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Assessment of Climate Change Impact on Maize Production in Serbia

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Abstract: Climate factors have an impact on plant life cycle, yield, productivity, economy and profitability of agricultural production. There are not a lot of studies on understanding of influence of climate factors variation on maize yield in agro-ecological conditions of Serbia. The aim of this paper is analysis of variation of climatic factors over a long-time period, as well as assessment of impact of the examined climate parameters on maize yield in two localities in the Republic of Serbia. For the analysis of climatic factors (temperature, precipitation, sunshine, humidity) in the region of Central Serbia and Vojvodina, the data of meteorological stations Kragujevac and Sombor during two thirty-year periods (1961–1990 and 1991–2020) were used. In order to determine the existence and strength of the relationship between the observed climatic factors and maize yield, a correlation analysis of these indicators for the period 2005–2020 years, was performed. In the period 1991–2020, the average values of temperature were annually increased for 0.046 °C in Kragujevac and for 0.05 °C in Sombor, and in the same period the average value of sunshine on an annual level was increased for 1.3 h in Kragujevac and for 5.01 h in Sombor, 2020 in comparison to average values in period of 1961–1990. The humidity was decline annually for 1.3 in Kragujevac and for 3.4 in Sombor in period 1991–2020 in comparison to average humidity in period of 1961–1990. The results of the correlation analysis showed that the maize yield was significantly lower in the years with expressed high temperatures and precipitation deficit. Based on these studies, established effect of climate change on maize yield and that this demand developing adaptation agricultural practice through creating maize hybrids and varieties with greater adaptability and improvement of agrotechnic measure.

Keywords: climate changes; Republic of Serbia; agriculture; maize; economic production

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1. Introduction

Climate change effects on plant growth and productivity of agricultural crops, what is connected with regional climate changes. The changes of temperature and precipitation trends have influence on yield with negative impacts on maize as well on wheat [1]. The increasing of temperature accelerates directly crop development and decline of seasonal amount of precipitation contribute to increasing of evaporation and evapotraspiration and together make drought stress for crops [2].

The distinction of regional climate changes is based on variation of heat waves, drought and amount of precipitation. The specificity of regional weather events indicate current risk or long term risk for production and required developing and application of prevention and adaptive measures for mitigating losses in the each subject of food production in chain [3].

Climate variability has been found that have significant influence on maize yield variation as well in other agricultural crops (rice, wheat, soybean) in different areas on the world [4]. Decreasing of maize yield as well other staple cereal in major producing regions, effected with weather and other conditions have negative impacts on price, trade and food security [5–7]. Climate change characterized by rising temperatures and changes in precipitation which would have mostly negative impacts on maize yields [8]. In study reported that yield of maize in China would decrease by 8% with a warming of 1 °C [9]. Higher temperatures and changes in precipitation have influence on social and economic activity for mitigation of negative impact of climate change on natural and agricultural resources through occurrence drought, heat stress, floods, rise of see level, lack of drinking water etc. The negative effect of projected climate changes on maize yield can mitigated by optimizing sowing date and plant density which contribute increasing of grain yield of spring maize, especially this adoption is more effective in spring maize with longer growing season [10]. Except that, in study of cultivated maize under rained conditions in Southern Italy and other similar climatic areas of the Mediterranean established that plants cultivated under deficit irrigation gained less biomass, slowdown of growth, prolonged period to ripening and lower yield. Also, significantly lower yield was observed under deficit irrigation treatments than under full irrigation [11].

The economics of climate change and modeling of the global economy-climate system are becoming increasingly important areas of economic research. Activities within the economic subsystem affect the processes within the climate subsystem, and these processes in turn affect the economic subsystem [12]. In the last two decades, we have witnessed great climate variability, which is expressed all over the world, even in our country. Fears of how it could affect food production, especially primary production, which is directly affected by climate change, have led a large amount of scientific research to be directed in this direction [13]. The causes and consequences of climate change are very diverse, low-income countries contribute the least to climate change and are most vulnerable to its effects [14].

Maize as one of the major crops in European Union (EU-28) which share is about 21% of total cereal production [15]. In Serbia maize is the most significant cereal which in last decade planted and harvested on approximately 1.15 million hectares with average yield 5300 kg ha^{-1} and in average total amount of production 5.7 million tons [16]. Also, maize is the most exported cereals with income over the 500 million US $ per year (Chamber of Commerce and Industry of Serbia, 2013), which share 40% of agricultural export. During the period 2004–2014 by agricultural trading realized surplus of 3.1 billion EUR in Republic Serbia [17].

Agriculture is important segment of the economy in Serbia. Both rural and urban areas are highly dependent on this branch of the economy. Observing the correlation between agriculture and economic development of a country, an inverse relationship can be observed, primarily measured by participation in GDP and GDP/per capita [18]. The economic policy in the agriculture is significant associated with primary production and have influence to income in agriculture, achievement of profit. In Republic Serbia, in rural region share about 85%, which characterized low productivity due to structure of ownership (mainly less than 10 ha land) of household, limited investment in modern technology. Also, in agriculture policy is not stable budget and plan of priority in agriculture development in rural area to become competitive in future [19,20].

However, it is very important to invest in the improvement of primary agricultural production, especially if there are favorable natural conditions, such as in the Republic of Serbia. Primary sector is the raw material basis of the food industry, which indicates a high degree of correlation and interdependence [21]. The potential for employment in the Republic of Serbia is also very important, because the agricultural sector contributes GDP about 6.0% and employs 18.7% of the working population [22]. The share of agriculture in GDP and national income in the period 1990–2004 was significantly higher to the current and amounted to 15–22% and employed 24% of the total number of employees in Serbia [23].

In period from 2012 to 2016 the growth rates of GDP in Serbia was from 1.0% in 2012 to 2.8% in 2016 and in this period agriculture and food industry accounted for 23.0% of the total GDP. The agriculture have share of 19.3% of total employment in economy of Serbia [24].

Climate change can be estimated on the base of detection and quantification of climatic conditions during the long term period by measuring values of changes in multi aspects of the climatic system [25]. The numerous studies estimated that climate change requires joint work to reduce the negative impact of climate change on the biosphere and for a safer life for society as a whole in the world [26,27]. The primary task is to mitigate climate change by bringing under control the sources of greenhouse gas emissions to slow and limit temperature rise. This is the way of avoiding the negative consequences of climate change and preventive measures to reduce financial investments for the necessary adaptations required by climate change [28–30].

Climate changes are also a long-term problem, because "the negative impact on crop production will be manifested on food production, and irregularities in the supply chain of raw materials will cause economic instability and social insecurity [31]." Agriculture is sensitive to weather conditions and therefore is directly exposed to the effects of climate changes. Changed weather conditions are reflected in agricultural production [32]. Adapting to the negative effects of climate change is essential to foster food safety [33].

Sustainable crop production based on application innovative developed or indigenous technologies developed over many generation give chance for adapting to existing climatic condition and achieving stable yield. The optimization of farming technologies under climate change conditions provides sustainable productivity of different agricultural production system [34]. The different input level in agricultural production under climate change, aimed to ensure existing yield and also increase yield levels. while the gross margin, as the difference between production value and variable costs, depends on market and economic conditions for production [35–37]. Food production and trade are of strategic importance for any organized society and market-oriented economy. The achievement of sustainable crop production as well maize production is necessary harmonization environmental, economic and social factors [38].

Maize is one of the most widely produced and consumed cereal crops in the world, and its global production reached 1.1 billion tons in 2019. In addition to its primary use for food, it is also used in industry [39]. Among agricultural crops, maize (kg ha^{-1}) is the most important crop product in the territory of Vojvodina and Central Serbia. In the structure of the harvested area under cereals, it dominates with 53.0% [40]. As the dominant crop, it is grown on over 35% of arable land [41], and the main economic importance of maize stems from its diverse use [42]. Also, in the Republic of Serbia maize is one of the important plant species whose yield and productivity vary under the influence of climate change [43]. Climate change is seriously affecting agricultural production, which endangers food security and causes market prices to rise. At different stages of its development, the society sets different tasks for agriculture, as well as for agricultural production, thus changes the economic position of this branch and its parts [44]. The knowledge of specificity of regional climate change enables adequate planning of crop production and adaptation of cultivation technology depending on specific ecological crops, soil characteristics of the region.

The aim of the research is to analyze climate elements (temperature, precipitation, number of sunshine hours, humidity) by comparing two thirty-year observation periods (1961–1990 and 1991–2020), to identify deviations, in order to further analyze the potential impact of climate changes on yield of selected agricultural crop (maize).

2. Materials and Methods

For analysis of variability values of weather condition during long time period used date of two places Sombor and Kragujevac which are on geographical distance. Those two regions characterize different orographic, edaphic and ecological factors. The Sombor region is spread in a steppe-continental plain area at an altitude ~90 m, on fertile soil chernozem type, with crumbly structure, rich in humus pH ~7.5. The chernozem is ideal type of soil for crop production according to their physical and chemical properties, The Kragujevac region is at an altitude ~182 m with a hilly area dominated by vertisol type of soil which is fertile with clay content, it is sticky and moderate acidity pH ~4.5–5.5 [45].

Sombor is located in northen part of Republic Serbia, in the region named Bačka in province Vojvodina, and Kragujevac islocated in the central region of Republic Serbia, in the region named Sumadija. The study of differences of climate change in micro regions will give new results which will be useful for assessment change of climatic factors and their possible effect on maize production as well assesment how to adapt sustain crop production in changed conditions.

The study of the impact of climate change on maize production in the Republic of Serbia, carried out through an analysis of the fluctuation of key meteorological parameters in correlation with changes in maize yields in two multi-year periods in the area of Sombor and Kragujevac.

In order to determine the level of variation of climate factors in Serbia, the following parameters were analyzed: maximum annual temperature (°C), mean annual temperature (°C), precipitation amount (mm), humidity (%), and sunshine (h) during two multy-year periods: 1961–1990. and 1991–2020.

Variation of climatic factors (temperature, precipitation, sunshine, humidity) was analyzed based on data from the main meteorological station in Kragujevac (φ 44°02N λ 20°56E, a.s. 185 m) and the main meteorological stations in Sombor (φ = 45°46N λ = 19°09E, a.s. 88 m) for two thirty-year periods (1961–1990 and 1991–2020).

A comparison of the established values of climatic factors and the dynamics of their variation in two thirty years periods in two localities and between localities was performed.

In order to determine the connection between the change of climatic factors and the grain yield of corn, the analysis of data on the production of this crop in the area of Kragujevac and Sombor was performed, as well as the dynamics of variation of climatic factors in these two localities for the period 2005–2020. The dynamics of changes in the values of climatic factors were analyzed in the vegetation period of maize (April-September). The database of the Republic Bureau of Statistics was used as a source of data on maize production in the observed period [46,47].

Descriptive statistics and analysis of variance were calculated by using the IBM SPSS 26 Statistics statistical program for analysis of the climatic factors. The interrelationship of the tested parameters (yield and price of maize, weather parameters) was expressed by the calculation of Pearoson's correlations coefficient (r),

$$\mathrm{r} = \frac{\sum x \cdot y}{N S_x S_y}$$

where: -x and y—deviation from the arithmetic mean of variables X and Y; N—number of items; S_x—the error of the arithmetic mean for the variable X; S_y- the error of the arithmetic mean for the variable Y;

The significance of the correlations was tested by a t-test for $\mathrm{n} - 2$ degrees of freedom and a significance threshold of 0.05 and 0.01 [48], according to the following formula

$$\mathrm{t} = \frac{\mathrm{r}\sqrt{\mathrm{n} - 2}}{\sqrt{1 - \mathrm{r}^2}}$$

where: -r—correlation coefficient, -n—number of analyzed parameters;

The linear regression method shows the degree of correlation between the variables of the summary model analysis and the ANOVA test. For analysis effect of temperature, sunshine, humidity and precipitation on maize yield, in each of two regions, were used regression model as a reliable mathematical function for description the dependence of random variable Y (dependent) in terms of one or more non-random (independent) variable (X), by using basic formula:

$$Y = f(X1, X2, \ldots..Xk) + \varepsilon$$

where Y—dependent variable, X_1, X_2, . . . , X_k—independent variables, f—some of the mathematical functions whose form depends on a specific example of interdependence of the studied phenomena, ε—random (stochastic) variable that expresses non-systemic influences on the dependent variable or error).

The strength of connection is determined by analyzing a random variable of the regression model. The random variable represents non systemic influences, i.e., the influences of phenomena that are not included in the model. According to the number of variables included in the model, regression models are divided into simple and multiple. A simple regression model has one dependent and one independent variable, and multiple models have one dependent and two or more independent variables.

A panel analysis was done between two models that obtained in analysis of two regions. Both models were made using a multiple regression analysis, in addition to the correlation (Pearson's), the *Beta* coefficient was calculated, in order to obtain the exact influence of all weather conditions on corn yields. The results that were obtained clearly point out that those parameters are key in value of maize yield. In addition, the Panel analysis gives a clear overview between the results in two different regions, in which the climatic conditions are different.

3. Results

3.1. Analysis of the Fluctuation of Selected Climatic Parameters during Long-Term Period

The analysis of climatic condition in two different locations (Kragujevac and Sombor) in Serbia, during the two thirty-year periods (1961–1990 and 1991–2020) showed changes in the following climate factors: temperature, precipitation, sunshine, and humidity. The analysis of values of temperature showed that in both regions was fluctuation of average temperature per year within both long term periods. In first long-term period (1961–1990) the average temperature value in Kragujevac (11.0 °C) was higher than in Sombor (10.5 °C). Also, in second long term period (1990–2020) the average temperature in Kragujevac (12.1 °C) was higher than in Sombor (11.7 °C). However, in both region the average temperature for recent long period (1991–2020) was higher than in previous (1961–1990). In Kragujevac the average temperature per year in 18 year was higher (>12.1 °C) than average temperature (12.1 °C) for long term period (1991–2020), while in the same long term period in Sombor was 15 year with average temperature values that are higher (>11.7 °C) than average temperature (11.7 °C) for long term period. In Kragujevac, the 10 from 18 year are with higher average temperature than average temperature for long term period was the last year of period (2011–2020), and in Sombor nine of 15 year is with higher average temperature than average temperature for long term period was the last year of period (2011–2020). In both region average temperature values in recent long term period (1991–2020) was higher than in previous long term period (1961–1990) for 1.1 °C in Kragujevac and 1.2 °C in Sombor (Figure 1).

By comparing the values of the average annual air temperatures by months between the two thirty-year's periods in the meteorological station Kragujevac, deviations can be noticed. The largest deviations are in the summer months, for July the deviation is 2 °C, August 1.9°C and June 1.7 °C. It is noted that the average January air temperature in the second observation period (1991–2020) was positive with 1.3 °C compared to the climatological norm (1961–1990), where it was minus 0.1 °C. Deviations are observed in all other months and range from 0.5 °C (December) to 1°C (November). Average annual temperature deviation between the two observation periods is also noticeable and was 0.9 °C (Figure 2).

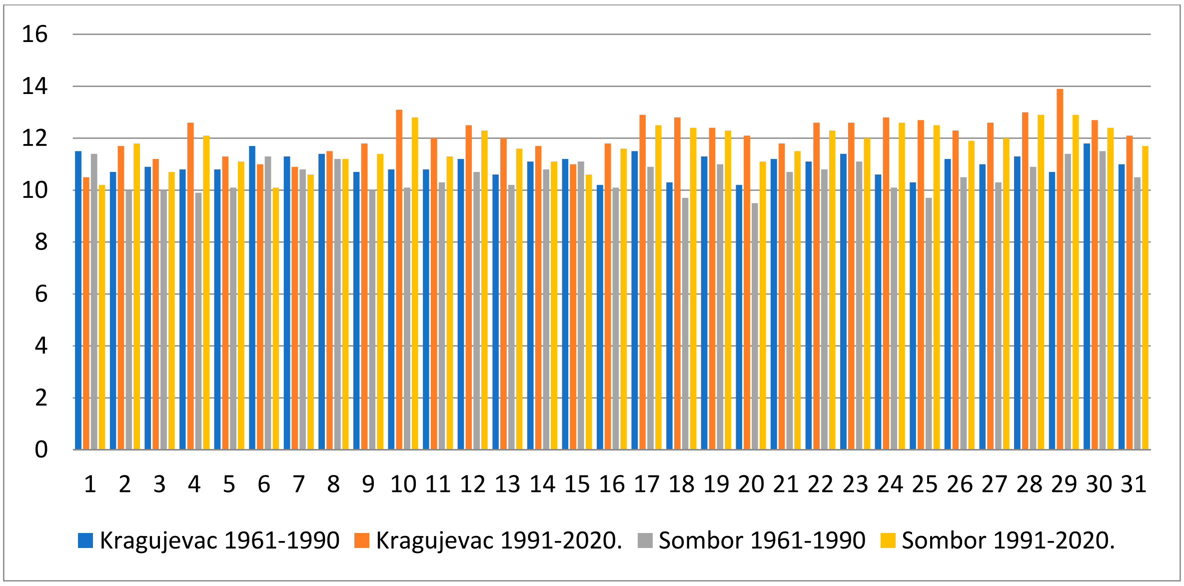

Figure 1. Average temperatures per year and two long period 1961–1990 and 1991–2020 in Kragujevac and Sombor. Remark: 1–30 are average t values per year for each period and each region; 31-average values for each period and each region.

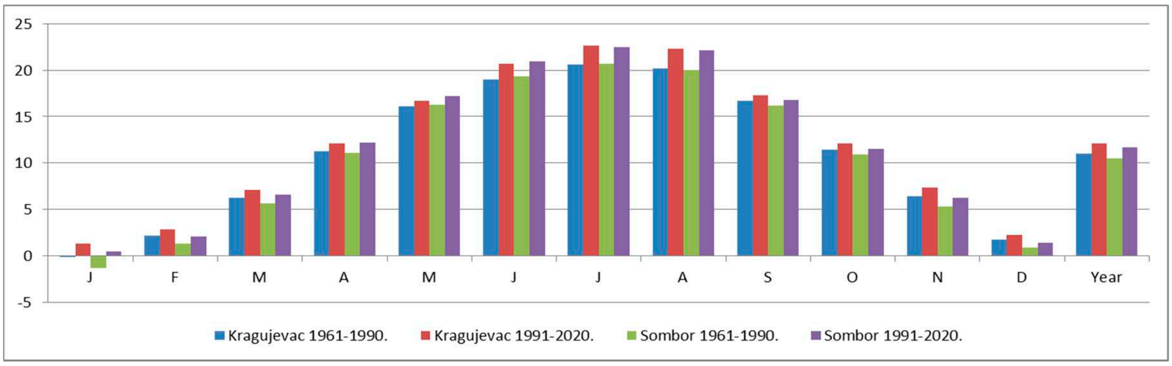

Figure 2. Average monthly temperatures per month and year for the period 1961–1990 and 1991–2020 in Kragujevac and Sombor.

The average monthly air temperatures values in the meteorological station Sombor for the same observation period show the deviations that are greatest in the summer months: August 2.1 °C, July 1.8°C and June 1.6 °C. Deviations for the average January temperature are 1.8 °C. At the annual level, the deviations between the two thirty-years periods for the meteorological station Sombor are more pronounced than the meteorological station Kragujevac and amount to 1.2 °C (Figure 2).

The values of average maximum temperatures in both locations (Kragujevac and Sombor) in the Republic of Serbia in each month from January to December were higher in the second long period (1991–2020) than in the same months in the first long period (1961–1990). The average value of maximum temperatures at the annual level in Kragujevac was 1.4 °C higher, and in Sombor 1.5 °C higher in the second long period (1991–2020) than in the same months in the first long period (1961–1990). The increasing of average maximum temperatures in Kragujevac was 1.9 °C in January and June, followed July by 2.1 °C and the highest in August by 2.3 °C, while the lowest 0.7 °C in September in the second period (1991–2020), compared to the same months in the first long period (1961–1990). In the Sombor, the largest increase in average maximum temperatures was in January by 2.1 °C, in June and July by 1.9 °C and in August by 2 °C, while the smallest in September by 0.4 °C, in October by 0.5 °C, and December by 0.6 °C, in the second period (1991–2020) compared to the same months in the first long period (1961–1990) Figure 3.

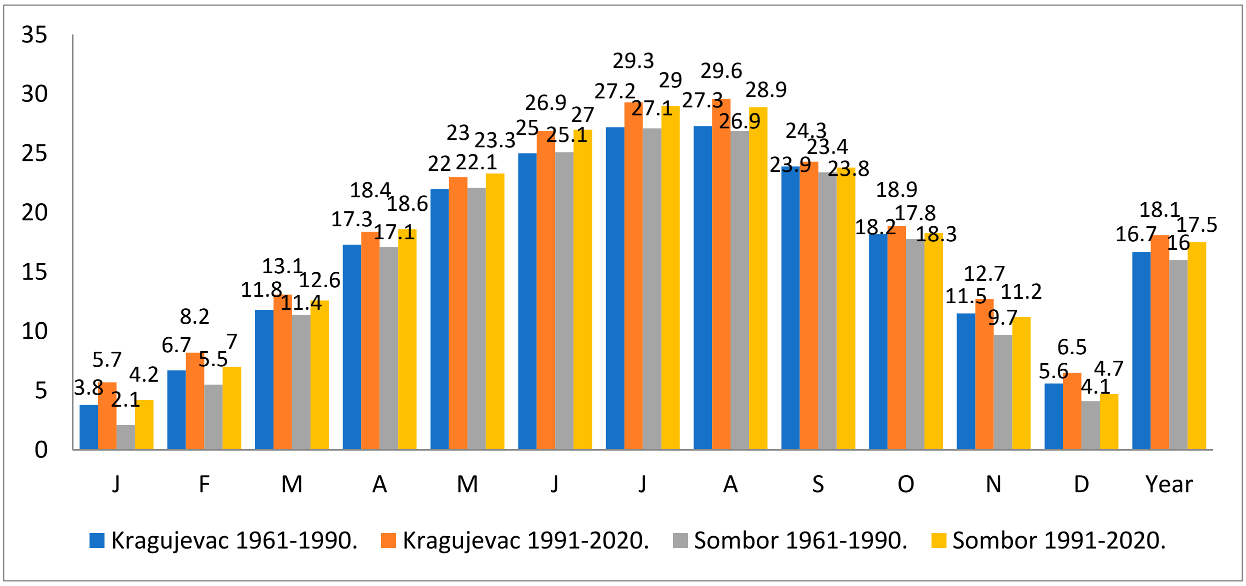

Figure 3. Maximum temperature for the meteorological stations Kragujevac and Sombor for a period of time 1961–1990 and 1991–2020. Source: RHMS-Meteorological yearbooks.

Total amount of precipitation per year varied in both region and in both long term period. In first long-term period (1961–1990) the total amount of precipitation in Kragujevac was higher than in Sombor in 23 years, but in seven years precipitation values was higher in Sombor region than in Kragujevac. The lowest amount of precipitation was 401 mm in 1971 year and highest in 1974 in Sombor, while in Kragujevac during the first period the lowest precipitation was 413 mm in 1990 year and the highest 901 mm in 1970 year. In second long term period (1991–2020) in the total amount of precipitation in 1997–2003 2005, 2006,2009, 2011–2017 2019–2020 was higher in Kragujevac than in Sombor region. The lowest amount of precipitation in Sombor was 277 mm in 2000 year and the highest 1035 mm in 2010 year, while in Kragujevac during the second period the lowest precipitation was 379 mm in 2000 year and the highest 839 in 1999 year in Kragujevac (Figure 4).

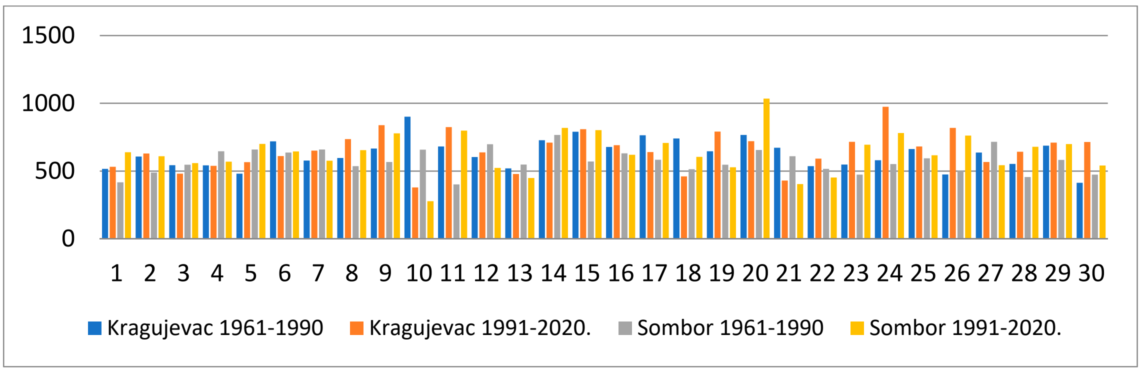

Figure 4. Amount of precipitation per year in Kragujevac and Sombor for the periods 1961–1990 and 1991–2020.

The average annual value of precipitation in the Kragujevac region in the second long time period (1991–2020) was 652.3 mm and that amount of precipitation is slightly higher than during the first long time period (1961–1990) with an average annual precipitation of 627.6 mm. Also, in the region of Sombor, there was an increase in average annual precipitation in the second period (1991–2020) with a value of 635.5 mm, while in the first period (1961–1990) it was 573.5 mm (Figure 4).

Although the amount of precipitation was lower in the second period (1991–2020) than in the first period (1961–1990), it was found that these were the months with the highest average amount of precipitations (Figure 4). The amount of precipitation less than 500 mm in Kragujevac was in following years: 1993 (480.9 mm), 2000 (378.8 mm), 2003 (478.1 mm), 2008 (461.4 mm) and 2011 (430.3 mm), and in Sombor was in 2000 (277.5 mm), 2003 (449.3 mm), 2011 (403.8 mm) and 2012 (452.6 mm).

The distribution of average monthly precipitation was different in the locations selected for the study over two multi-year periods. In both region in the both long term period the highest precipitation was in June and then in May in Kragujevac and in July in Sombor region (Figure 5).

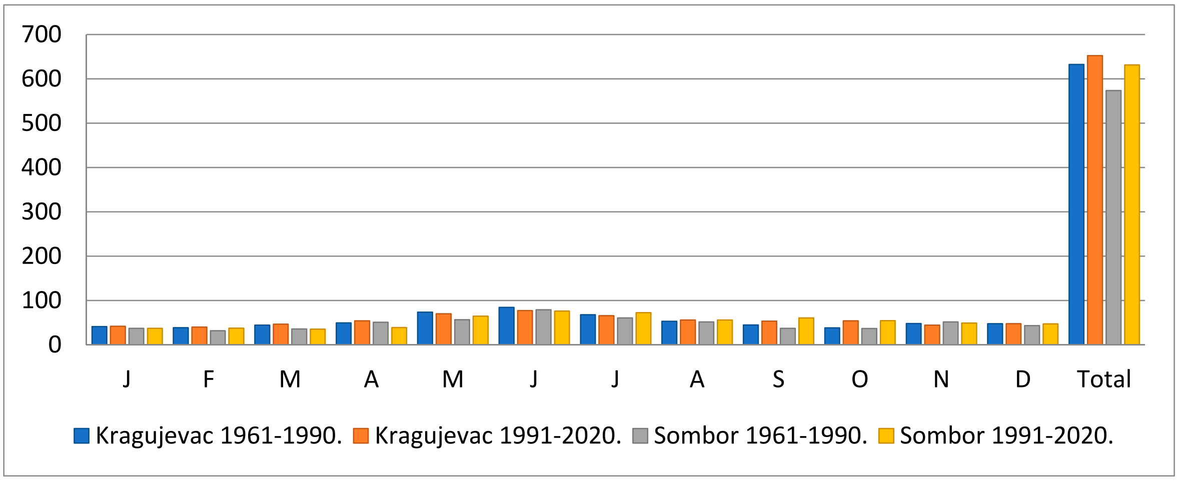

Figure 5. Amount of precipitation per month and average amount per year in Kragujevac and Sombor for the periods1961–1990 and 1991–2020.

The average amount of precipitation in the first long term period in both region (Kragujevac and Sombor) was the lowest in October, than in February, January, March and September. In second long term period the lowest amount of precipitation was in February, January, March, November and December (Figure 5).

In comparison of values of precipitation in Kragujevac region in January, February, March, April, August, September, October, December, and in Sombor region in January, February, March, May, June, November, established that the average amount of precipitation per month was higher in second long term period (1991–2020) than during the first long term period (1961–1990) Figure 5.

However, the values of average monthly precipitation in the second long-term observation period (1991–2020) in relation to the period (1961–1990) were reduced in the months when precipitation was most necessary for the vegetative development of plants. In the region of the Kragujevac locality, the decrease in the amount of precipitation was in the months: May, June and July. In the region of the Sombor locality, the decrease in the amount of precipitation was in the months: April, and June (Figure 6).

Relative humidity as a significant climatic element is the amount of water vapor in the atmosphere and it depends on the air temperature with which it is inversely proportional. The average monthly values of humidity varied in both long time period and were different in both region i.e., Kragujevac (Central Serbia) and Sombor (Vojvodina), Figure 7.

Average monthly and annual values of relative humidity have a decreasing trend in both locations (Kragujevac and Sombor) in the territory of the Republic of Serbia. In both, Kragujevac and Sombor region during the second long term period (1991–2020), the average humidity values were less than average humidity in every month and per year in the first long time period (1961–1990). In Kragujevac, the prominent decreasing humidity recorded in July and August for approximately 5.0%, while in Sombor region the prominent decreasing humidity recorded in June, July and August for approximately 5.3% in second long time period (1991–2020) in comparison to first long time period (1961–1990). Also, in Sombor region average values of humidity decreased for about 4.0% in March, April, May in second long time period (1991–2020) in comparison to first long time period (1961–1990).

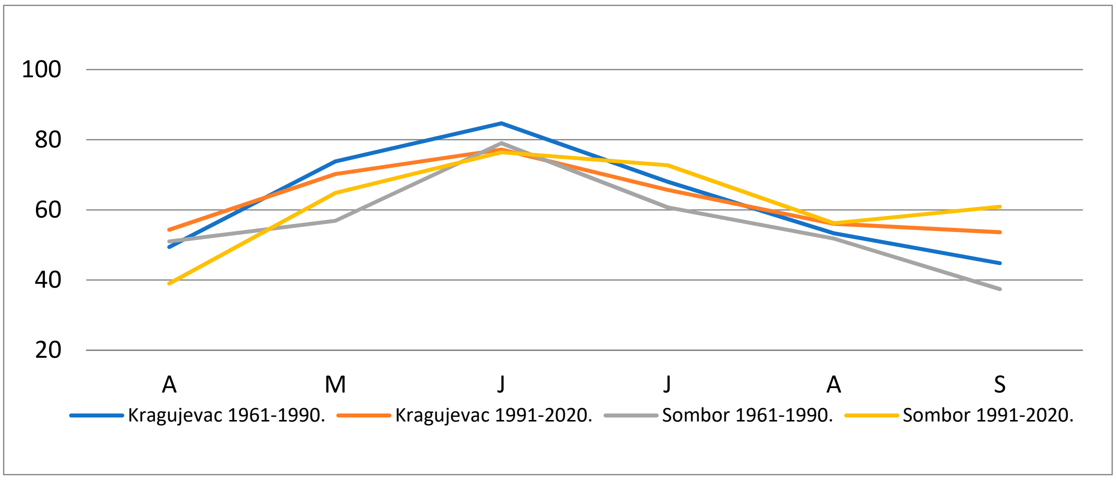

Figure 6. Amount of precipitation in average per month from growth stage to ripening of maize (April-September) in Kragujevac and Sombor for the periods 1961–1990 and 1991–2020. Source: RHMS-Meteorological yearbooks.

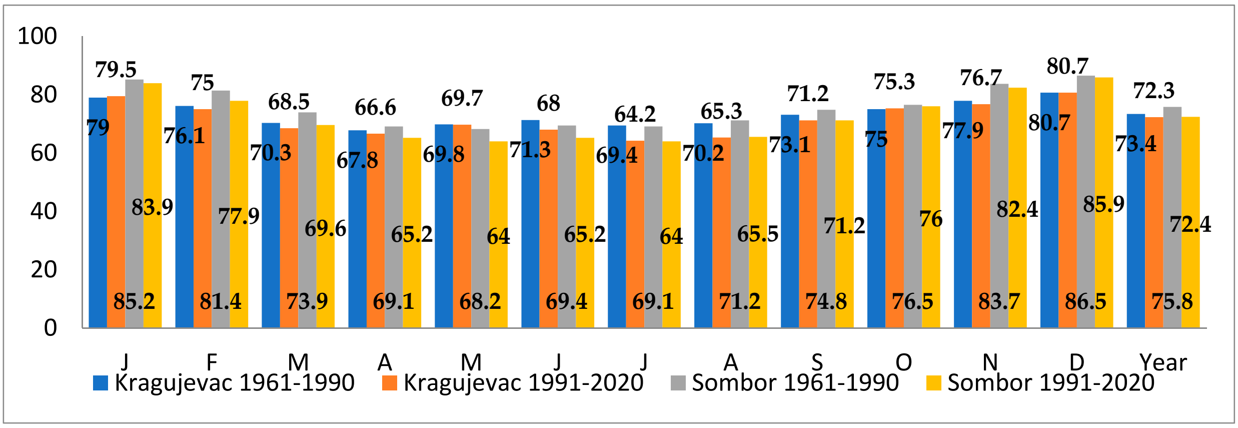

Figure 7. Annual average monthly values of relative humidity (Januar-December) in Kragujevac and Sombor for a period of time 1961–1990 and 1991–2020. Source: RHMS-Meteorological yearbooks.

The number of sunny hours varied in both long-term periods (1961–1990 and 1991–2020) and was the lowest in December and the highest in July in both regions Kragujevac and Sombor) Figure 8.

The average annual values of sunshine hours in the Kragujevac region in the second period (1991–2020) were 39.2 h higher than in the first period (1961–1990), in the climatic normal (1961–1990). Also, the values of sunshine in Sombor, in the second long-term period (1991–2020) were higher for 151.5 h than in the first period (1961–1990). Comparison by months of two multi-years periods, the values for sunshine increased from January to August, and decreased from September to December in both localities during both long periods. In average in the months from January to August the sunshine (in hours) was higher in both localities (Kragujevac and Sombor) in the second long period (1991–2020) than in the same months in the first long period (1961–1990). Also, the average value of sunshine in December in Kragujevac and in November in Sombor was higher in the second period (1991–2020) than in the first period (1961–1990). However, in September, October and November in Kragujevac, as well as in September, October and December in Sombor, the values of sunshine hours in the second long period (1991–2020) are lower than in the same months in the first long period (1961–1990) Figure 8.

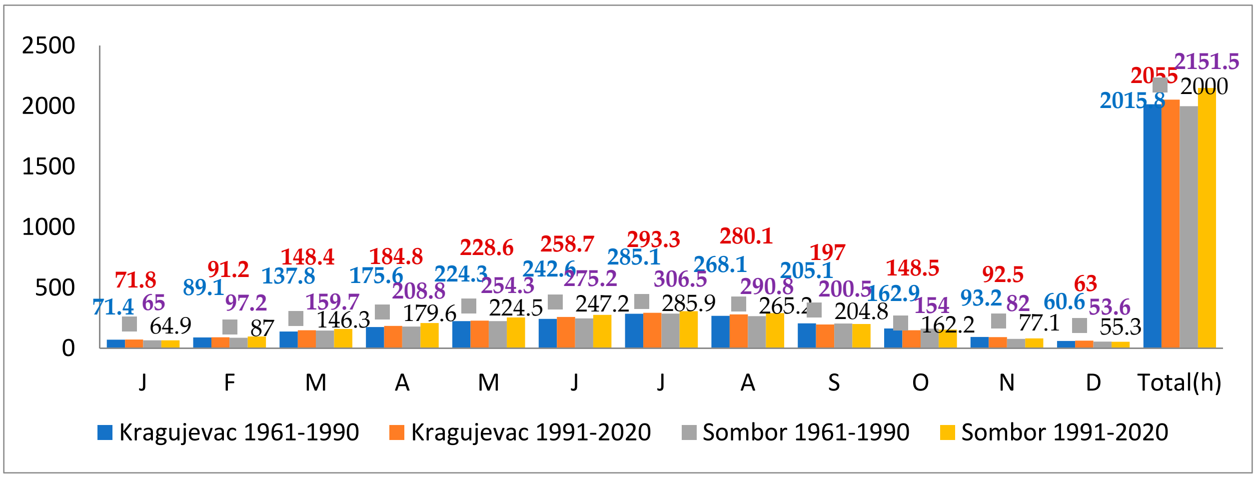

Figure 8. Average annual per monthly values of sunshine and total yearly average of sunshine in Kragujevac and Sombor for a period of time 1961–1990 and 1991–2020. Source: RHMS-Meteorological yearbooks.

The variation of sunshine, precipitation and humidity and association with yield of maize in both region Kragujevac and Sombor which were analyzed. The estimated values were different in those two regions. Yield of maize in Sombor was higher than in Kragujevac region in each year during long term period.

The sunshine values were higher in Sombor region than in Kragujevac region, while this difference was less than expressed differences for yield of maize. The amount of precipitation during growth period was higher in Sombor than in Kragujevac region period from 2010 to 2020, while in period from 2005 to 2009 was approximately on the same level. Humidity of air in Sombor was without significant deviation and approximately on the similar level, while in Kragujevac, humidity n some year was higher than in Sombor region (Figure 9).

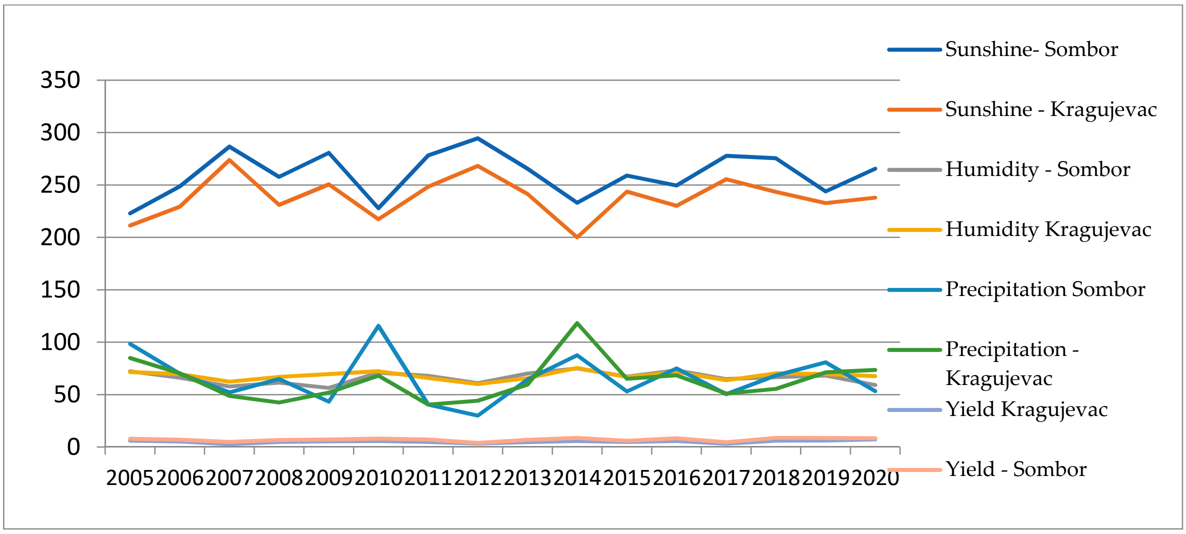

Figure 9. Variation Yield and purchase price of maize in the Republic of Serbia for the period 2005–2020.

Based on the average values of six variables for a period of 16 years and the values of standard deviation, the descriptive analysis found that the average yield of maize in Vojvodina (7000 kg ha^{-1}) is significantly higher than Central Serbia (5000 kg ha^{-1}), as and deviations (1500 kg ha^{-1}) that are larger than the area of Central Serbia (1200 kg ha^{-1}) Table 1.

Table 1. Descriptive analysis of the space of the Republic of Serbia for the time period 2005–2020.

	Mean	Std. Deviation	N	Mean	Std. Deviation	N
	Sombor (Vojvodina)			***Kragujevac (Central Serbia)***		
Maize yield	7000	1500	16	5000	1200	16
Average temperature	18.9	0.7	16	18.8	0.8	16
Maximal temperature	25.4	1.1	16	25.6	0.09	16
Precipitation	392.9	134.5	16	380.2	116.3	16
Humidity	66.1	5.6	16	68.0	4.0	16
Sunshine	1548.6	162.4	16	1430.5	116.1	16

The average temperature in Sombor, for the vegetation period of maize was 18.9 °C, for the time period 2005–2020. Variation of the average value of temperature ranged from 17.7 °C in 2005 to 20.4 °C 2018. The average temperature in Kragujevac was 18.8 °C, and the variation of the average temperature value ranged from 17.2 °C in 2006 to 19.9 °C in 2018.

The maximum temperature in the vegetation period of maize in Sombor was 25.4 °C, which varied in the range from 23.5 °C in 2005 to 27.3 °C in 2012. The maximum temperature in Kragujevac in the vegetation period of maize was 25.6 °C and varied in the range from 23.9 °C in 2005 to 27.5 °C in 2012.

Humidity in Sombor was 66.1%, with a deviation of 5.6%, which was slightly lower than in Kragujevac, where the humidity was 68.0% with a deviation of 4.0%. The lowest average value in the vegetation period of maize in Kragujevac was 60.6% (2012), while in Sombor the lowest average value was 57.8% (2007). The highest value of humidity in the vegetation period of maize in both locations was in 2014, whose value was 75.5% (Kragujevac) and 75.0% (Sombor) Table 1.

Sunshine in Kragujevac over the year for the period 2005–2020 is 2021.8 h averaged, while in the vegetation period it was 1430.5 h, and in the remaining period it is 591.3 h. The deviation of sunshine in the vegetation period was 116.1 h. The insolation interval varied from 1200.7 h in 2014 to 1642.7 h in 2007. Sunshine in Sombor, for the same time period (2005–2020), over the year was 2151.5 h, while in the vegetation period it amounted to 1548.6 h. In the remaining period the sunshine in average was a 602.9 h with a deviation of 162.4 h. The interval of sunshine in the vegetation period varied from 1308.4 h in 2005 to 1767.1 h in 2012 (Table 1).

3.2. Modeling of the Relationship between the Analyzed Meteorological Parameters and Maize Yield

According to the descriptive analysis, a slight deviation of some variables (climatic conditions) was found between the values measured in the meteorological station in Vojvodina (Sombor) and in the meteorological station in Central Serbia (Kragujevac). For further analysis, the Pearson's correlation degree was used to estimate which one of the five climatic condition have impact on maize yield in Vojvodina and Central Serbia, as well as ocean determination of correlation dependence of analyzed variables. Based on the analysis of maize yield and weather conditions in Vojvodina, Pearson's correlation coefficient shows that all five independent variables (air temperature, sunshine, humidity, precipitation) are correlated ($p < 0.01$ and $p < 0.05$) with dependent variable (maize yield).

Namely, the negative correlation (r = −0.549 *) has sunshine with the yield of maize, i.e., increased sunshine is the cause of extremely high maximum and average air temperatures, increased evapotranspiration, the appearance of water deficit in the soil as well as drought stress, which affects the reduction of maize yield (Table 2).

Table 2. Correlation between annual values of climate elements and maize yield (t ha^{-1}) in the Republic of. Serbia in the period 2005–2020.

		Vojvodina (Meteorological Station Sombor)					Central Serbia (Meteorological Station Kragujevac)				
		Sunshine (h)	**Precipitation (mm)**	**Max Temperature (°C)**	**Aaverage Temperature (°C)**	**Humidity (%)**	**Sunshine (h)**	**Precipitation (mm)**	**Max Temperature (°C)**	**Aaverage Temperature (°C)**	**Humidity (%)**
Maize yield (t/ha)	Pearson correlation	−0.549 *	0.629 **	−0.420	−0.345	0.497 *	−0.692 **	0.532 *	−0.575 *	−0.488	0.762 **
	Sig.(2-tailed)	0.027	0.009	0.105	0.190	0.050	0.003	0.034	0.020	0.055	0.001
Sunshine (h)	Pearson correlation		−0.861 **	0.875 **	0.798 **	−0.676 **		−0.797 **	0.926 **	0.772 **	−0.890 **
	Sig.(2-tailed)		0.000	0.000	0.000	0.004		0.000	0.000	0.000	0.001
Precipitation (mm)	Pearson correlation			−0.830 **	−0.699 **	0.684 **			−0.764 **	−0.656 **	0.751 **
	Sig.(2-tailed)			0.000	0.003	0.004			0.001	0.006	0.001
MaxTemperature (°C)	Pearson correlation				0.951 **	−0.606 *				0.923 **	−0.785 **
	Sig.(2-tailed)				0.000	0.013				0.000	0.000
AverageTemperature (°C)	Pearson correlation					−0.498 *					−0.644 **
	Sig.(2-tailed)					0.050					0.007
N		16	16	16	16	16	16	16	16	16	16

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed). Source: Authors processing in SPSS.26.

In the Vojvodina, the other two variables, air humidity (r = 0.497 *) and rainfall (r = 0.629 **) are positively correlated with maize yield, but to a slightly different extent than in the Central Serbia. This indicate that precipitation approximately 62.9% influenced increasing the maize yield, greater than the impact of humidity, which also has a positive relationship with maize yield (49.7%). All five independent variables are in a linear relationship with the dependent variable (maize yield).

Based on the analysis of maize yield and weather conditions in Central Serbia, according to Pearson's correlation coefficient, all independent variables are in a linear relationship with the dependent variable (p <0.01 and p <0.05). The analysis shows that sunshine has a negative correlation (r = −0.692 **) with maize yield (Table 2). Also, it was found that maize yield and maximum temperatures have a negative correlation (r = −0.575 *). In Central Serbia, maize yield is positively correlated with precipitation (r = 0.532 *) and humidity (r = 0.762 **), which indicates higher rainfall and higher humidity have had a positive effect on increasing maize yield (t ha^{-1}) in the period from 2005–2020.

In Central Serbia, the analysis confirmed that the average and maximum values of temperature have a positive correlation with maize yield and sunshine, and a negative correlation with humidity and rainfall. All coefficients are statistically significant, so they can be considered accurate and reliable (Table 2).

According to the results of the parameters that test the model, it can be said that both models provide more information compared to descriptive statistics. The model of multiple regression analysis shows the intensity of the correlation between the research variables. The multiple correlation coefficient (R) for the area of Vojvodina is 62.3%, and for the area of Central Serbia is 74.7%. The coefficient is greater than 0.6 and it is a high intensity of the correlation between the variables. The coefficient of determination (R Square shows) shows the influence of independent variables on the change of the dependent variable (maize yield).

It is 40.4% for the area of Vojvodina, and 56.9% for the area of Central Serbia, which is a moderate level of influence. When it comes to Central Serbia, the standard error (Std. Error of the Estimate) is significantly smaller compared to the standard error for the area of

Vojvodina. Durbin Watson test shows whether there is a correlation between the residuals (Table 3).

Table 3. Regression analysis for correlation of climate elements and maize yield in the Republic of Serbia for the period 2005–2020.

Model	Model Summary									
	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
Vojvodina	0.623 [a]	0.404	0.263	1.30253	0.404	2.810	3	12	0.042	2.123
Central Serbia	0.747 [a]	0.569	0.476	0.76990	0.539	5.425	3	12	0.014	1.855

[a] Predictors: (Constant): Precipitation, humidity, sunshine, temperature (max. average); [b] Dependent Variable: Maize yields. Source: Authors processing in SPSS.26.

Based on the analysis of variance, the relationship between the independent variables (air temperature (average and maximum), sunshine, precipitation, humidity) and the dependent variable (maize yield) the hypothesis was set:

-X1: Climate elements (temperature, precipitation, humidity, sunshine) affect the yield of maize.

Based on the sample size and the empirical value of the F test, a significance value was obtained, which in the case of multiple regression is Sig. = 0.04 and Sig. = 0.01, so F is statistically significant, and the hypothesis is accepted: Climate elements (temperature, precipitation, humidity, sunshine) affect maize yield, which means that it makes sense to use a regression model. In this case, the analysis showed that there is a compatibility of dependent and independent variables, and that it is statistically significant, less than the significance level of 0.05. Based on the ANOVA test (Table 4), it was found that there is a high degree of interdependence between the analyzed variables, which confirms that the hypothesis is proven, i.e., there is a significant relationship between the dependent variable (maize yield) and the independent variables (climate elements).

Table 4. Indicators of regression analysis for the correlation of climatic elements and maize yield in the Republic of Serbia for the period 2005–2020.

Model	ANOVA [a]					
		Sum of Squares	df	Mean Square	F	Sig.
Vojvodina	Regression	14.577	3	4.853	3.011	0.049 [b]
	Residual	20.673	12	1.723		
	Total	35.249	15			
Central Serbia	Regression	12.997	3	4.332	5.725	0.011 [b]
	Residual	9.081	12	0.757		
	Total	22.078	15			

Source: Authors processing in SPSS.26. [a] Dependent Variable: Maize yields; [b] Predictors: (Constant): Precipitation, humidity, sunshine, temperature (max. average).

The obtained values of the coefficients of the model indicate that there is a positive correlation between maize yield and humidity, which is the highest, then between maize yield and precipitation, and that there is a negative correlation between sunshine and maize yield in the Kragujevac region (Central Serbia). Based on the analysis of the results, it was established that an increase in humidity by 1.0% is linked with an increase in maize yield by 0.6%. However, in Vojvdina the obtained values of the coefficients of the model indicate that the highest positive correlation is between amount of precipitation and maize yield, and than between humidity and maize yield, while negative correlation was between sunshine and maize yield. It was found that that an increase of precipitation by 1.0% is related to an increase in maize yield by 0.7%, while that an increase in sunshine by 1.0% was linked with a decrease in maize yield for 0.1% (Table 5).

Table 5. The comparioson of coefficient relationship between climatic elements and maize yield in two location in the Republic of Serbia for the period 2005–2020.

Model		Standardized Coefficients Beta	t	Sig.
Vojvodina	(Constanta)		−0.2964	0.013
	Sunshine (h)	−0.147	−2.431	0.031
	Humidity (%)	0.580	2.250	0.041
	Precipitation (mm)	0.749	2.642	0.022
Central Serbia	(Constanta)	−2.523	−2.505	0.023
	Sunshine (h)	−0.179	−1.932	0.046
	Humidity (%)	0.631	2.780	0.019
	Precipitation (mm)	0.336	2.437	0.032

Dependent Variable: Maize yields.

The value of the coefficients of the model are representing the influence of the humidity, precipitation and sunshine (independent variable) on the maize yield (dependent variable) are statistically significant (r < 0.05).

3.3. Relationship between Maize Yield and Purchase Price

In Republic Serbia, the cultivation area of maize crops varied per year during the period of obsrvation. In generally the area of cultivation maize crops is higher in Central Serbia where is located Kragujevac (Šumadija region) than in North Serbia in province Vojvodina where is located Sombor. The area on which maize is grown in the analyzed period in North Serbia (Vojvodina) is approximately from 30% to 40% smaller than the area with maize crops in Central Serbia. Cultivated area in North Serbia (Vojvodina) varied between 355,407 ha in 2014 year and 421,573 ha in 2005 year, while in Central Serbia the lowest cultivated area was 550,388 ha in 2018 year and the highest 656,869 ha in 2014 year (Figure 10).

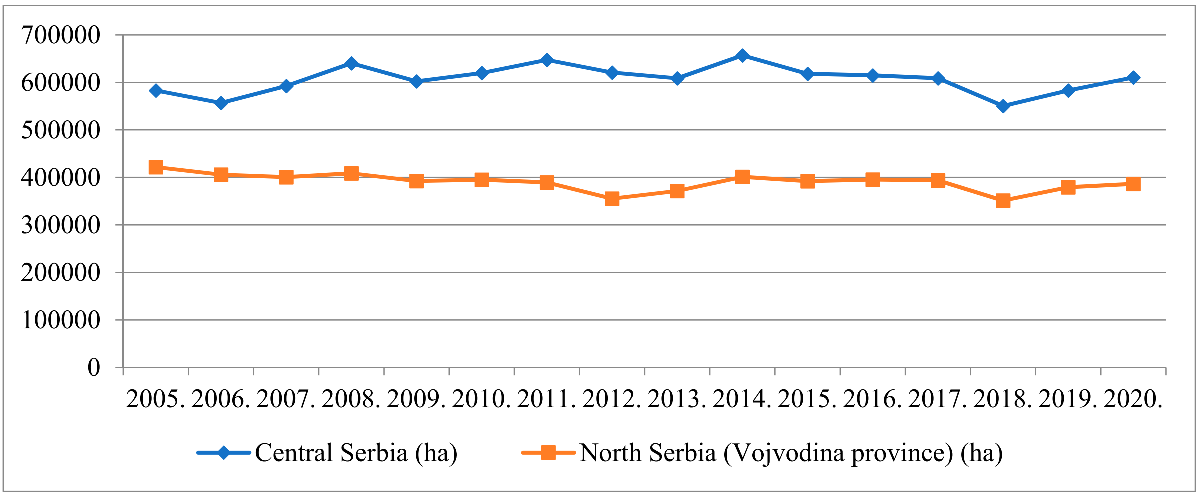

Figure 10. Area of cultivation maize crops in Republic Serbia during the period 2005–2020.

The achieved yield on planted area calculated in kg per hectare and obtained data of quantity production collected in database of Serbian Chamber of Comerce.

According to the results of the analysis of variation maize yield and purchase price of maize per year the Pearson's correlation degree was used to estimate correlation dependence of tose two analyzed variables (Table 6).

Table 6. Correlation between annual purchase price of grain maize and maize yield (t ha^{-1}) in the Republic Serbia in the period 2005–2020.

		Price	**Vojvodina Yield**	**Central Serbia Yield**
Price	Pearson Correlation	1	−0.564	−0.548
	Sig. (2-tailed)		0.023	0.045
	N	16	16	16
Vojvodina Yield	Pearson Correlation	−0.564	1	0.916 **
	Sig. (2-tailed)	0.023		0.000
	N	16	16	16
Centralna Srbija Yield	Pearson Correlation	−0.548	0.916 **	1
	Sig. (2-tailed)	0.045	0.000	
	N	16	16	16

** Correlation is significant at the 0.01 level (2-tailed).

The obtained value of Pearson's correlation coefficient, indicate that there is a negative correlation between the yield of maize in Vojvodina and Central Serbia and the purchase price of corn. Namely, it is visible that both coefficients are in a negative relationship, which shows that in the years when the price increased, the maize yield decreased and vice versa. In addition, all analyzed correlation coefficients are statistically significant because $p < 0.05$. Also, it is important to emphasize that there is a strong correlation between corn yields in Vojvodina and Central Serbia (Table 6).

The obtained negative correlation shows that the price of grain maize is largely determined by the yield. Given that the formation of the purchase price of grain maize is not only influenced by the yield, but also price influenced by numerous elements such as: costs of seeds, fuel, fertilizers, pesticides, plowing, sowing, application fertilizers and pesticides treatment protective means, depreciation, labor costs, service costs, overhead costs, harvest costs, transport costs etc., that were not taken into account because they were not known, this is a shortcoming for a clear determination of the mutual relationships of the elements that influence the price, in addition to the yield.

Yield of maize have share in total quantity of produced grain of maize per year and connected with expected determining the prices in the country. In Republic Serbia price defined on the state level, considering total level of production in state and under reflection of global market. However in work was not studied policy of price.

Yield of maize have share in total quantity of produced grain of maize per year and connected with expected determining the prices in the country. In Republic Serbia price defined on the state level, considering total level of production in state and under reflection of global market. However in work was not studied policy of price. The relationships between maize yield and purchase price kg^{-1}, in the Republic of Serbia (the municipality of Kragujevac and the municipality of Sombor) by using the comparative method, was analyzed. Based on these data, trend and fluctuation of interdependence yield of maize in both locations and purchase price were estimated (Figure 11).

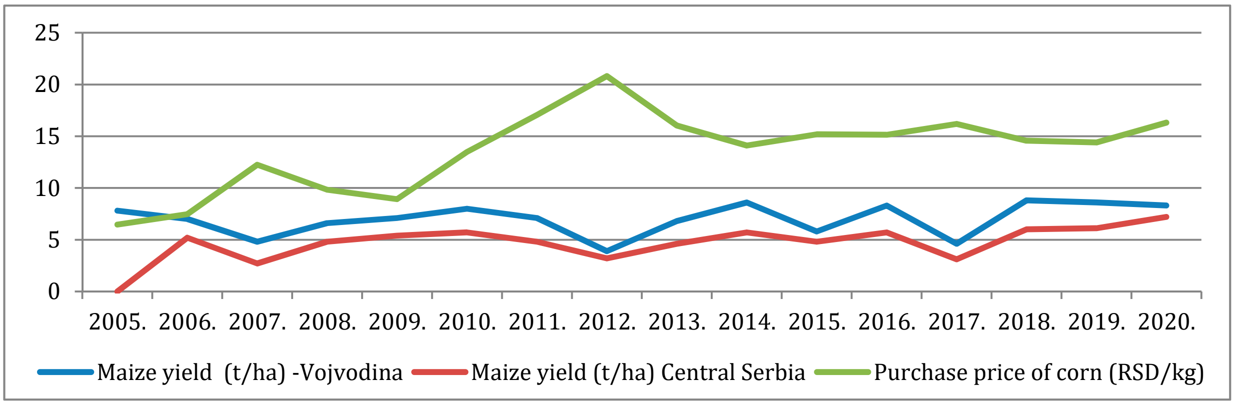

Figure 11. Yield and purchase price of maize in the Republic of Serbia for the period 2005–2020.

The purchase price of maize varied in the analyzed period and had an upward trend in the Republic of Serbia. The increase in the price of maize was almost two times higher in 2007 than in 2005. From 2007 to 2009, the price decreased and then increased again until 2012 and was 2.5 times higher than in 2009. After 2012, the price of corn per kilogram was lower and there were no significant fluctuations. In the period after 2012, the lowest price was in 2014, and slightly higher corn prices were in 2017 and 2020. The rise and fall of the price of maize in the Republic of Serbia was an expression of price changes on the world market, which was determined by the amount of realized yields, storage reserves and supply and demand on the world market. However, in our study was not focused correlation between price of maize on global and regional level.

In both region i.e., in Sombor and Kragujevac the trend of average maize yield (t ha^{-1}) was similar. The maize hybids had similar response to climatic condition in both regions in forming the yield, what is related to total yield in year production during long term period. High maize prices were expressed in years in which low maize yields were achieved in 2007, 2012, 2015 and 2017. In those year maize yield affected by drought, heat and less precipitation during growth phases, particularly in July and August. Furthermore the price of maize increased on domestic market on the on supply and demand. Although price support for corn producers was present throughout the observed period, defined by the price policy, the overall level of support for domestic corn producers was not sufficient to cover expenses in corn production with the yield achieved. Also, the situation at the global level has also been affected, because especially in 2012, the year was extremely dry.

Agriculture in the region has suffered increasing economic losses due to natural disasters in the last decade, especially during the drought of 2012 and the floods of 2014 [22]. Total material damage caused by extreme climatic and weather conditions in Serbia, in the period 2000–2015 are more than five billion EUR. More than 70% of losses are associated with drought and high temperatures. Another major cause of significant losses is flooding. They caused huge damage in 2014, and according to estimates, 1.35 billion EUR are needed for recovery [49,50]. The causes and consequences of climate change are very diverse, low-income countries contribute the least to climate change and are most vulnerable to its effects [14].

This confirm that the differences of values sunshine, maximum and average air temperatures, precipitation and humidity related to efficiency of maize yield forming and further total maize yield which is linked with forming purchase price on the market. In this study was established that during the analyzed long period, in the seasons with low maize yield, the purchase price of maize was higher, which indicates that the price of maize was inversely proportional to the yield. Different maize yields in the observed time period suggest the existence of disparities between the observed parameters. On the base of data in this study, in generally, the average maize yield is negatively correlated with purchase price. However, how much the price compensates for the economy of production is an open question and can be answered based on the analysis of all costs and factors of production.

4. Discussion

Thanks to favorable agro-ecological conditions, agriculture is traditionally one of the most important sectors of the Serbian economy, and the factors that affect agriculture also affect the entire economy of the country [51]. The global food demand and limited arable land require intensification of additional production through innovation of production technology in terms of adapting to climatic change. Maize is a staple food for approximately 4.5 billion people on the world [52], and decline in its productivity could implicate negatively on global food security. The yield of maize mainly affected by drought, heat and less precipitation during growth phases, particularly in July and August [53]. Considering share of maize in agricultural export of Serbia, and potential decline of grain yield under predicted drought period in Serbia, is necessary make activities for sustainable production and save significant share of maize and agriculture on macroeconomic and social issues [30].

Climate changes have often adverse influences on yield crop yields. To study the effect of climate change on variation of maize yield as well as other crop species growth and yield with regard to the share of single climatic parameters, is able achieve on the base of estimation of correlations between climatic data, as indicator of climate change effects, and the change of crop yields (maize) under different ecological conditions [54,55].

The harvested areas of maize among years are mainly similar (~1.0 million ha) in Serbia. The yield varied in range from 4.0 to 8.0 t ha^{-1}, due maize genotypes, crop density, and technology growing, ecological factors [56]. The significant influence on yield formation has precipitation and temperature regimes during vegetation season of maize. The lower precipitation and the higher temperatures are mainly related to low yield of maize [57–59]. So, for maize crop, the critical period for precipitation is at the flowering phase and grain filling phase, i.e., in the summer period with high air temperature and low humidity [37,53,60,61].

The numerous experimental studies reported that maize has shown to be most sensitive to environmental stresses in the period of bracketing to flowering [62–64] and that yield of maize associated soil water sufficiency at phase of flowering [65–67]. For their survival in different climatic conditions, plants require favorable adaptations of their life cycle to the prevailing conditions [68].

In Serbia, annual temperature increased for 0.3 °C per decade, but in period from June to August increased for 0.57 °C per decade, while amount of precipitation decreased per decade in the end of 20th and beginning of 21st century (1990–2012) [25]. This trend confirmed in our study of two thirty years period, so that in the last thirty years period (1991–2020) average annual temperature was higher for 0.9 °C in Kragujevac region and for 1.2 °C in Sombor in comparison to previous thirty years period (1961–1990). The recorded increase of the average temperature and changes in the amount of precipitation indicate changes of climatic conditions condition in the territory of the Republic of Serbia [69]. The values of climate change based on variations in the amount of precipitation in the Republic of Serbia did not have a pronounced trend as temperatures, but there is a decrease in precipitation at the end of the 21st century, especially in Kragujevac in central and southern Serbia [70].

Changes in meteorological and climatological parameters analyzed for the period 1991–2020 year in relation to first long time period (1961–1990) in the area of two locations (Kragujevac and Sombor) show in Serbia a significant increase in the number of hours and sunshine, medium and maximum temperatures and precipitation. Although an increase in precipitation was found, during the second long period (1991–2020), there were several pronounced drought periods in the Republic of Serbia. Based on data Republic Hydrometeorological Service of Serbia (RHMS), the average annual rainfall in the Republic of Serbia ranged from 540 to 820 mm [71].

Climate change in Serbia will affect agricultural production by adapting the vegetation period of plant species to eco-climatic conditions. In order to avoid conditions of temperature shock with high temperatures in the stages of plant development, which are important for productivity, it is necessary to sow up to 20–30 days earlier, which will significantly affect production planning and time of field work [72]. Climate change significantly affects the quantity and quality of plants and products from them, and at the same time it will affect the overall quality of life of the population of Serbia, the economy, and especially agriculture.

Maize is one of the leading plant species, which is grown on areas over 1,000,000 ha in the Republic of Serbia, of which sown areas in Vojvodina (60%) and in other parts of Serbia (40%). During the vegetation period, the maize crop is greatly influenced by various abiotic and biotic factors. Among these factors, weather conditions during the growing season can have a direct impact on maize yield [73,74].

In the Republic of Serbia, agricultural production, mostly takes place without irrigation, which results in lower yields, especially in years with low rainfall and dry years. This kind of maize production has harmful effect on the supply, prices and exports of essential agricultural products, which particularly increases the significance of planning both yield and total production volume. The optimal and profitable production of maize can achieve by irrigation [30,53,75]. The study reported that application of irrigation production system which contribute increase of grain yield for 18.7%. The amount and distribution of precipitation during the vegetation period play a significant role in achieving the genetic potential of maize yield, especially in the phenophases of flowering and seed filling [67,76,77]. The precipitation contributes to better availability Nitrogen absorption with root plant. Except, weather factor (temperature, precipitation, solar radiation, humidity) the significant influence on yield of maize crops have technology production (tillage, irrigation, nutrition etc.). Nitrogen is needed for maize production, which contribute to increasing yield, but have negative impact to environment connected with economic losses, what require improvement of way, time and rate of nitrogen application. The efficiency of nitrogen application depends on soil textural class, growing stage of plants, and hybrid responses to applied nitrogen. Considering that nitrogen fertilizer cost, and positive and negative effect of nitrogen application, producers need calculated the net benefits of N fertilizer use for maize production [78,79]. Maize yield varies over the years due to insufficient rainfall and unequal distribution and high air temperatures, especially during flowering and seed filling, in the period from June to August [59,80,81]. During the 1979–2016 period in China, temperature negatively impacted the maize yield, and precipitation was found to have a positive but overall negligible impact [9,82].

In this study in Central Serbia (Kragujevac region) found that the average and maximum values of temperature have a positive correlation with maize yield and with sunshine, while a negative correlation with humidity and rainfall, but in Vojvodina (Sombor region) air humidity and rainfall have positive correlation with maize yield. The amount of precipitation for the vegetation period of maize (April-September) in Sombor was 392.9 mm with a deviation of 134.5 mm. During the remaining period, the average rainfall was 245.3 mm. In Kragujevac during the vegetation period, the amount of precipitation was 380.2 mm with a deviation of 116.3 mm, while the average amount of precipitation during the off-vegetation period was 296.6 mm. The interval of precipitation in Sombor varied from 180.2 mm (2012) to 590.2 mm (2005), while the variation of precipitation in Kragujevac was from 243.0 mm (2011) to 709.0 mm (2014).

Among the variables relevant to weather conditions there are two important factors, precipitation and temperature, which have a large impact on crop yields [60,79,83–85]. The worming temperature, increase losses associated with drought and heat, and have impact in reducing yield of maize for 7.1% as well as for major crop by 3–13, [86]. The processing of raw (measured) data on meteorological quantities is especially interesting when it comes to the precipitation and air temperature, because the availability of water on Earth depends on them. Water shortages in combination with high temperatures are significant descriptors of droughts in agricultural areas such as Vojvodina as the most extensive lowland part of Serbia [87].

The average yields of maize in the 16-year period (2005–2020) in Vojvodina (Sombor) were 28% higher than the average yields of maize in the Central region of Serbia (Kragujevac) in the same period. This indicated that the sunshine in the area of the meteorological station Sombor was 7.6% higher than in the area of the meteorological station Kragujevac. Humidity in the area of Kragujevac was about 2.8% higher than in Sombor, while the amount of precipitation in the area of Vojvodina in Sombor was slightly higher by 3.2% than in Kragujevac.

The variation of climatic factors related to maize yield and which effect is different and can be stressful due to crop density, soil type and soil fertility and stage of plant development. The high temperature during flowering have a negative effect on pollen fertility, reduced germination of pollen grains, and in the grain pouring phase affects photosynthesis and change in the amount of carbohydrate and protein synthesis and reduced translocation into maize seeds, which negatively affects yield [88]. Also, at the time of drought, low relative humidity is often present, which is reflected in the yield, so the deficit of precipitation can be solved by irrigation or cultivation of drought-resistant crops ("In northern Serbia, droughts and periods with uniform weather conditions for vegetation, while the rest of the country is dominated by periods with conditions suitable for vegetation [89]."

Variations of climate factors and climate change in different regions have different characteristics and affect the manifestation of specific and different responses of plant crops. The effects of variable values of climate factors can be positive and negative on crops, achieving yields, and further can have negative consequences such as unstable and insecure food supply [90,91]. For example, the obtained result in this study showed that an increase in humidity by 1.0% is related to increasing of maize yield for 0.6% in Kragujevac (Central Serbia) and that increase of precipitation for 1.0% related to increasing of maize yield for 0.7%, while an increase of sunshine for 1.0% was associated with decreasing of maize yield for 0.1% in Sombor region (Vojvdina). In comparison affect of climatic parameters was found that sunshine has a slightly more negative impact on the maize yield in the central Serbia than in Vojvodina. Air humidity has a greater positive influence in the central Serbia than in Vojvodina, while precipitation has greater influence in Vojvodina than in Central Serbia.

The studied climatic factors (temperature, precipitation, solar radiation, humidity) have an individual and synergistic influence on on maize yield, although individually each of these factors can be a limiting factor for the growth, development and formation of the yield of the plant. However, in addition to climatic factors, the growth of crops and the formation of yields are influenced by other factors individually and synergistically, among which are tillage, irrigation, nutrition, chemical protection against diseases and pests and weeds, etc., which are not included in this research.

Complex climate factors have an impact on the quantity and quality of maize seeds, which affects the formation and variation of the purchase price of maize. In the seasons of growing maize with a lower yield, which is partly caused by the action of unfavorable climate factors, the current price is expected to be higher due to higher demand and fewer resources, and which was expressed in the period 2011–2013 (Figure 11). Based on data on maize yield in the Republic of Serbia and the purchase price of maize (RSD/kg) at two selected locations (Vojvodina and Central Serbia) for the period 2005–2020 year were studied. The variation of yield associated with price, which is important for producer's income. However, in Serbia during this period the budgetary payment to produces was absent, and income of producers based on price. Furthermore, the maize price growth rate of 9.75% on the internal market was significantly falling behind world prices, whose growth rate in the analyzed period was 33.52% [92].

In the analysis of basic climate factors, it was found that high values are the duration of sunshine, high maximum and average air temperatures, low rainfall and reduced humidity. Research has shown that climate factors affect the yield of maize, which varied in changing climate conditions, which requires further research to optimize maize production in climate change, because "the climate system is a global system". However, in the context of global climate change, it is necessary to anticipate climate change at the regional level and plant production should be adapted to regional climate change. It is also necessary to create new hybrids with greater adaptability to changing conditions and connectivity and regional integration at the European level with an interdisciplinary approach to the implementation of research and production programs, as well as at the level of other continents [93,94].

5. Conclusions

On the base of analysis of climatic factors (temperatures, precipitation, sunshine, humidity) and comparison of two thirty-years periods in the area of the meteorological station Kragujevac and meteorological station Sombor, established that there are changes, which are particularly pronounced at air temperature (average and maximum temperatures) in last thirty years period (1991–2020) in comparison to previous thirty years period (1961–1990).

The climatic changes was established on the base of increase in average annual and maximum annual temperatures of decrease of amount of annual precipitation in average for 6.3 mm, particularly decrease in the summer months in both region in Serbia. The average values of relative humidity for 1.3% in Kragujevac and for 3.4% in Sombor, annually was decreased in last thirty years period (1991–2020) in comparison to previous thirty years period (1961–1990). Also, the sunshine in the area of Sombor was 7.6% higher than in the area of Kragujevac. Humidity was higher in the area of the meteorological station Kragujevac by 2.8%, and the amount of precipitation was slightly higher in the area of Vojvodina by 3.2%.

In research on the influence of climatic factors on the yield of maize in the territory of the Republic of Serbia, was found that there is a correlation and influence of climatic parameters on maize yield. At the same time, it was determined that all four independent variables (air temperature, sunshine, humidity, precipitation) are correlated with the dependent variable (maize yield). The correlation coefficient between dependent (maize yield) and independent variables was high 74.7% in Kragujevac region (Central Serbia), and 62.3% in Sombor region (Vojvodina). Based on the results and the obtained coefficients of the model was found that the greatest impact on yield, maize, has humidity and precipitation in both region Central Serbia and Vojvodina. A significant reduction in maize yield was found at both locations in the 2007, 2012, 2015 and 2017 years.

The policy of agricultural development should be aimed at the strengthening and sustainability of producers in conditions that are both predictably variable and especially unforeseeable. The economic policy in the agriculture is significant associated with primary production and have influence to income in agriculture, achievement of profit. Direct and indirect financial incentives in agricultural production are necessary in order to optimize production, achieve economic interest based of low input and higher output, and create profit in agricultural production. For prevention of negative impact of drought, water deficit, heat stress and achieve stable yield farmer is necessary improve farming practices.

For improvement of production of maize is necessary support from government planning budget for agriculture aimed to support procurement of new machines, implementation in operational monitoring and warning systems, for better irrigation system, investment in infrastructure for efficient use of smart technologies in maize production and primary for developing breeding program and creation new maize varieties more tolerant to drought and high temperature in specific region. The adaptation to climate change in agriculture require adoption time of sowing and density of sowing of selected hybrid for specific region, and optimizing measures of farming.

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