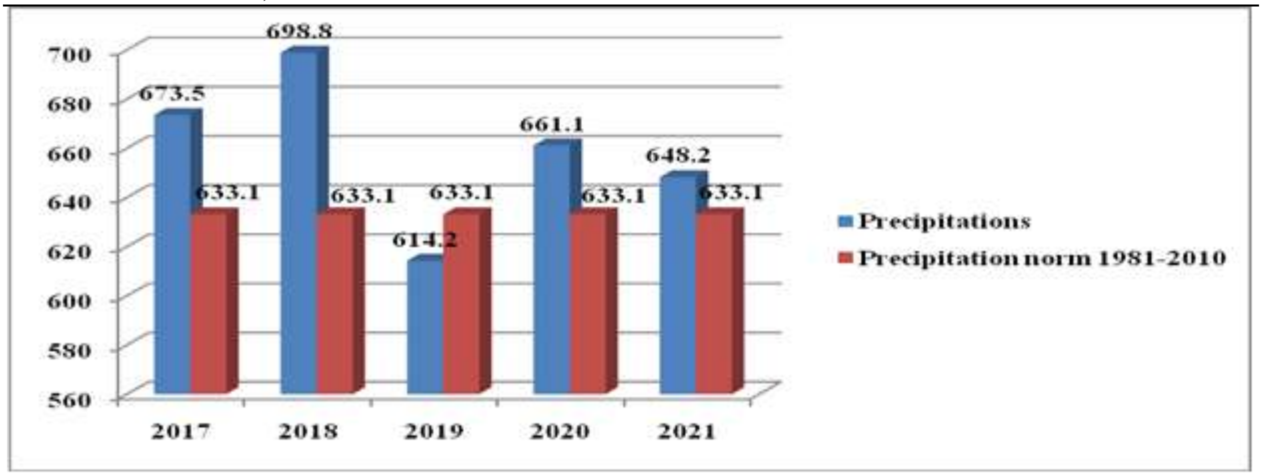


Fig. 2. Annual precipitations in Romania, 2017-2021 compared to climatological norm 1981-2010 (mm)
Source: Own design based on the data from [27, 28, 29, 30, 31].

Compared to the climatological norm 1981-2010, the deviations were positive in most of the months except June (-15.9), August (-28.1) and September (-0.4).

***The year 2018*** registered 11.57$^0$C average air temperature, being by +2.47$^0$C higher than the climatological norm (9.1$^0$C), and for this reason, "this year was considered the 3rd year with the highest temperature since the year 1901 till present" [26].

The annual precipitations accounted for 698.8 mm, being by +65.7 (10.3%) higher than the climatological norm (633.1) [30].

The precipitations varied between 20 mm in October, the minimum and 159 in June, the maximum, the monthly average being 58.2.

Compared to the multiannual norm 1981-2010, negative deviations were registered in: April (-31.6), May (-7.5), August (-33.7), September (-27), October (-23.5), November (-1.5), in the other months the deviations being positive.

***The year 2019*** was in the top of the warmest years, reaching the record of 12.13$^0$C average air temperature, exceeding by +3.03$^0$C the climatological norm 1981-2010 (9.1$^0$C). This year was characterized by long and severe drought periods and even pedological drought in some regions of Romania, affecting the normal phenological development of the agricultural crops [29].

The annual precipitations accounted for 614.2 mm, being by -18.9 (-3%) smaller than the multiannual norm 1981-2010 (633.1).

The maximum amount of precipitations was 120, registered in May, and the minimum level was 20 recorded in February and March, the average monthly level being 51.1.

Compared to the climatological norm, there were noticed negative deviations in February (-11.6), March (-18.3), July(-20.8), August (-22.7), September (-27), October (-11.5) and December (-14.8) which had a negative impact on the production performance per surface unit in agriculture for various crops [29].

***The year 2020*** was considered by experts as being "an atypically meteorological year, coming on the 2nd position in the top of the warmest years in the period 1961-2020, after the year 2019".

In fact, starting from November 2019 till March 2020, the period was characterized by cold, then, the first months of 2020 were lacked of precipitations, and suddenly in June higher temperatures than the climatological norm 1981-2010 were registered.

The average temperature in 2020 was 11.87$^0$C, being by +2.7$^0$C higher than 9.1$^0$C, the climatological norm.

The average monthly temperatures varied between 23$^0$C, the maximum level in August and 3.5$^0$C, the minimum level in December.

High deviations from the multiannual norm were noticed on large surfaces in Moldova, Dobrogea, Muntenia and Oltenia, which resulted in lower performances in agricultural productions.

Their persistence led to a hot summer season, as the precipitations were below 200 l/s. m. in June, July and August, leading to an water deficit into the soil mainly in Muntenia, Moldova and Dobrogea regions.

In addition, in some parts of Romania, the fast and huge rains, accompanied by hail and storms produced important damages.

After September 1st, in most of the regions, the precipitation level was reduced, except the North West of the country [28].

The amount of precipitations in 2020 was 661.1, by +28 higher (+4.4%) than the climatological norm 1981-2010.

The monthly precipitations varied between the minimum 10.3 in January and the maximum 131.4 in June, with a monthly average of 55.

Negative deviations from the norm 1981-2010 were registered in January (-23.30, April (-38.1), August (-18.8) and November (-23.2) [28].

***The year 2021*** recorded 10.98$^0$C average air temperature, exceeding the 1981-2010 norm by +1.88$^0$C, and for this reason, it was included among the warmest years of the decade 2012-2021 (which in the decreasing order are: 2019, 2020, 2015, 2018, 2014, 2013, 2012, 2021).

Taking into account, the period 1900-2022, the experts consider that 2021 is the 15th warmest year.

After the record of temperature 39$^0$C achieved in the west part of the country on June 24-25, at the end of July the temperatures reached 40$^0$C. More than this, the first part of August was the warmest period in the last 60 years. The records of over 40$^0$C were registered in the South-Western part of Romania.

The prolonged heat waves of July and August affected the South, East and West of Romania.

Besides the high temperatures and low precipitations, in 2021, there were registered extreme meteorological phenomena like huge rains, floods, storms and hail [27].

In 2021, the quantity of precipitations accounted for 648.2 mm, being by +15.1 higher than the climatological norm 1981-2010, meaning +2.3%.

In this year, the average monthly precipitations level was 54 mm, with variations between 28.8, the minimum in September and 96.8, the maximum in June.

Negative deviations from the multiannual norm were registered in February (-1), April (-1.7), July (-8.9), September 9-26.2), October (-10), November (-4.2), in the rest of the months positive deviations being noticed [27].

**Precipitations recorded by agricultural years**

As the purpose of this research work is to assess the impact of climate change in terms of temperatures and precipitations on the yield of three major crops cultivated in Romania, it was considered necessary to calculate the total amount of precipitations characteristic for the agricultural years specific to each crop.

In consequence, for wheat it was taken into consideration the period September till June, next year, for maize it was considered the period January-October and for sunflower, it was considered January-August.

Table 1. Annual precipitations by agricultural years, related to each agricultural crop: wheat, maize and sunflower compared to the climatological norm 1981-2010 (633.1 mm)

| | **WHEAT September-June** | | **MAIZE January-October** | | **SUNFLOWER January -August** | |
|---|---|---|---|---|---|---|
| | Absolute values | Deviations | Absolute values | Deviations | Absolute values | Deviations |
| 2017 | 550.4 | +59.8 | 575.4 | +28.6 | 441.2 | **-7.1** |
| 2018 | 632.9 | +142.3 | 599.5 | +52.7 | 551.5 | +103.2 |
| 2019 | 529.0 | +38.4 | 540 | **-6.8** | 480.0 | +31.7 |
| 2020 | 460.1 | **-30.5** | 580.8 | +34 | 454.6 | +6.3 |
| 2021 | 598.0 | +107.4 | 527.3 | **-19.5** | 465.0 | +16.7 |

Source: Own calculations based on the data from [27, 28, 29, 30, 31].

The results regarding the amount of precipitations by each agricultural year an also the deviations from the climatological norm 1981-2010 are shown in Table 1.

The average monthly precipitations and their deviations from the climatological norm 1981-2010 by agricultural year connected to each crop: wheat, maize and sunflower are presented in the Figures 3, 4 and 5.

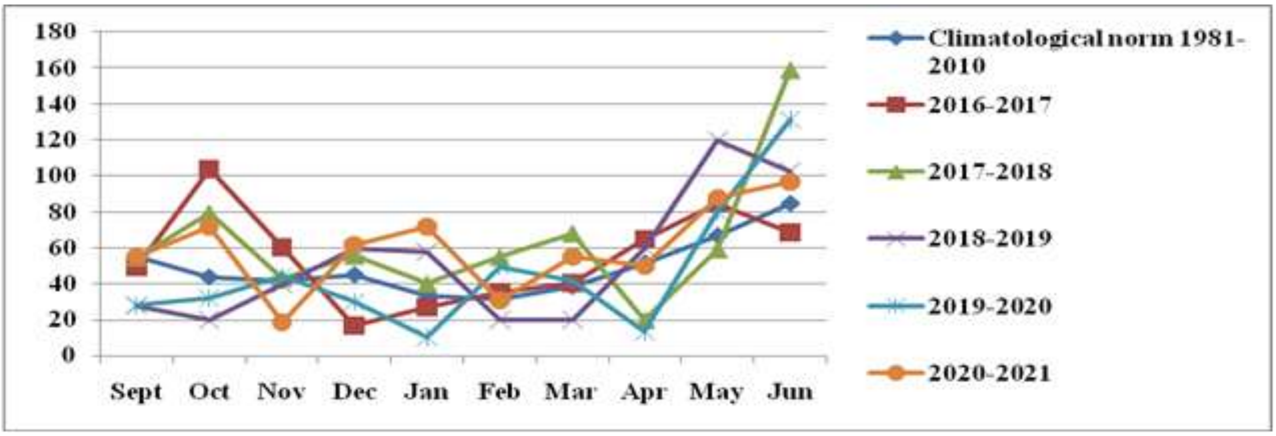


Fig. 3. Distribution of average monthly precipitations by agricultural year connected to Winter Wheat compared to climatological norm 1981-2010 (mm)
Source: Own design and calculations based on the data from [27, 28, 29, 30, 31, 32].

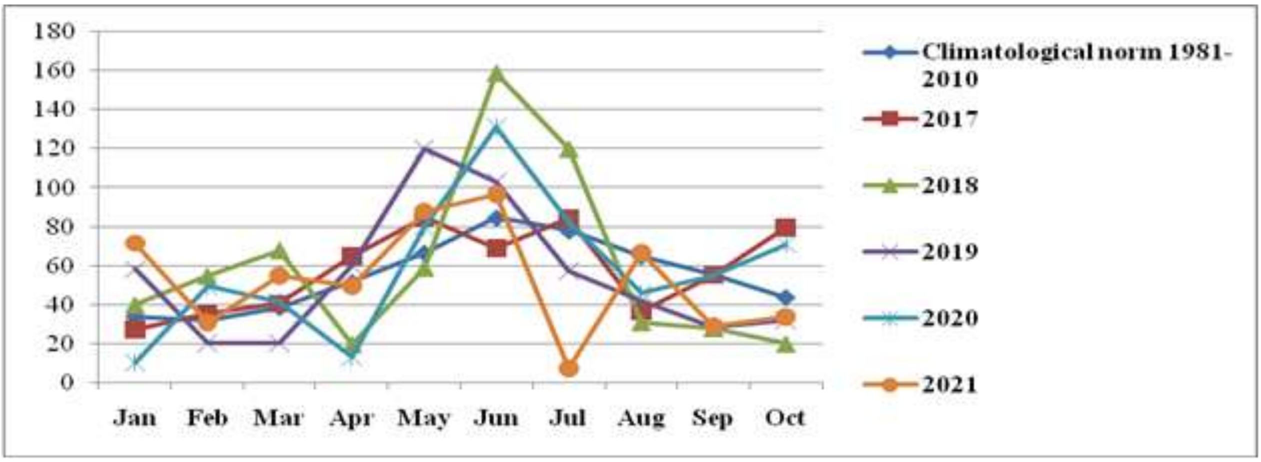


Fig. 4. Distribution of average monthly precipitations by agricultural year connected to Maize and their deviations compared to climatological norm 1981-2010 (mm)
Source: Own design and calculations based on the data from [27, 28, 29, 30, 31].

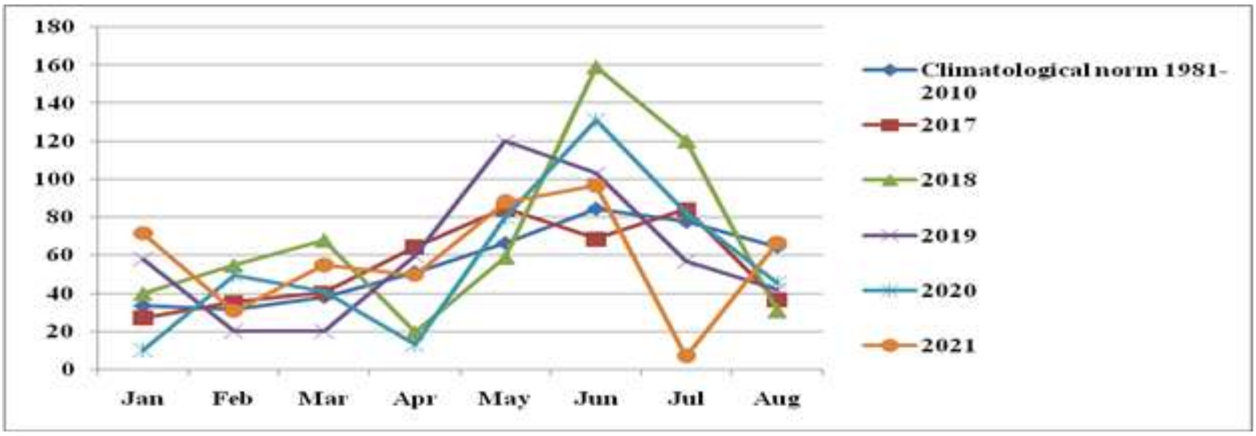


Fig. 5. Distribution of average monthly precipitations by agricultural year connected to Sunflower and their deviations compared to climatological norm 1981-2010 (mm)
Source: Own design and calculations based on the data from [27, 28, 29, 30, 31].

The months with negative deviations from the climatological norm 1981-2020 by each agricultural year and crop are presented in Table 2.

Table 2. The months with negative deviations from the climatological norm 1981-2010 by each agricultural year and crop in the period 2017-2021 in Romania

| Agric. year | WHEAT | MAIZE | SUNFLOWER |
|---|---|---|---|
| 2017 | 2016 (Sept., Dec) | 2017 (Jan., June, Aug., Sept.) | 2017 (Jan., June, Aug.) |
| 2018 | 2017 (Sept), 2018 (April, May) | 2019 (April, May, Aug., Sept., Oct.) | 2018 (April, May, Aug.) |
| 2019 | 2018 (Sept., Oct., Nov.), 2019 (Feb., March) | 2019 (Feb., March, July, Aug., Sept, Oct.) | 2019 (Feb., March, July, Aug.) |
| 2020 | 2019 (Sept., Oct., Dec.), 2020 (April) | 2020(Jan., April, Aug.) | 2020 (Jan., April, Aug.) |
| 2021 | 2020 (Nov.), 2021 ( Feb., April) | 2021 (Feb., April, July, Sept. Oct.) | 2021 (Feb., April, July) |

Source: Own conception based on the data from [27, 28, 29, 30, 31, 32].

In the years 2019 and 2020, the most affected region by thermal stress and unsufficient precipitation was Dobrogea [1].

**Wheat, Maize and Sunflower yield by agricultural years**

***Wheat yield*** registered the highest performance of 4,888 kg/ha in the year 2017, and the lowest one, accounting for 2,966 kg/ha in the year 2020 ( Fig. 6).

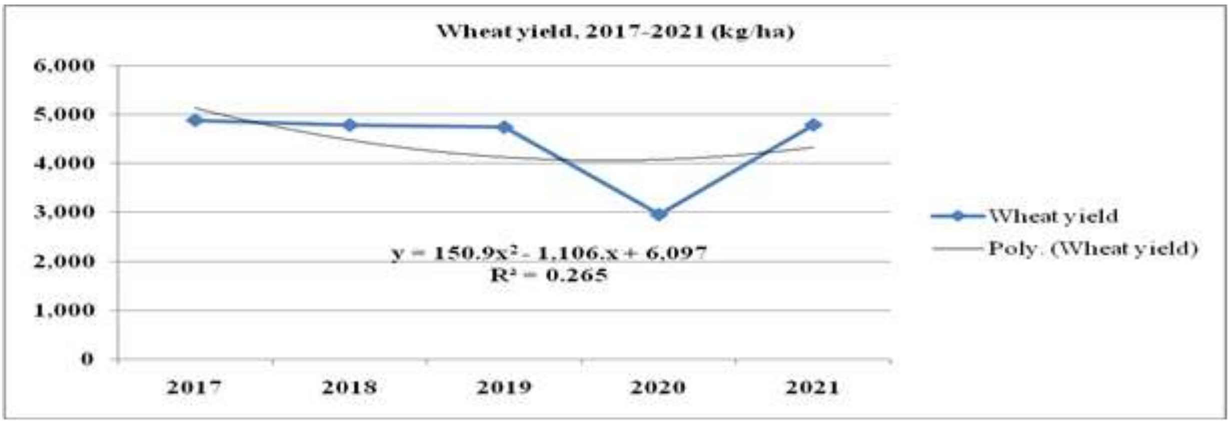


Fig. 6. Dynamics of wheat yield, 2017-2021, Romania (kg/ha)
Source: Own design and calculation based on the data from [33].

***Maize yield*** registered the highest performance of 7,644 kg/ha in the year 2018, and the lowest one, accounting for 3,977 kg/ha in the year 2020 (Fig. 7).

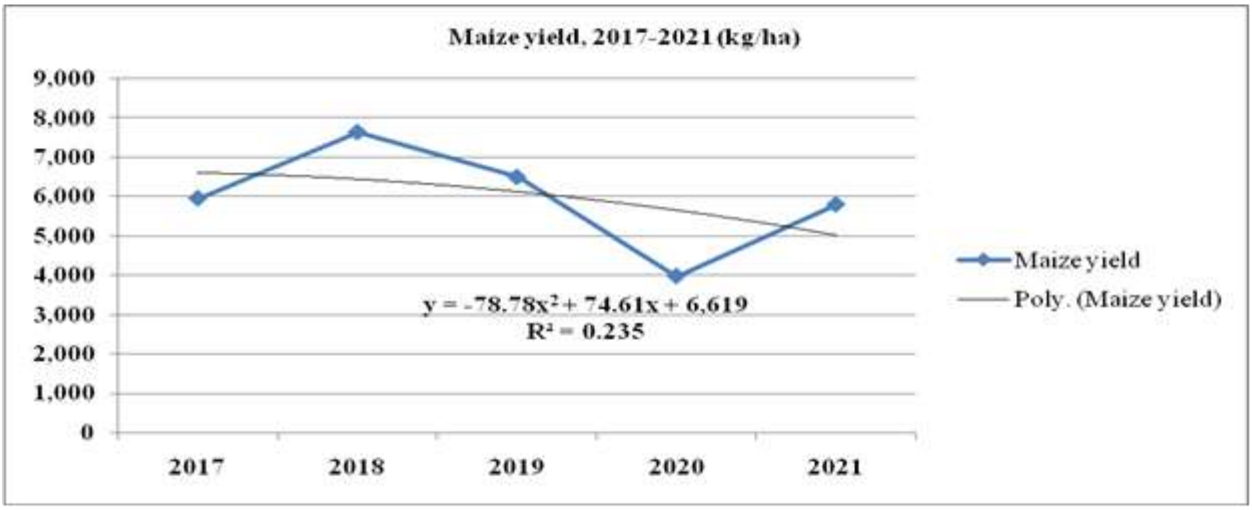


Fig. 7. Dynamics of maize yield, 2017-2021, Romania (kg/ha)
Source: Own design and calculation based on the data from [33].

***Sunflower yield*** registered the highest performance of 3,041 kg/ha in the year 2018, and the lowest one, accounting for 1,858 kg/ha in the year 2020 ( Fig. 8).

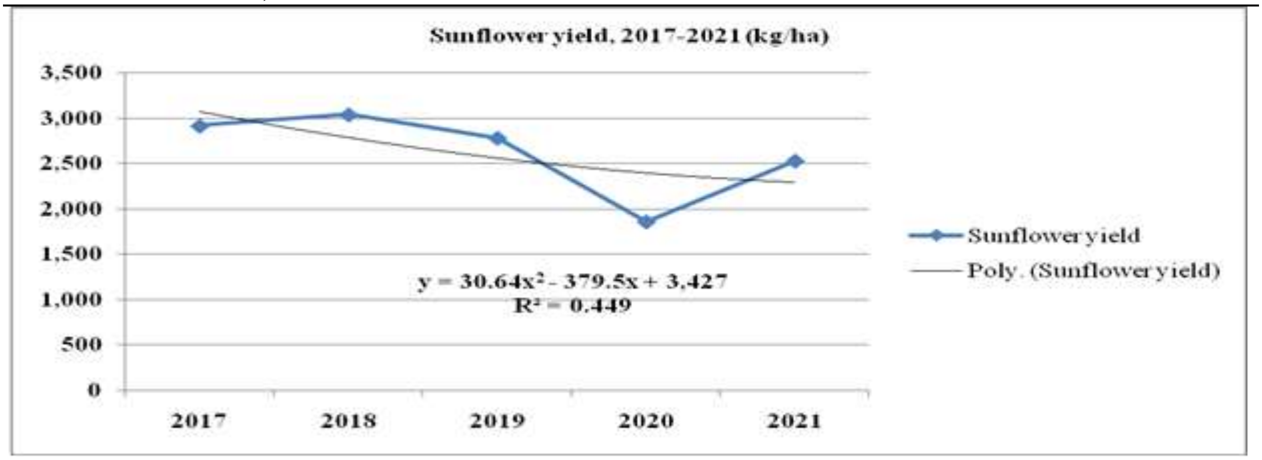


Fig. 8. Dynamics of sunflower yield, 2017-2021, Romania (kg/ha)
Source: Own design and calculation based on the data from [33].

The descriptive statistics in terms of mean, standard deviation and coefficient of variation for yield performance of wheat, maize and sunflower and also average annual temperature and total amount of precipitations by agricultural year in the interval 2017-2021 in Romania is presented in Table 3.

It worth to mention that the coefficient of variations was low in case of annual precipitations and average annual temperatures, but in case of yields it reflected a higher variability, ranging between 17.9% for sunflower, 18.5% for wheat and 22.2% for maize (Table 3).

Table 3. Descriptive statistics: Mean, Standard deviation and variation coefficient for wheat, maize and sunflower yield and also for average annual temperature and precipitations, by agricultural years for the whole period 2017-2021, Romania

| Crop | Statistical parameter | Yield 2017-2021 (kg/ha) | Average annual temperature 2017-2021 ($^0$C) | Annual precipitations 2017-2021 (mm) |
|---|---|---|---|---|
| Wheat | Mean | 4,438.6 | 11.29 | 554.08 |
| | Stand. Deviation | 824.75 | 0.88 | 66.36 |
| | Variation Coeff. (%) | 18.5 | 7.8 | 11.9 |
| Maize | Mean | 5,976.8 | 11.29 | 564.6 |
| | Stand. Deviation | 1,330.92 | 0.88 | 29.97 |
| | Variation Coeff. (%) | 22.2 | 7.8 | 5.3 |
| Sunflower | Mean | 2,625.8 | 11.29 | 478.46 |
| | Stand. Deviation | 469.2 | 0.88 | 43.23 |
| | Variation Coeff. (%) | 17.9 | 7.8 | 9.0 |

Source: Own calculations based on the data from [27, 28, 29, 30, 31, 32, 33].

**Correlations between yield, average annual temperature and annual amount of precipitations**

Starting from the reality that yield level is influenced by temperatures and precipitations, there were calculated the correlations between each pair of variables, considering that all the other factors determining yield are at optimum level and also as a constant factor.

***Correlations between pairs of variables***

In case of wheat, the correlation coefficient reflects the existence of a positive and relatively moderate connection between average production per ha and the average annual temperature (r=0.420) and a strong relationship between yield and annual precipitations. In case of maize, the correlation coefficient shows a weak and positive link between yield and the two climate factors: temperature (r=0.036) and precipitations (r=0.113), and also between temperature and precipitations (r=0.046).

In case of sunflower, the coefficient of correlation reflected a relatively moderate connection between yield and temperature (r=0.343), between yield and precipitations (r=0.479) and between temperature and precipitations (r=416) ( Table 4).

Table 4. Coefficients of correlation between yield and average annual temperature and annual amount of precipitations by crops

| | Wheat | Maize | Sunflower |
|---|---|---|---|
| Correlation coefficient between yield and average annual temperature | 0.420 | 0.036 | 0.343 |
| Correlation coefficient between yield and annual amount of precipitations | 0.787* | 0.113 | 0.479 |
| Correlation coefficient between average annual temperature and annual amount of precipitations | 0.263 | 0.046 | 0.416 |

Source: Own calculations.

The t Test of the correlation coefficient reflected the existence of a significant relationship between wheat yield and annual precipitations. In the other cases, the test results proved that the correlations are not significant.

***Correlation between all the three variables: yield, temperature and precipitations***

Using multiple total correlation formula, it was found that in case of wheat crop, there is a high connection (r=0.817) between the three variables, for sunflower the multiple correlation showed a positive a moderate relationship (r=0.504) and in case of maize, the multiple correlation was positive but very weak (r=0.116) ( Table 5).

Table 5. Multiple correlation between yield, temperature and precipitations by crop

| | Wheat | Maize | Sunflower |
|---|---|---|---|
| $r_{z.xy}$ | 0.817 | 0.116 | 0.504 |

Source: Own calculations.
r= correlation coefficient; z= yield, x= temperature, y = precipitations

**Regression equations and coefficient of determination**

***In case of wheat,*** the regression equation between yield and average annual temperature could be interpreted that a reduction by one unit of temperature, could induce an average production of 8,458 kg/ha. R square reflects that only 17.65 % of the yield variation is caused by the variation of temperature.

Also, the increase of precipitations by one unit could diminish wheat yield by 0.96 kg/ha. In this case, R square shows that 62% of yield variation is determined by precipitations.

***In case of maize***, a reduction by one unit of the average annual temperature could assure 6,542 kg maize grains per ha. R square shows that practically, average temperature has almost zero influence of maize yield and other factors are more important in production performance.

An increase in precipitations could grow maize yield by 3.13 kg/ha. R square shows a weak determination of yield variation caused by precipitations. Also, in case of maize, other factors are more important for achieving a production performance.

***In case of sunflower***, the regression equation tells us that a reduction of temperature by $1^0$C could assure a yield of 4,495 kg/ha. R square reflects that an increase of precipitation by one unit could grow sunflower seeds yield by 0.1263 kg/ha. R square shows a weak variation of yield caused by the variation of precipitations (Table 6).

Table 6. Regression equations and coefficient of determination reflecting the dependence of yield (y) on average annual temperature ($x_1$) and annual precipitations ($x_2$)

| Crop | Pair of variables | Regression equation Y= bx +a | $R^2$ |
|---|---|---|---|
| Wheat | Yield y x Average annual temperature $x_1$ | Y= -390.62x +8,848.71 | 0.1765 |
| | Yield y x Annual precipitations $x_2$ | Y= 0.00978x -0.09788 | 0.620 |
| Maize | Yield y x Average annual temperature $x_1$ | Y= -54.93x+6,597.02 | 0.0013 |
| | Yield y x Annual precipitations $x_2$ | Y=0.005x+3.134 | 0.0128 |
| Sunflower | Yield y x Average annual temperature $x_1$ | Y= -181.69x+4,677.15 | 0.1180 |
| | Yield y x Annual precipitations $x_2$ | Y= 0.0052x +0.1211 | 0.2303 |

Source: Own calculations.

**yield depending on precipitations in an agricultural holding, in South East Dobrogea in the period 2018-2020**

As sunflower proved a high and positive coefficient of correlation between yield and precipitations, r= 0.479 at the national level, we considered to continue the analysis at the local conditions in the most dried area of Romania, in South Eastern Dobrogea, where the rainfalls are below 200 mm per year and the drought was very strong and for a longer period in the studied interval.

Using the data from [18, 19, 20], the deviations of rainfalls calculated by us in the agricultural years 2018, 2019 and 2020 from the 1991-1990 climatological norm, accounted for: +297.4 mm (+107.8%) in the year 2018, -95.2 mm (-35%) in the year 2019 and -140.7 mm (-52%) in the year 2020 (Figure 9).

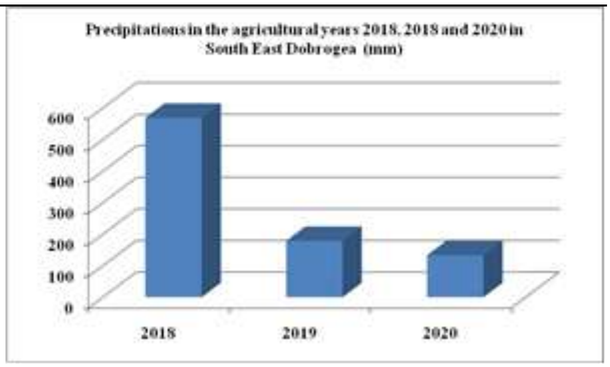


Fig. 9. Dynamics of precipitations in the agricultural years suitable to sunflower ( January-August) in the period 2018-2020 in South East Dobrogea
Source: Own design based on the data from [18, 19, 20].

The comparison between the rainfalls registered in the studied period and 1961-1990 climatological norm for each month of the agricultural year suitable to sunflower is shown in Figure 10.

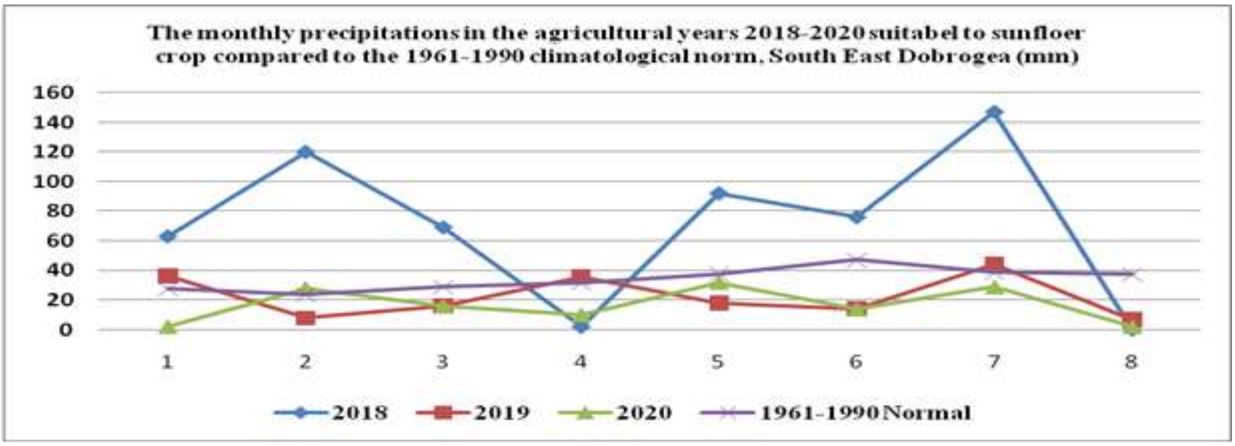


Fig. 10. The monthly precipitations in the agricultural years 2018, 2019 and 2020 compared to the 1961-1990 climatological norm
Source: Own design based on the data from [18, 19, 20].

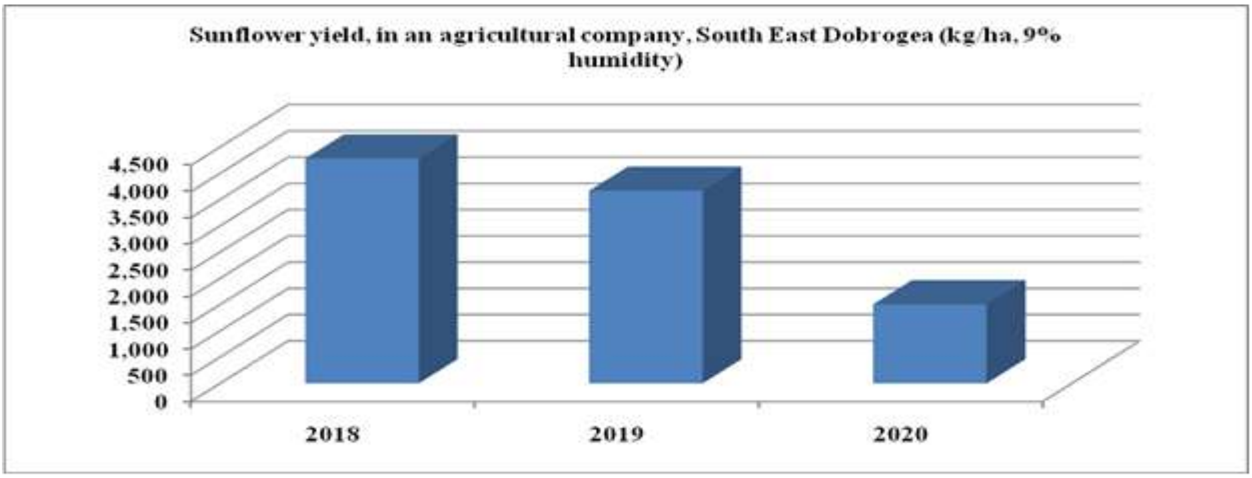


Fig. 11. Dynamics of sunflower yield, in an agricultural company, South East Dobrogea, 2018-2020 (kg/ha, 9% humidity)
Source: Own design based on the data from [18, 19, 20].

Sunflower yield declined from 4,282 kg/ha at 5% humidity in the year 2018, the best agricultural year for this crop, to 1,503 kg/ha in 2020, when it was by 65% smaller than in the year 2018 (Figure 11)

The correlation between precipitations and sunflower yield in the studied period was positive and very strong, r = 0.737.

Also, an increase in rainfalls by one unit could grow sunflower yield by 4.49 kg/ha as shown by the regression equation and the coefficient of determination $R^2$ = 0.544 reflects that 54.4% of the variation in sunflower seeds yield is determined by the variation of rainfalls (Figure 12).

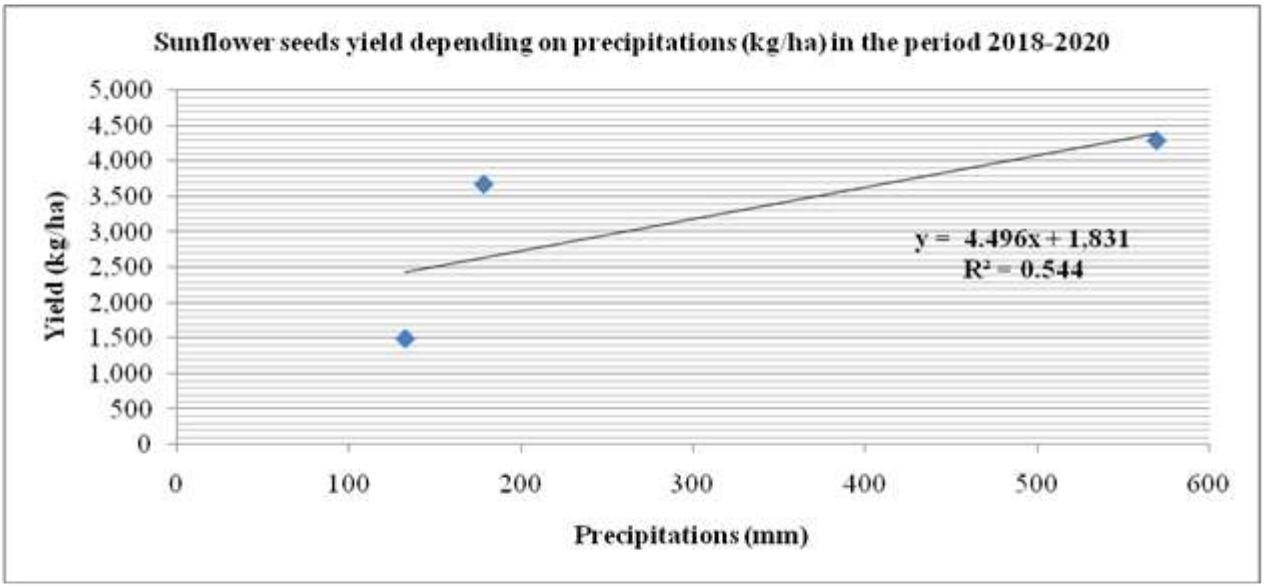


Fig. 12. The dependence of sunflower yield on precipitations, 2018-2020
Source: Own design and calculations based on the data from [18, 19, 20].

## CONCLUSIONS

This research study reflects the evolution of temperatures and precipitations levels as well as their impact on three important agricultural crops in Romania; wheat, maize and sunflower.

At the national level, the average air temperature increased reaching the highest level of 12.13$^0$C in 2019. However, in the period 2017-2020, the average annual temperatures exceeded the climatological norm 1981-2010 accounting for 9.1$^0$C.

The precipitations level registered a variation from a year to another, but the lowest rainfalls 614.2 mm were recorded in the year 2019, being below of 633.1 mm the climatological norm for the period 1981-2010.

The results showed large the variations regarding both the monthly air temperatures as well as the monthly precipitations from the climatological norms.

The high temperatures associated with drought and also the low precipitations have deeply affected yield of many agricultural crops, including maize, wheat and sunflower.

Wheat yield registered the highest performance of 4,888 kg/ha in the year 2017, and the lowest one, accounting for 2,966 kg/ha in the year 2020.

Maize yield registered the highest performance of 7,644 kg/ha in the year 2018, and the lowest one, accounting for 3,977 kg/ha in the year 2020.

Sunflower yield registered the highest performance of 3,041 kg/ha in the year 2018, and the lowest one, accounting for 1,858 kg/ha in the year 2020.

Therefore, the worst agricultural years for these three crops was 2020. The year 2017 favored wheat, while the year 2018 favored maize and sunflower.

In case of wheat, the values of the correlation coefficient (r=0.420) proved a positive and relatively moderate relationship between yield and average annual temperature and a strong relationship between yield and annual precipitations (r= 0.787).

In case of maize, the correlation coefficient reflected a weak and positive link between yield and the two climate factors: temperature (r=0.036) and precipitations (r=0.113).

In case of sunflower, the coefficient of variation reflected a relatively moderate connection between yield and temperature (r=0.343) and yield and precipitations (r=0.479).

The multiple correlation between yield, air temperatures and precipitations was: r= 0.817 for wheat, r = 0.116 for maize and r = 0.504 for sunflower.

The regression equations reflecting the dependence of yield on temperatures and precipitations have shown differences from a crop to another.

The study case run in South Eastern Dobrogea, the driest area in Romania, showed that the decline in rainfalls in the agricultural year 2018, 2019, 2020 had a deep negative impact on sunflower seeds yield, which decreased from 4,282 kg/ha at 9% humidity in the year 2018, to 1,503 kg/ha in 2020, when it was by 65% smaller than in the year 2018. In this part of the country, the correlation between precipitations and sunflower yield in the studied period was positive and very strong (r = 0.737).

This statistical analysis of yield level in close connection with two main climate factors: temperature and precipitations is not comprehensive, as yield depends on the combined effect of a large range of factors: soil type, its structure, quality (humus content and other nutrients), fertility level, water content, pollution degree, crop technology, the moment of application and quality of the agricultural works, varieties and hybrids and their production potential, the degree of resistance to drought, diseases and pests, work force training level, technical endowment, environment in terms of geographical area, climate factors and their evolution across the years (temperature and precipitations level, other weather conditions) in connection to the specific phenological development of each crop etc.

For this reason, the analysis at the national level has just indicative results which do not reflect a precise image of climate change impact on yield.

The influence of these factors should be analyzed under the local conditions of each farm and to represent a starting point to adapt the production technologies to climate change.

Farmers have to be aware that important measures have to be taken in order to sustain production and diminish the negative impact of climate change.

In this respect, a few recommendations are given below:

- to keep under control soil fertility, air temperature and water content for choosing the best moment for sowing, so that the seeds to germinate in good conditions;
- to use certificated seeds which are of the best quality for assuring a high germination rate and yield;
-to diminish the amount of chemical fertilizers and pesticides and to pass to organic agriculture;
-to chose varieties and hybrids of high value, well adapted to local conditions, resistant to drought, diseases and pests;
-to change the zone of crop farming to favorable areas;
-to establish an optimal crop structure including leguminous plants which are able to fix the nitrogen and plants which are able to achieve Carbon sequestration into the soil;
- to apply the agricultural works at the optimal moment and of high quality;
-to install protective forest curtains;
-to enlarge the surfaces covered by irrigation systems and utilize them in a more efficient way; to assure a high quality irrigation water.

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