ISSN 1330-7142
UDK = 633.15:551.583(497.5)(497.11)(439)(497.6)

CLIMATE CHANGE IN CROATIA, SERBIA, HUNGARY AND BOSNIA AND HERZEGOVINA: COMPARISON THE 2010 AND 2012 MAIZE GROWING SEASONS

V. Kovačević [1], D. Kovačević [2], P. Pepo [3], M. Marković [4]

Scientific review
Pregledni znanstveni članak

SUMMARY

Maize is the main field crop on arable land in Croatia, Serbia, Hungary and Bosnia and Herzegovina (B&H). In the period 2006-2010 total of 2 854506 ha (5-y mean) of arable lands in this area was covered by maize. Annual maize yield variations were from 3.6 to 7.5 t ha^{-1} (Hungary), from 3.2 to 5.9 t ha^{-1} (Serbia), from 4.9 to 8.0 t ha^{-1} (Croatia) and from 3.2 to 5.1 t ha^{-1} (B&H). The aim of this study was testing the 2010 and 2012 growing seasons for maize in terms of weather characteristics. Maize yields in 2012 (4.34 t ha^{-1} in Croatia, 3.98 t ha^{-1} in Hungary 2.78 t ha^{-1} in Serbia and 2.74 t ha^{-1} and in B&H were lower than in especially favorable 2010 by 53%, 38%, 38% and 40% respectively.

Key-words: climate changes, maize yield, precipitation, air-temperature, the growing season effects

INTRODUCTION

Climate change is a significant change in the average weather conditions, or in the distribution of weather around the average conditions. It is caused by different factors including human-induced alterations of the natural world. Global warming and more frequency of the extremely weather conditions is often connected with climatic changes. Climate changes, especially precipitation and temperature regimes, have a direct, often adverse, influence on the quantity and quality of field crop yields. Many studies have considered the impacts of future climate changes on food production (Parry et al., 2005; Fischer et al., 2005; Lobell and Field, 2007; Vučetić, 2006; Blanc, 2012). Annual global temperatures have increased by about 0.4ºC since 1980, with even larger changes observed in several regions (IPCC, 2001). Lobell and Field (2007) estimated that about 30% variations of global average yields for the world's six most widely grown crops (wheat, rice, maize, soybeans, barley and sorghum) are the result of growing season precipitation and temperature variations. Production of these crops accounts for over 40% of global cropland area, 55% of non-meat calories and over 70% of animal feed (FAO, 2006).

Maize is main field crop on arable land of Croatia (SLJ, 2011), Serbia (SG, 2011a), Hungary (SYB, 2011) and Bosnia and Herzegovina (SG 2011b; SG/LJ 2011). In the period 2006-2010 1149410 ha (25% of arable lands) was covered by maize in Hungary, Serbia 1216786 ha (37%), Croatia 298697 ha (34%) and Bosnia Herzegovina (B&H) 189613 ha (19%). In general, maize participates with about 30% of arable lands in area covering the mentioned countries. Average yields of maize in the studied period were 6.17 t ha^{-1} (Hungary), 4,86 t ha^{-1} (Serbia), 6,76 t ha^{-1} (Croatia) and B&H (4,56 t ha^{-1}), respectively. Also, considerable variations of annual maize yields such as 3.6 to 7.5 t ha^{-1} (Hungary), from 3.2 to 5.9 t ha^{-1} (Serbia), from 4.9 to 8.0 t ha^{-1} (Croatia) and from 3.2 to 5.1 t ha^{-1} (B&H) were found in the 2006-2010 period. Weather characteristics are main factors of maize yield variations among years.

(1) Prof.DSc. Vlado Kovačević (vkovacevic@pfos.hr)- Faculty of Agriculture, Josip Juraj Strossmayer University of Osijek, Kralja Petra Svačića 1d, 31000 Osijek, Croatia, (2) Prof.DSc. Dušan Kovačević - Faculty of Agriculture, University of Belgrade, Serbia, (3) Prof.DSc. Peter Pepo - Faculty of Agriculture, Food and Environmental Sciences, University of Debrecen, Hungary, (4) Prof.DSc. Mihajlo Marković - Faculty of Agriculture, University of Banja Luka, Bosnia & Herzegovina

In general, the lower precipitation and the higher air-temperatures in summer, especially in July and August, are usually in close connection with the lower yields of maize (Shaw, 1988; Maklenović et al., 2009; Kovačević V. et al., 2008, 2009, 2012; Kovačević D. et al., 2012, 2012a; Markulj et al., 2010; Rastija et al., 2012).

The aim of this study was to test two growing seasons (2010 and 2012) extremely different regarding precipitation and temperature regimes in Croatia, Serbia, Hungary and B&H in terms of their favorability for maize growing.

MATERIAL AND METHODS

The data of State Bureaus for Statistics (The Statistical Yearbooks) in Croatia, Serbia, Hungary and Bosnia and Herzegovina (separately editions for two entities in B&H: Federation B&H and Republic of Srpska) were used as the sources for maize harvested area and yields in 2010 and 2012. These four countries cover 2854506 ha by maize (average 2006-2010) or about 30% of arable land of this area. Also, the FAO data were used as the source of the information (faostat.fao.org).

The Climatological reports of State Hydrometeorological Institutes of the mentioned countries were used as the source of the weather data (DHI, 2010, 2012). Choice of eight meteorological stations was made as follows: Osijek (OS) and Varazdin (VZ) in Croatia, Novi Sad (NS) and Nis (NI) in Serbia, Debrecen (DE) and Gyor (GY) in Hungary and Banja Luka (BL) and Bijeljina (BI) in B&H (Table 1).

The rain factor (RFm) was calculated monthly as a quotient of precipitation (mm) and mean air temperatures (°C) according to Gracanin (1950).

Table 1. The meteorological stations (MS)

Tablica 1. Meteorološke stanice (MS)

MS *MS*		Coordinates and elevation asl *Koordinate i nadmorska visina*
1	Osijek (OS)	45°33′03″ N, 18°41′38″ E; 102 m
2	Varaždin (VZ)	46°18′15″ N, 16°20′16″ E; 154 m
3	Novi Sad (NS)	45°15′00″ N, 19°51′00″ E; 88 m
4	Nis (NI)	43°19′28″ N, 21°54′11″ E; 193 m
5	Debrecen (DE)	47°31′59″ N, 21°37′59″ E; 122 m
6	Győr (GY)	47°40′59″ N, 17°38′06″ E; 109 m
7	Bijeljina (BI)	44°45′24″ N, 19°12′57″ E; 91 m
8	Banja Luka (BL)	44°46′32″ N, 17°11′08″ E; 158 m

Air-distance (km): OS-VZ=200;NS-NI=270;GY-DE=300
Udaljenost (km): BL-BI=150;NI-GY=585; BL-DE=450

RESULTS AND DISCUSSION

Two growing seasons (2010 and 2012) are typical examples of climate trend characterized deviation of precipitation and temperature regimes in short period at the same areas compared to standard averages 1961-1990 (Tables 2-5). Precipitation and mean air-temperatures (average of eight sites) in the April-September period were 644 mm and 18.1°C for 2010 and 323 mm and 19.6°C (30-year means 397 mm and 17.3°C, respectively). Average precipitation (1961-1990) in this period was from 219 mm (NI) to 547 mm (BL) and air-temperatures from 16.0°C (GY) to 18.3°C (BI).

Regarding maize water requirements, the growing season 2010 was especially favorable because of adequate precipitation, with exception of Central Serbia (Nis: 296 mm). Namely, in the remaining seven sites precipitation amounts were from 585 mm (DE) to 803 mm (BL). Although the 2010 growing season was colder than usual air-temperatures were in tested sites above the average 1961-1990 and varying from 16.9°C (GY) to 19.3°C (NI) – Table 2. However, the growing season 2012 was characterized by both dry and hot stresses for maize. Precipitation quantity was lower by 74 mm or close to 20% lower than usual and air-temperature was even for 2.3°C higher.

Table 2. Monthly values of precipitation and mean air-temperatures

Tablica 2. Oborine i srednje temperature zraka po mjesecima

Precipitation and mean air-temperatures in 2010, 2012 and average 1961-1990 (*61-90*) *Oborine i srednje temperature zraka u 2010., 2012. i prosjek 1961.-1990. (61.-90.)*														
Year *God.*	Monthly precipitation (mm) *Mjesečne količine oborina (mm)*							Monthly mean air-temperatures (°C) *Mjesečne srednje temperature zraka (°C)*						
	Apr. *Tra.*	May *Svi.*	June *Lip.*	July *Srp.*	Aug *Kol.*	Sept *Ruj.*	Σ	Apr. *Tra.*	May *Svi.*	June *Lip.*	July *Srp.*	Aug *Kol.*	Sept *Ruj.*	$\overline{x}$
Osijek (OS)														
2010	71	121	234	32	111	108	*676*	12.4	16.5	20.4	23.2	21.7	15.6	*18.3*
2012	47	94	68	48	4	32	*293*	12.5	16.9	22.5	24.8	24.1	18.9	*20.0*
61-90	*54*	*59*	*88*	*65*	*58*	*45*	*368*	*11.3*	*16.5*	*19.5*	*21.1*	*20.3*	16.6	17.6
Varaždin (VZ)														
2010	71	107	132	68	212	186	*775*	11.2	15.7	19.5	22.1	19.7	14.0	*17.0*
2012	42	128	80	81	10	120	*461*	12.2	16.3	21.4	22.5	22.0	18.1	*18.8*
61-90	*70*	*84*	*98*	*92*	*98*	81	524	10.3	15.1	18.3	19.8	18.9	15.4	16.3
Novi Sad (NS)														
2010	64	113	172	99	168	68	*684*	12.3	17.0	20.2	23.1	21.9	16.1	*18.4*
2012	83	52	27	48	4	13	*227*	13.0	17.5	23.0	25.2	24.6	19.8	20.6
61-90	47	57	83	61	55	36	339	11.4	16.6	19.6	21.1	20.6	16.9	17.7
Nis (NI)														
2010	79	69	67	37	29	15	*296*	12.9	17.2	21.0	23.0	23.6	17.9	*19.3*
2012	86	162	6	38	11	15	*317*	13.4	12.9	20.4	22.8	22.5	19.2	*18.6*
61-90	*51*	*67*	*70*	*44*	*43*	*44*	*219*	*11.9*	*16.6*	*19.5*	*21.3*	21.1	17.2	17.9
Debrecen (DE)														
2010	74	142	93	92	78	106	*585*	11.7	16.3	19.7	22.5	21.3	14.9	*17.7*
2012	30	57	66	49	13	35	*250*	12.2	17.1	21.4	24.1	23.2	18.8	*19.5*
61-90	*42*	*59*	*80*	*66*	61	38	346	10.7	15.8	18.7	20.3	19.6	15.8	16.8
Győr (GY)														
2010	110	204	124	57	116	111	*722*	10.7	15.0	19.2	22.3	19.9	14.1	*16.9*
2012	46	36	64	85	5	26	*262*	11.5	16.8	20.8	22.2	21.8	17.5	*18.4*
61-90	*49*	*71*	*80*	*74*	*69*	*54*	*397*	*9.9*	*14.5*	*17.7*	*19.5*	*19.0*	*15.4*	*16.0*
Bijeljina (BI)														
2010	84	86	197	65	99	79	*610*	12.4	17.3	20.6	23.3	22.6	16.2	*18.7*
2012	91	97	44	36	0	19	*288*	13.1	16.7	25.3	26.0	24.8	20.3	*21.0*
61-90	*65*	*69*	*105*	*72*	*66*	*59*	*436*	*11.8*	*17.2*	*20.3*	22.1	21.6	17.0	18.3
Banja Luka (BL)														
2010	71	148	235	66	87	196	*803*	12.0	16.5	20.4	23.1	21.8	15.7	*18.3*
2012	103	168	70	53	2	92	*488*	12.7	16.1	23.0	25.2	24.5	18.9	*20.1*
61-90	*86*	*89*	*113*	82	77	100	547	11.4	16.6	19.9	21.8	21.3	16.5	17.9

Climate (1961-1990) of the eastern part of the tested area is characterized by considerable lower precipitation during maize growing season (DE, NS and NI April-Sept. average: 301 mm) in comparison to the western part (GY, VZ and BL: 489 mm). However, greater differences of temperature among tested sites were found in NW direction (DE and GY average 16.4°C and NI and BL average 17.9°C). For this reason, the SE part of the region is more exposed to hot and drought stress (NI: 219 mm and 17.9°C) compared to its NW part (GY: 397 mm and 16.0°C).

Maize water requirements are especially high in two summer months July and August (Shaw, 1988; Markulj et al., 2010). For this reason, drought and high air-temperature during these two months are unfavorable for maize growth. Thus, climate (1961-1990) in the western part of the region (July + August: VZ = 190 mm and 19.3°C) is more favorable than in the eastern part (NI: 87 mm and 21.2°C).

Precipitation and temperature status in July and August of tested growing seasons were quite different. For example, in 2010 precipitation were mainly considerable higher in six sites compared to usual (30-y average) from 11% (BI) to 125 (NS), while in the remaining two sites they were by 32% lower (NI) or at usual level (BL). Air-temperatures in these two months

were higher than usual or from 0.9ºC (BL) to even 2.9ºC (DE). This phenomenon is indication of global warming because under wet conditions of moderate continental climate (more rainy days) air-temperatures are mainly lower. Combination of adequate precipitation and warmth was favorable for maize growth and maize yields in 2010 under non-irrigated conditions were considerably higher than usual (Table 6). However, weather in July and August of 2012 was unfavorable for maize growth because of drought and hot stress (Tables 2, 3 and 4). Precipitation decreases compared to usual were from 44% (NI) to 76% (BI). More favorable conditions were in the western part of the region (VZ 91 mm and GY: 90 mm), while at the remaining six station precipitation amounts were from 36 mm (BI) to 55 mm (BL). Air- temperature at two meteorological stations were higher by 1.5ºC (NI) and 2.5ºC (VZ), while at the remaining six sites these values were higher than usual from 3.3ºC (BL) to even 4.0ºC (NS). These unfavorable weather conditions resulted in considerable yield reduction (Table 6).

Table 3. Precipitation and mean air-temperature over 10-days periods

Tablica 3. Oborine i srednje temperature zraka po dekadama

Month *Mjesec*	Precipitation and mean air-temp. in the 10-days intervals of 2012 (a = 1-10; b = 11-20; c = 21-30/31) *Oborine i srednje temp. zraka po 10-dnevnim intervalima 2012. (a = 1.-10.; b = 11.-20.; c = 21.-30./31.)*											
	Precipitation (mm) *Oborine (mm)*			Mean air-temp. (ºC) *Srednje temp. zraka (ºC)*			Precipitation (mm) *Oborine (mm)*			Mean air-temp. (ºC) *Srednje temp. zraka (ºC)*		
	a	b	c	a	b	c	a	b	c	a	b	c
	The 2010 growing season / *Vegetacija 2010. godine*											
	Osijek (OS)						Novi Sad (NS)					
June	81	14	139	19.0	23.9	18.3	60.5	17.2	94.1	18.7	23.5	18.4
July	3	4	25	22.3	26.3	21.3	43.7	45.1	10.2	21.6	26.1	21.7
August	89	0	21	22.0	23.3	20.0	100.7	42.0	25.8	21.9	23.7	20.3
Sept.	25	72	11	15.8	16.5	14.4	43.0	17.7	7.0	16.4	17.1	15.0
	Debrecen (DE)						Bijeljina (BI)					
June	24.1	24.1	39.0	20.5	21.7	18.7	61	44	91	19.1	24.7	18.1
July	46.7	2.0	42.9	20.9	25.5	21.2	32	17	18	22.4	25.9	21.8
August	11.7	45.2	21.0	22.0	22.8	19.1	70	8	24	23.2	23.9	20.9
Sept.	53.4	38.1	15.0	15.1	14.2	14.0	33	24	22	17.9	16.7	14.9
	The 2012 growing season / *Vegetacija 2012. godine*											
	Osijek (OS)						Novi Sad (NS)					
June	40.8	17.8	9.3	20.6	22.7	24.2	8.3	18.1	1.1	21.3	23.0	24.7
July	0	0.9	46.9	27.9	23.8	22.9	10.5	0.0	37.2	28.4	24.2	23.4
August	0	0	4.0	26.1	21.8	24.3	0.0	0.0	3.5	26.5	22.0	25.2
Sept.	2.0	28.7	1.6	21.0	16.9	18.7	0.6	3.4	9.1	21.8	17.8	19.8
	Debrecen (DE)						Bijeljina (BI)					
June	13.0	40.1	2.6	19.8	22.3	22.2	9.2	29.1	5.4	22.0	24.2	25.3
July	0	25.7	23.2	27.5	21.6	23.2	20.9	0	15.2	28.6	25.4	24.3
August	0	11.7	1.5	25.6	19.6	24.3	0	0	0	27.4	22.7	24.4
Sept.	8.4	7.1	19.8	21.4	20.3	16.9	1.0	11.7	6.6	21.6	16.8	20.3

Cindrić et al. (2009) detected climate variations and changes in air temperature and precipitation in Croatia are since the beginning of the 20th century (1901) including Osijek and Zagreb. Consequence of the faster atmosphere warming up during the last period of time is the fact that, out of ten warmest years since the beginning of the 20th century, 7 of them were recorded in Zagreb and 4 in Osijek. Also, precipitation amounts have large interannual variability, both on annual and seasonal scales. During the 20th century annual amounts of precipitation showed a downward trend in all parts of Croatia (10-year decreasing trend: -1.3% in Osijek and -0.3% in Zagreb). The decline over the area north of the River Sava is due to decrease in spring (Osijek and Zagreb: -4.1% and -1.1% in 10 years, respectively) and autumn (-3.0% and -1.4%, respectively). In the period 1901-2008 there was statistically significant increase of annual number of dry days (daily rainfall $<$1.0 mm) in the whole area of Croatia, mostly negative trend of wet days.

If only the climate change effect is included, the maize growing season in NW Croatia became significantly shorter (by 34–44 days) and the decrease in maize yields varied from 8% to 15% under the climate change scenarios considered at the end of the 21st century (Vucetic, 2006). Similar results have been simulated for western Hungary (Bacsi and Hunkar, 1994).

Table 4. Mean maximal and absolute maximal air-temperatures

Tablica 4. Prosječne maksimalne i apsolutno maksimalne temperature zraka

Month *Mjesec*	Average maximal (AverageM) and absolute maximal (AbsoluteM) air-temperature in the 10-days intervals in July and August 2010 and 2012 (a = 1- 10; b = 11– 20; c = 21– 30/31) *Prosječne maksimalne* (AverageM) *i apsolutno maksimalne* (AbsoluteM) *temp. zraka u 10.dnevnim intervalima tijekom srpnja i kolovoza 2010. i 2012. (a = 1.- 10.; b = 11. – 20.; c = 21. - 30./31.)*											
	AverageM (ºC)			AbsoluteM (ºC)			AverageM (ºC)			AbsoluteM (ºC)		
	a	b	c	a	b	c	a	b	c	a	b	c
	The 2010 growing season / *Vegetacija 2010. godine*											
	Osijek (OS)						Novi Sad (NS)					
July	28.5	32.0	26.5	31¸.6	34.2	34.0	27.9	31.8	27.0	30.1	34.3	33.4
August	27.5	29.4	26.6	32.0	31.5	35.0	27.4	29.7	27.1	31.8	33.2	36.1
	Debrecen (DE)						Bijeljina (BI)					
July	25.9	28.1	25.7	30.0	34.0	33.1	28.3	31.8	29.0	32.0	35.1	35.3
August	27.7	29.1	25.3	31.5	35.0	32.2	28.2	30.7	31.5	32.1	33.4	37.8
	The 2012 growing season / *Vegetacija 2012. godine*											
	Osijek (OS)						Novi Sad (NS)					
July	35.8	30.7	29.0	37.0	36.0	35.0	35.5	31.2	29.6	37.1	34.8	36.6
August	33.3	29.5	33.8	40.1	34.6	40.3	33.5	29.6	33.9	38.4	33.9	39.7
	Debrecen (DE)						Bijeljina (BI)					
July	34.5	27.7	28.9	36.6	31.8	33.2	36.2	32.0	30.6	37.8	37.0	38.0
August	31.9	26.2	32.4	37.5	34.1	36.7	34.7	30.8	35.1	40.2	35.6	40.3

The two longest drought periods occurred during the 2012 growing season as follows: from June 21 to July 20 (A) and from August 1 to September 10 (B). Drought intensity in these periods was different depending on the tested four sites (Table 3). Thus, weather characteristics in the eastern part of Hungary were slight by more favorable in comparison to remaining three tested sites in Croatia, Serbia and B&H (the period A: 10 mm and 25.3ºC; 12 mm and 25.8ºC; 28 mm and 23.8ºC; 26 mm and 26.4ºC, the period B: 6 mm and 23.3ºC; 4 mm and 23.9ºC; 22 mm and 22.7ºC; 1 mm and 24.0ºC, for OS, NS, DE and BI, respectively). Also, based on the mean air-temperature values (Table 3), the warmest part of the 2012 growing season was the first 10-day of July (27.9ºC, 28.4ºC, 27.5ºC and 28.6ºC, for OS, NS, DE and BI, respectively).

Table 5. Values of the Rain factor according Gracanin

Tablica 5. Vrijednosti kišnoga faktora po Gračaninu

Rain factor monthly values (RFm) according Gračanin (1950) in 2010, 2012 and average 1961-1990 (*61-90*) *Kišni faktor (RFm) po Gračaninu (1950.) u 2010., 2012. i prosjek 1961.-1990. (61.-90.)*									
Year *God.*	**Osijek** (OS)			**Varazdin (VZ)**			**Novi Sad** (NS)		
	June *Lip.*	July *Srp.*	Aug *Kol.*	June *Lip.*	July *Srp.*	Aug *Kol.*	June *Lip.*	July *Srp.*	Aug *Kol.*
2010	11.5h	1.4a	5.1sh	6.8h	3.1a	10.8h	8.5h	4.3sa	7.7h
2012	3.0a	1.9a	0.2pa	3.7sa	3.6sa	0.5pa	1.2a	1.9a	0.2pa
61-90	4.5sa	*3.1a*	*2.9a*	*5.4sh*	*4.6sa*	*5.2sh*	4.2sa	2.9a	2.7a
	Nis (NI)			**Debrecen** (DE)			**Győr** (GY)		
2010	3.2a	1.6a	1.2a	4.7sa	4.1sa	3.7sa	6.4sh	2.6a	5.8sh
2012	0.3a	1.7a	0.5pa	3.1a	2.0a	0.6a	3.1a	4.1sa	0.2pa
61-90	3.6sa	2.1a	2.0a	4.3sa	3.3a	3.1a	4.5sa	3.8sa	3.6sa
	Bijeljina (BI)			**Banja Luka** (BL)			The Legend / *Legenda*		
2010	9.6h	2.8a	4.4sa	11.5h	2.9a	4.0sa	pa = perarid		sh =semihumid
2012	1.7a	1.4a	0pa	3.0a	2.1a	0.1pa	a = arid		h = humid
61-90	5.2sh	*3.3a*	*3.1a*	*5.7sh*	*3.8sa*	*3.6sa*	sa = semiarid		ph = perhumid

Table 6. Maize harvested area and yields (faostat.fao.org)

Tablica 6. Požete površine i prinosi kukuruza

	Maize harvested area (ha) and grain yields (kg ha^{-1}) in 2010 and 2012 (YR = yield reduction) *Požete površine (ha) i prinosi zrna kg ha^{-1}) u 2010. I 2012. (YR = smanjeni prinos)*							
		Serbia *Srbija*	Hungary *Mađarska*	Croatia *Hrvatska*	B&H *BiH*	Romania R*umunjska*	France *Francuska*	USA *SAD*
2010	ha	1223579	1078825	296768	188752	2094249	1582400	32960380
	t ha^{-1}	5.89	6.47	6.97	4.52	4.31	8.83	9.59
2012*	ha	1268544	1190000	299161	196504	2722180	1718600	35359790
	t ha^{-1}	2.78	3.98	4.34	2.74	2.19	9.08	7.74
YR (%) 2012 : 2010		53	38	38	40	49	0	19

*preliminary data (status August 8, 2013); / * *preliminarni podaci (stanje 8. kolovoza 2013.)*

However, absolute maximal temperature (Table 4) occurred at the beginning (DE 37.5ºC) and the end of August (OS and BI 40.3ºC; NS 39.7ºC). Precipitation and temperature regime in the same period of 2010 were normal regarding maize growth (Tables 3 and 4). For example, mean air- temperature in the warmest part of the 2010 growing season (the second 10-day of July) were from 25.5ºC (DE) to 26.3ºC (OS) and absolute maximal temperature (mainly at the end of August) in 2010 were in range from 35.0ºC (OS and DE) to 37.8ºC (BI). Also, the RFm values in the 2010 growing season were close to usual (30-year averages) in comparison to those in 2012 (Table 5).

The 2012 drought devastated non-irrigated maize yields in the region (Serbia for 53%, Hungary and Croatia for 38%, B&H for 40%) compared to normal 2010 growing season (Table 6). The data for Romania and France were added because these two countries have the highest maize production in Europe, whereas USA is the first ranged country in the World.

CONCLUSION

The growing seasons 2010 and 2012 quite different in terms of maize growing and extreme weather conditions are in accordance with the global climatic changes. Alleviation of drought stress and extreme high air-temperature stress for maize is possible by irrigation in critical stages of maize growth, by growing of more tolerant genotypes and by adequate soil management (soil tillage, fertilization, etc).

REFERENCES

1. Bacsi, Zs., M. Hunkar (1994): Assessment of the impacts of climate change on the yields of winter wheat and maize using crop models, Időjárás, 98 (2): 119–134.
2. Blanc E. (2012): The Impact of Climate Change on Crop Yields in Sub-Saharan Africa. American Journal of Climate Change, 2012, 1, 1-13 (http://www.SciRP.org/journal/ajcc).
3. Cindrić K., Gajić-Čapka M., Zaninović K. (2009): Observed climate changes in Croatia. In: Fifth National Communication of the Republic of Croatia under the United Nation Framework Convention on the Climate Change (UNFCCC) – selected chapters, Meteorological and Hydrometerological Service of Croatia, Zagreb. p.1-17.
4. http://klima.hr/razno/publikacije/climate_change.pdf
5. DHZ (2010, 2012): Klimatološki izvještaji (Climatological Reports), The State Hydrometeorological Institute, Zagreb.
6. FAO (2006,2013): FAO (Food and Agriculture Organization of the United Nations) FAO Statistical Databases Available from: http://faostat.fao.org
7. Fischer G, Shah M, Tubiello F N and van Velhuizen H (2005): Socio-economic and climate change impacts on agriculture: an integrated assessment, 1990–2080 Phil. Trans. R. Soc. B 360 2067–83
8. Gračanin M. (1950): Mjesecni kišni faktori i njihovo značenje u pedološkim istraživanjima. Poljoprivredna znanstvena smotra, 12: 51.-67.
9. IPCC (Intergovernmental Panel on Climate Change Working Group 2) (2001): Climate Change 2001: Impacts, Adaptation and Vulnerability IPCC Working Group 2.
10. Kovačević, D., Oljača S., Dolijanović, Z., Milić V. (2012): Climate changes: Ecological and agronomic options for mitigating the consequences of drought in Serbia. Third International Scientific Symposium „Agrosym 2012" Jahorina, Book of the proceedings, November 15-17, (Editor in Chief D. Kovačević). - Istočno Sarajevo: Poljoprivredni fakultet, pp 17-36
11. Kovačević, D., Dolijanović, Z., Jovanović, Ž., Simic M., Milić V. (2012a): Climate change in Serbia: Depedence of maize yield on temperatures and precipitation. Third International Scientific Symposium „Agrosym 2012" Jahorina, „Agrosym 2012" Jahorina, Book of the proceedings, November 15 - 17, (Editor in Chief D. Kovačević). - Istočno Sarajevo: Poljoprivredni fakultet, pp. 263-269.
12. Kovačević V. (2008): Vremenske prilike sa stajališta uzgoja kukuruza u Hrvatskoj 2007. godine. Agroznanje 9 (4): 43-50.
13. Kovačević V., Maklenović V., Jolankai M. (2009): Oborinski i temperaturni režim kao faktori prinosa kukuruza u Hrvatskoj, Srbiji i Mađarskoj. Agroznanje 10(3): 67-75.

14. Kovačević V., Rastija M., Josipović M. (2012): Precipitation and temperature regimes specifities for maize growing in the eastern Croatia since 2000. Proceedings of the Third International Scientific Symposium „Agrosym Jahorina 2012". 15-17 Nov. 2012. Jahorina. RS, B&H, p. 81-86.
15. Lobell D., Field C. (2007): Global scale climate–crop yield relationships and the impacts of recent warming. Public Health Resources. Paper 1 http://digitalcommons.unl.edu/publichealthresources/152)
16. Maklenović V., Vučković S., Kovačević V., Prodanović S., Živanović Lj. (2009): Precipitation and temperature regimes impacts on maize yields In: Proceedings of 44th Croatian and 4th International Symposium on Agriculture (Maric S. and Loncaric Z. Editors.), 16 th – 20 th Febr. 2009, Opatija; Fac. of Agriculture Osijek, p. 569-573.
17. Markulj A., Marijanovic M., Tkalec M., Jozic A., Kovacevic V. (2010): Effects of precipitation and temperature regimes on maize (*Zea mays* L.) yields in northwestern Croatia. Acta Agriculturae Serbica, Vol. XV, 29: 39-45.
18. Parry M, Rosenzweig C and Livermore M (2005): Climate change, global food supply and risk of hunger Phil. Trans. R. Soc. B 360 2125–38.
19. Rastija M., Iljkić D., Kovačević V., Brkic I. (2012): Weather impacts on maize productivity in Croatia with emphasis on 2011 growing season. Növénytermelés 61: 329-332.
20. SG (2011a): Statistički godišnjak Republike Srbije, Državni zavod za statistiku Beograd.
21. SG (2011b): Statistički godišnjak Republike Srpske. Zavod za statistiku Republike Srpske, Banja Luka.
22. SG/LJ (2011): Statistički godišnjak / Ljetopis Federacije Bosne i Hercegovine, Federalni zavod za statistiku Sarajevo.
23. SLJ (2011): Statistički ljetopis Republike Htrvatske, Državni zavod za statistiku Zagreb.
24. SYB (2011): Statistical Yearbook of Hungary, The State Bureau for Statistics, Budapest.
25. Shaw R.H. (1988): Climate requirement. In: Corn and corn improvement, Agronomy Monograph No 18, 3rd edition (Sprague G.F. ed.) ASA-CSSA-SSSA, Madison, Wisconsin, USA. 609-638.
26. Vučetić V. (2006): Modelling of the maize production and the impact of climate change on maize yields in Croatia (final report), Meteorological and hydrometeorological service of Republic of Croatia, Zagreb.

KLIMATSKE PROMJENE U HRVATSKOJ, SRBIJI, MAĐARSKOJ I BOSNI I HERCEGOVINI: USPOREDBA VEGETACIJE KUKURUZA 2010. I 2012. GODINE

SAŽETAK

Kukuruz je glavna ratarska kultura na oranicama u Hrvatskoj, Srbiji, Mađarskoj i Bosni i Hercegovini (BiH). U razdoblju 2006.-2010. ukupno 2,854.506 ha (5-god. prosjek) oranica toga područja bilo je pod kukuruzom. Variranja prinosa po godinama bila su od 3,6 do 7,5 t ha^{-1} (Mađarska), od 3,2 do 5,9 t ha^{-1} (Srbija), od 4,9 do 8,0 t ha^{-1} (Hrvatska) i od 3,2 do 5,1 t ha^{-1} (B&H). Cilj je ovoga rada analizirati vegetacije kukuruza 2010. i 2012. sa stajališta vremenskih prilika. Prinosi kukuruza u nepovoljnoj 2012. godini iznosili su 4,34 t ha^{-1} u Hrvatskoj, 3,98 t ha^{-1} u Mađarskoj, 2,78 t ha^{-1} u Srbiji i 2.74 t ha^{-1} u BiH, što je za 53%, 38%, 38%, odnosno za 40% manje nego u izrazito povoljnoj za kukuruz 2010. godini.

Ključne riječi: klimatske promjene, prinos kukuruza, oborine, temperature zraka, utjecaj godine

(Received on 9 October 2013; accepted on 18 November 2013 - *Primljeno 09. listopada 2013.; prihvaćeno 18. studenoga 2013.*)