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CLIMATE CHANGE IN SERBIA: DEPENDENCE OF MAIZE YIELD ON TEMPERATURES AND PRECIPITATION

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Abstract

High and quality maize yields largely depend on climatic conditions. Since climate in Serbia provides good light conditions and sufficient heat energy in a greater part of Serbian territory, the success of maize cultivation mainly depends on precipitation sums and their distribution.

The objective of the present study was to determine dependence of the average maize yields during the past two decades at the end of last and the beginning of the new millennium on weather conditions, i.e. on temperatures and precipitations.

The analysis of temeperature and precipitation regimes during the 1991-2010 period at both levels, full-year periods and growing seasons, show extremely dry years such as 1992, 2000 and 2007. Based on a detailed analysis of data it is observable that drought during sowing and emergence occurred more often during the last ten years. The analysis of temperatures and precipitation sums in the period from tasseling to the milk stage, drought occurred more frequently during the last twenty years and it jeopardised early and medium late maturity hybrids.

A precise multiple regression analysis of the mode and the intensity of maize yield dependence on meteorological conditions indicates to the following:

The higher air temperatures in all periods (summer, growing season and full-year period for the Belgrade region) were the lower grain yields of maize were, while these yield reductions were significantly only during summer periods. On the other hand, the higher precipitation sums were, the statistically significantly higher maize grain yields were. Of the two observed meteorological conditions, precipitations sums, particularly summer and total annual ones, had greater effects on maize grain yields.

Keywords: *climate change, temperature, precipitation, yield, maize, Serbia*

Introduction

Drought presents a long period of abnormally low rainfall that adversely affects growing and developing of crops. At the same time, such a period is characterised with high temperatures and low air humidity. Damages caused by drought depend on its duration and intensity. The longer drought lasts the greater damages are, and sometimes they can be catastrophic.

Lesser adverse physiological effects of drought can result in plant stunting, while more severe effects can lead to plant death. Due to drought, transpiration and photosynthesis are decreased, but respiration does not stop and reserve organic matters are used. Plants loose their weight, leaves wilt, and their tips dry. Complete plants dry if subjected to longer drought.

Causes of droughts are different. Insufficient annual precipitations and their distribution during the growing season of crops as well as the evaporation intensity of the falling rain are the most important causes of droughts (Kovacevic et al., 2009; Kovacevic and Milic Vesna 2010). Under climate conditions of our region drought is an occasional phenomenon, which can be moderate or extremely severe. The evaporation intensity depends on temperature, effects of wind and geographic location of a certain region and increases from west to east or from north to south of our country. The highest intensity has been recorded in the south-eastern part of the country (Cvetkovic et al., 1996). Temperatures largely affect this phenomenon. Evaporation is a product of high temperatures and is most closely related with the direction of the precipitation decrease. This fact can be a reason why our eastern and south-eastern regions often suffer more or less from effects of drought (Spasov P. and Spasova Danica, 2001 Spasov, P. (2003).

Material and methods

The data of the Republic Hydrometeorological Institute of Serbia (precipitation and air-temperature, for the Belgrade territory for the 1991-2012 period were transformed in average in three summer months, vegetative period and total per year and the Statistical Office of the Republic of Serbia (Statistical Yearbooks: maize yields for central part of Serbia) were used for this study.

The data were statistically processed by the multiple regression analysis and the correlation analysis using the software package Statistica V5.5. Based on the equation of the linear regression ($\hat{y}_i=a+b_1*x_1+b_2*X_2$), the average change (increase or decrease) in maize grain yield was established in dependence on air temperatures (b_1) and total precipitation sums (b_2). Difference testing of partial regression coefficients by the t test (b_1 and b_2: H_0:ß$_1$=0 vs. H_a:ß$_1$#0 and H_0:ß$_2$=0 vs. H_a:ß$_2$#0) shows that these differences were statistically significant. The significance of the linear regression model was tested by the F test (H_0:ß$_1$=ß$_2$=0 vs. H_a:ß$_1$#0 v ß$_2$#0) and the simultaneous effect of the temperatures and precipitations on maize grain yield was established. The correlation dependence between variables was tested by the coefficient of multiple correlation (dependence of yield on the simultaneous effects of temperatures and precipitations) and by the coefficient of partial correlation (dependence of yield on the effect of one factor whereby the effect of the second factor is not considered). Testing of significance of correlation coefficients was done by the F and t tests.

Results and discussion

Climate in Serbia can be described as temperate-continental with less or more pronounced local characteristics. According to data of the Republic Hydrometeorological Institute of Serbia, the average annual air temperature for the regions with the altitude of up to 300 m amounted to 10.9^{o}C during the 1961-1990 period. The corresponding temperatures amounted to approximately 10.0^{o}C, i.e. 6.0^{o}C for the regions with the altitude of 300-500 m, i.e. over 1000 m, respectively.

Temporal and spatial distribution of precipitation over the territory of Serbia is irregular. A larger part of Serbia is characterised with the continental precipitation regime with greater amounts during the warmer half of the year. The greatest precipitation sums are recorded during May and June. Twelve to 13% of the total annual precipitation sums are detected in June. The lowest precipitation sums (5-6% of the total annual precipitation sum) are recorded in February or October. The higher altitude the higher annual precipitation sum.

The annual precipitation sum in lowland regions ranges from 540 to 820 mm. This amount seems to be sufficient to cultivate the majority of field and vegetable crops.

The precipitation amount has a crucial effect on occurrence of shorter or longer dry spells in crop cultivation under rainfed conditions. The favourable precipitation distribution during the year is the distribution that provides a proportionally large numbers rainy days and equal intervals between rainy and rainless periods, particularly during the growing season. The occurrence of longer rainless periods in spring and autumn, especially in years with dry summers, when drought continues from summer into autumn regularly affects grain crops due to uneven and long emergence. Drought during summer months (June, July and August) mostly affects broadcast crops germinating in spring.

Table1. Mean temperatures and precipitation sums during the maize growing season in the region of Central Serbia (1991-2010)

Year	Mean temperature (^oC)			Total precipitation sum (mm)			Maize grain yield t ha^{-1}
	VI-VIII	IV-IX	Year	VI-VIII	IV-IX	Year	
1991	18.5	16.1	10.7	163.0	334.8	628.5	4.9
1992	23.4	19.4	12.3	247.8	351.2	586.2	2.7
1993	22.5	19.7	12.2	131.8	224.8	541.1	2.3
1994	23.1	20.4	13.6	348.8	484.3	683.6	3.0
1995	22.3	18.8	12.4	167.6	404.8	701.2	4.0
1996	22.0	17.8	11.1	159.2	427.2	788.8	3.0
1997	21.5	17.9	11.8	275.0	444.0	754.6	4.7
1998	21.8	18.5	11.7	159.2	348.9	627.1	3.1
1999	20.7	18.5	11.8	418.4	611.5	1030.4	4.3
2000	24.1	21.0	14.2	56.2	203.3	367.7	1.9
Average	22.0	18.8	12.2	212.7	383.5	670.9	3.4
2001	22.0	18.7	12.6	262.4	651.0	893.1	4.1
2002	23.3	20.1	14.1	249.0	375.0	585.0	4.3
2003	24.7	21.1	13.1	154.0	273.0	556.0	2.9
2004	22.0	18.9	12.8	288.9	466.5	822.9	5.0
2005	21.5	19.0	12.2	329.0	486.0	791.0	5.0
2006	22.2	19.6	13.1	282.0	445.0	745.0	4.3
2007	25.5	21.1	14.4	198.0	316.0	774.0	2.2
2008	23.6	20.3	14.4	155.0	319.0	597.0	4.3
2009	23.2	21.1	14.0	277.0	321.0	807.0	5.0
2010	23.4	20.1	13.3	275.0	452.0	853.0	5.0
Average	23.1	20.0	13.4	247.0	410.4	742.4	4.2
Difference	1.1	1.2	1.2	34.3	26.9	71.5	0.8

Under conditions of our climate, the greatest precipitation sums are recorded in June. If precipitation sums are well distributed over decades and if there are rainfalls during July, maize - our most important crop - rarely suffers from drought. Insufficiency of precipitation in July, and later on, a longer rainless period accompanied with high temperatures and heat waves cause the greatest problems. Under conditions of favourable precipitation distribution during the growing season it is not necessary that the annual precipitation sum is high.

The analysis of weather conditions in the 1991-2000 period related to maize shows that 1992, 1993, 1998 and especially 2000 were extremely dry years. Out of 12 years of 21st century four were favourable and high yield years (2004, 2005, 2009 and 2010), while the following three years were very dry: 2003, 2007 and 2012. The driest year was 2012, when very low amounts of rainfall were recorded, while maximum daily temperatures in the May-

August period were over 35°C. Frequent heat waves have been observed during summer months of the growing season. In the beginning, heat waves were characteristic for September and they contributed to faster maize maturing, but during the last few years, heat waves have been occurring in August, while in 2012 they occurred in the second half of July. Heat waves contributed to accelerated maturation and they disturbed grain filling. Today, this is becoming a problem.

According to the 20-year mean air summer temperatures presented in Table 1 a disturbing increase is observed in the last decade of the 20th century in relation to the reference period from 1961 to 1990, especially in July (increase by 1.5°C). The temperature increase in June, July and August by 0.7°C, 1.2°C and 1.1°C, respectively, or on the average for these three months by 1.1°C had the highest effects on crops in certain extremely dry years, such as1992, 2000, 2007 and 2012. If the data of the first decade of the 21st century are compared with data of the reference period (1961-1990) the difference of exactly 2°C can be considered alarming. This is especially dangerous because these increases and a few heat waves increase nocturnal temperatures during July and August up to tropical temperatures not lower than 20°C.

Annual and maize growing season precipitation were greater in the first decade of the 21st century. Even in two months, June (with the greatest amount of rainfall under our climate conditions) and August precipitation sums were somewhat higher at the monthly level. Namely, there are rainfalls in the first half of June and the second half of August, which can additionally form dry conditions because these periods are critical for moisture in maize as they are the beginning of pollination and grain filling, respectively.

Table 2. Summer mean temperatures and precipitation sums in Belgrade (1991-2010 average)

Period	June	July	August	Summer average
1961-1990	Temperature (°C)			21.1
1991-2000	21.0	22.6	22.4	22.0
2001-2010	21.7	24.1	23.6	23.1
Difference	0.7	1.5	1.2	1.1 2.0
1961-1990	Precipitation (mm)			208.1
1991-2000	87.9	73.0	51.8	212.7
2001-2010	112.3	60.6	74.2	247.0
Difference	24.4	12.4	22.4	34.3 38.9

Based on data for maize grain yield (Table 1) and the equation of multiple linear regression (Table 3), a statistically significant or a very significant simultaneous effect of average temperatures and total precipitation sums in the growing season and full-year period, especially summer period, was established. However, when observing individual factors affecting maize grain yield, the effect of total precipitation sums, particularly summer and annual, was more significant. The 1-mm precipitation increase resulted in grain yields higher by 5.3, that is 3.9 kg ha^{-1}. Considering the effects of the mean air temperatures, statistical significance was obtained only in the summer period, when the temperature increase of 1°C reduced grain yield by 290 kg ha^{-1}. According to stated values, the changes in grain yields in relation to observed meteorological conditions are more affected by precipitation sums, especially during summer months, although data presented in Table 1 show greater differences over temperatures than over precipitation sums between the two 10-year periods.

Table 3. Results of statistical analysis in maize

Effects of average summer air temperatures and total summer precipitation sums on grain yields		
Tabular values: $F_{0.05;2;17}$=2.63; $F_{0.01;2;17}$=6.23;	$t_{0.05;17}$=2.11; $t_{0.01;17}$=2.898	Evaluation of significance
Equation of multiple linear regression	Y_i=9.136 + -0.2903X_1 + 0.0053X_2	F=7.0894**
Regression coefficient	b_1=-0.290; b_2=0.0053	t_{b1}=2.246*; t_{b2}=2.362*
Coefficient of multiple linear correlation and coefficient of determination	$R_{0.12}$=0.6744 d= 45.48%	F=7.091**
Coefficient of partial determination	$r_{01.2}$= -0.478; $r_{02.1}$=0.497	$t_{01.2}$=2.246*; $t_{02.1}$=2.362*
Effects of average summer air temperatures and total growing season precipitation sums on grain yields		
Equation of multiple linear regression	Y_i=5.4298 + -0.164X_1 + 0.0039X_2	F=3.4576*
Regression coefficient	b_1=-0.164; b_2=0.0039	t_{b1}=0.920^ns^; t_{b2}=1.915^ns^
Coefficient of multiple linear correlation and coefficient of determination	$R_{0.12}$=0.5377 d= 28.92%	F=3.457*
Coefficient of partial determination	$r_{01.2}$= -0.218; $r_{02.1}$=0.421	$t_{01.2}$=0.920^ns^ $t_{02.1}$=1.915^ns^
Effects of average annual air temperatures and total annual precipitation sums on grain yields		
Equation of multiple linear regression	Y_i=1.379 + -0.025X_1 + 0.0039X_2	F=3.8645*
Regression coefficient	b_1=-0.025; b_2=0.0039	t_{b1}=0.128^ns^ t_{b2}=2.667*
Coefficient of multiple linear correlation and coefficient of determination	$R_{0.12}$=0.5591 d= 31.25%	F=3.865*
Coefficient of partial determination	$r_{01.2}$= -0.031; $r_{02.1}$=0.543	$t_{01.2}$=0.128^ns^ $t_{02.1}$=2.667*

*, ** significantly difference at $p \leq 0.05$ and $p \leq 0.01$. ^ns^ not significantly difference

The dependence of the maize grain yield on both observed factors, temperature and precipitation, or on individually observed factors, analysed by the coefficient of multiple correlation, was also the most significant in the summer period. Values of obtained coefficients of multiple linear determination ranged from d=28.92% (percentile dependence of yields on temperatures and precipitation sums in the growing period) to d=45.48% (percentile dependence of yields on temperatures and precipitation sums in the summer period). Values and evaluation of significance of coefficients of partial correlation, also indicate to a trend of greater dependence of maize grain yields on precipitation sums, particularly on total summer and annual sums.

Previous results (Kovacevic et al., 2005, 2007b, 2008; Dolijanovic et al., 2006, 2007, 2010) point out to effects of meteorological conditions, especially the precipitation distribution, on grain yield of maize. It could be added that the precipitation distribution in summer months is important, particularly if unfavourable, and if accompanied with high air temperatures can significantly reduce yields of the most widely grown crop in the sowing structure of the Republic of Serbia. Debreczeni et al., 2006, have studied the dependence of maize grain yields on growing season precipitations and have established a high dependence in variants without fertilisation (r=0.7357), while this dependence in variants with fertilisation amounted to r=0.6245. The same authors have determined that the 1-mm increase of precipitation increased grain yield by 6.4-24 kg ha^{-1} (variants without fertilisation) and by 16.1-42.9 kg ha^{-1} (variants with fertilisation).

Conclusion

According to the detailed analysis of temperature and precipitation regimes on the territory of Belgrade in the 1991-2010 period and the analysis of average maize yields in Serbia proper, the following can be concluded:

General global climate changes also affect the Balkan Peninsula including Serbia. Two most important climate parameters in agronomy, temperatures and precipitations, have been changing faster during the past two decades. The extremely dry years were 1992, 1993, 1998 and particularly 2000, 2003 and 2007.

The average temperature for the three summer months increased by 2°C in the 1991-2010 period compared to period 1961-1990. Heat wave with extremely hot summer days and tropical nights contribute to the yield reduction. The temperature increase did not resulted in the precipitation reduction. Rainfalls were shifted more towards the first decade of June and the last decade of August and in such a way they simply masked the actual moisture insufficiency in the critical period for maize that lasts from the mid June to mid July under our climate conditions.

According to the detailed analysis of the form and the intensity of dependence of maize yields on meteorological conditions done by the method of multiple linear regression and correlation the following can be concluded:

The air temperature increase in all observed periods (summer, growing season and the full-year period for the region of Belgrade) resulted in the maize grain yield reduction. This reduction was statistically significant only for the summer period. On the other hand, the increase of the precipitation sums was regularly accompanied by the statistically significant maize grain yield increase. Of the two observed meteorological conditions, the greater effect on the maize grain yield was expressed by the precipitation sums, especially summer and annual ones. Maize grain yield variations over meteorological conditions (average air temperatures and total precipitation sums) ranged from 0.5377 (growing season), over 0.5591 (full-year period) to 0.6744 (summer period).

The changes in temperature and precipitation regimes show that the growing season starts earlier in this region. Based on these analyses it is necessary to consider the adaptation of many cropping practices that indirectly can reduce damages from drought starting from the adequate tillage systems, dates, depths, methods and densities of sowing, fertilising, cultivation methods during the growing season and selection of hybrids resistant to drought stress conditions. Certainly, irrigation, as a measure with the direct effect, can most efficiently eliminate effects of drought.

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