REVIEW ARTICLE

Climatic changes impacts on maize, sugar beet, soybeans and sunflower yields in Croatia

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Abstract

In the 5-y period from 2008 to 2012 mean harvested areas (ha year^{-1}) of field crops in Croatia were 302 266 (maize), 49 908 (soybean), 31 197 (sunflower) and 22 825 (sugar beet). Mean yield (t ha^{-1}) in the above mentioned period in Croatia was 6.6(maize), 2.5 (soybean), 2.8 (sunflower) and 51.2 (sugar beet) with ranges of variation among the years from 4.3 to 8.0 for maize, from 1.8 to 3.0 for soybean, from 2.3 to 3.1 for sunflower and for sugar beet from 39.1 to 57.7. The lowest annual yields of maize, soybean and sugar beet were found in 2012 because of drought and high temperature stresses in summer, especially in August. However, the lowest annual yield of sunflower was achieved under extremely wet conditions in 2010.

Key words: weather impacts, maize, soybean, sunflower, sugar beet

Introduction

Global warming and higher frequency of the extreme weather conditions is often connected to climate changes. Annual global temperatures are increased by about 0.4°C since 1980, with even larger changes observed in several regions (IPCC, 2001). Climate changes have often adverse influence on the field crops yields. Approximately 30% variations of global average yields for the world's six most widely grown crops are the result of growing season precipitation and temperature variations (Lobell and Field, 2007). In general, with that regard in the last period weather properties are more influencing factor of spring crops yields in comparison with those of the winter crops. Aim of this study was testing yield variations of some spring crops (maize, sugar beet, sunflower and soybean) for the 5-year period (2008 – 2012) in Croatia. In the previous studies, the period from 1996 to 2003 (Kovacevic and Kaucic, 2006) and from 2005 to 2007 (Kovacevic et al., 2010) were elaborated.

Material and methods

The Statistical Yearbooks were source of the maize, soybean, sunflower and sugar beet yields data. Source of meteorological data (precipitation and mean air-temperatures: Osijek, Slavonski Brod, Sisak and Varazdin) was State Hydrometeorological Institute in Zagreb. The rain factor (RFm) was calculated monthly as a quotient of precipitation (mm) and mean air temperatures (°C) according to Gračanin (1950). Based on the RFm, climate is characterized as follows: arid (<3.3), semiarid (3.3–5.0), semihumid (5.0 – 6.6), humid (6.6 – 13.3) and perhumid (>13.3).

Results and discussion

In the 5-y period 2008-2012 mean harvested areas (ha year^{-1}) of tested field crops in Croatia were 302 266 for maize, 49 908 for soybean, 31 197 for sunflower and 22 825for sugar beet. Mean grain yield of maize in the above mentioned period in Croatia was 6.5 tha^{-1}, with range of variation among the years from 4.3 to 8.0 t ha^{-1}. Regarding this, the lowest annual yield of maize was by 46% lower compared to the highest annual yield. According to the same

model of comparison, grain yield of soybean and sunflower were lower by 40% and 26%, respectively, while yield of sugar beet root was lower by 31% (Table 1).

Table 1. The harvested areas and yields of spring field crops in Croatia

Croatia:		The harvested areas (ha) and yields (t ha^{-1}) for 2008-2012 period					
The spring crop		2008	2009	2010	2011	2012	Average
Maize	ha	314 062	296 210	296 768	305 130	299 161	302 266
	tha^{-1}	8.0	7.4	7.0	5.7	4.3	6.6
Soybean	ha	35 789	44 292	56 456	58 896	54 109	49 908
	t ha^{-1}	3.0	2.6	2.7	2.5	1.8	2.5
Sunflower	ha	38 631	27 366	26 412	30 041	33 534	31 197
	t ha^{-1}	3.1	3.0	2.3	2.8	2.7	2.8
Sugar beet	ha	22 000	23 066	23 832	21 723	23 502	22 825
	t ha^{-1}	57.7	52.8	52.4	53.8	39.1	51.2
Croatia		Used arable lands (ha) and share of individual crop (% of arable lands)					
Arable lands (ha)		855 416	863 023	899 594	892 221	903 508	882 752
Maize (%)		36.7	34.3	33.0	34.2	33.1	34.3
Soybean (%)		4.2	5.1	6.3	6.6	6.0	5.6
Sunflower (%)		4.5	3.2	2.9	3.4	3.7	3.5
Sugar beet (%)		2.6	2.7	2.6	2.4	2.6	2.6

The majority of harvested areas of these field crops are situated in the five counties of the eastern Croatia. Although the eastern Croatia region occupies only 22% of the country territory, this region participates with about 60% of arable land and close to 50% of maize harvested area of the country. Also, above 90% of soybean, sunflower and sugar beet harvested areas have been situated in the eastern Croatia (Kovacevic and Kaucic, 2010). Based on the previous studies, the higher intensity and frequency of drought stress is more likely to occur in the eastern part of Croatia (Kovacevic, 2004; Kovacevic and Josipovic, 1998).

In general, the 2008, 2009 and 2010 growing seasons were favorable for maize, soybean and sugar beet growing (Table 2), mainly because of adequate amount of summer precipitation (July to August: 145 mm, 133 mm and 183 mm – averages of four meteorological stations, for 2008, 2009 and 2010, respectively; long term mean, LTM,is 158 mm). At the same period, mean air-temperatures were 21.5 ºC, 21.9 ºC and 21.9 ºC, respectively while LTM is 20.1ºC). Average yields of these crops in Croatia (2008-2010) were 7.5 t ha^{-1}, 2.8 t ha^{-1} and 64.3 t ha^{-1}, for maize, soybean and sugar beet, respectively. However, the 2011 and 2012 growing seasons were less favorable for growing of these crops because of drought and the high temperature stresses. For example, precipitation and air-temperatures in July and August (means of four stations) were 116mm and 22.3 °C in 2011 and only 56 mm and even 23.8 °C in 2012. Under such conditions yields of these crops were considerably lower as follows (2-year averages): 5.0 t ha^{-1} (maize), 2.1 t ha^{-1} (soybean) and 4.65 t ha^{-1} (sugar beet). Especially unfavorable conditions were in August of 2012 as in average for all four observed areas only 10 mm of precipitation was recorded and high air-temperature of 23.6 °C. However, sunflower is more tolerant to the drought and high temperature and more susceptible to excessive precipitation. For this reason, yield of sunflower was the lowest under wet conditions of 2010 (2.3 t ha^{-1}), while in remaining tested year mean yield was 2.9 t ha^{-1} (Table 1).

Table 2. Precipitation and mean air-temperatures (The Climatologically reports, SHI Zagreb)

The	Year (LTM = the long-term averages 1961-1990)											
month	2008	2009	2010	2011	2012	LTM	2008	2009	2010	2011	2012	LTM
	Precipitation (mm)						Mean air-temperature (°C)					
	Osijek (OS): 45°33′ N, 18°41′ E; 102 m											
April	50	19	71	20	47	*54*	12.5	14.6	12.4	13.2	12.5	*11.3*
May	67	39	121	81	94	*59*	18.1	18.3	16.5	16.7	16.9	*16.5*
June	76	63	234	50	68	*88*	21.5	19.2	20.4	20.8	22.5	*19.5*
July	79	14	32	74	48	*65*	21.8	23.2	23.2	22.2	24.8	*21.1*
Aug.	46	61	111	5	4	*59*	21.8	22.9	21.7	23.1	24.1	*20.3*
Sept.	86	10	108	16	32	*45*	15.7	19.1	15.6	20.3	18.9	*16.6*
Oct.	30	55	67	29	65	*41*	13.0	11.5	9.1	10.6	12.1	*11.2*
Σ (X)	*434*	*261*	*744*	*275*	*358*	*411*	*20.7*	*21.5*	*19.8*	*21.2*	*22.0*	*19.4*
	SlavonskiBrod (SB):45°16′ N, 18°00′ E; 88 m											
April	69	13	53	18	74	*58*	12.6	14.2	12.3	13.1	12.4	*10.9*
May	70	44	161	44	99	*73*	17.5	18.1	16.2	16.3	16.2	*15.9*
June	88	104	177	47	67	*86*	21.4	19.3	20.2	20.6	22.4	*19.0*
July	85	61	44	109	21	*83*	21.8	22.6	22.7	22.5	25.3	*20.7*
Aug.	35	29	44	18	11	*73*	21.5	22.3	21.8	23.3	24.5	*19.8*
Sept.	83	29	88	11	49	*62*	15.0	18.8	15.3	20.0	18.3	*16.1*
Oct.	44	45	58	32	84	*54*	12.2	11.0	8.9	10.2	11.7	*10.6*
Σ (X)	*474*	*325*	*625*	*279*	*405*	*489*	*20.3*	*21.1*	*19.6*	*21.0*	*21.8*	*18.8*
	Sisak (SI): 45°50′ N, 16°36′ E; 106 m											
April	48	31	59	31	34	*73*	12.4	14.8	12.4	13.6	12.8	*11.1*
May	36	44	157	32	120	*82*	17.5	18.7	16.5	16.7	16.6	*15.8*
June	155	153	146	125	114	*91*	21.4	19.7	20.5	20.9	22.7	*19.1*
July	120	171	65	88	33	*77*	22.0	22.5	23.4	22.2	24.0	*20.8*
Aug.	65	37	157	42	15	*85*	21.4	22.4	20.9	22.8	23.8	*19.8*
Sept.	98	30	172	30	109	*76*	15.0	18.0	14.9	19.5	17.8	*16.0*
Oct.	88	88	65	80	68	*64*	12.6	11.3	9.1	10.1	11.7	*10.8*
Σ (X)	*610*	*554*	*821*	*428*	*493*	*548*	*20.4*	*21.2*	*19.6*	*21.0*	*21.6*	*18.9*
	Varazdin (VZ): 46°18′ N, 16°20′ E; 154 m											
April	29	35	71	29	42	*70*	11.6	14.0	11.2	12.7	12.2	*10.3*
May	30	74	107	41	128	*84*	17.1	17.2	15.7	16.2	16.3	*15.1*
June	142	102	132	49	80	*98*	20.4	18.7	19.5	20.5	21.4	*18.3*
July	107	95	68	102	81	*92*	21.1	21.3	22.1	21.0	22.5	*19.8*
Aug.	54	64	212	25	10	*98*	20.6	20.7	19.7	21.5	22.0	*18.9*
Sept.	74	26	186	36	95	*81*	15.1	16.9	14.0	18.4	17.2	*15.4*
Oct.	66	40	61	84	109	*69*	11.8	10.8	8.1	9.6	11.2	*10.1*
Σ (X)	*502*	*436*	*837*	*366*	*545*	*592*	*19.6*	*19.9*	*18.4*	*20.0*	*20.5*	*18.0*

Table 3. Mean maximal and absolute maximal air-temperatures

Month	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.)											
	AverageM (ºC)			AbsoluteM (ºC)			AverageM (ºC)			AbsoluteM (ºC)		
	a	b	c	a	b	c	a	b	c	a	b	c
	The 2010 growing season											
	Osijek (OS)						Slavonski Brod (SB)					
July	28.5	32.0	26.5	31.6	34.2	34.0	21.9	25.6	20.9	31.0	34.8	34.7
August	27.5	29.4	26.6	32.0	31.5	35.0	21.9	23.9	20.3	31.3	32.5	36.5
	Sisak (SI)						Varazdin (VZ)					
July	23.1	26.2	21.3	31.6	34.9	36.4	22.0	24.4	20.2	31.5	33.9	33.6
August	21.0	22.2	19.5	31,2	29.7	33.4	19.7	21.0	18.5	29.0	28.6	32.2
	The 2012 growing season											
	Osijek (OS)						Slavonski Brod (SB)					
July	35.8	30.7	29.0	37.0	36.0	35.0	28.3	24.5	23.4	37.2	36.7	35.4
August	33.3	29.5	33.8	40.1	34.6	40.3	26.7	22.8	23.9	40.5	35.4	40.2
	Sisak (SI)						Varazdin (VZ)					
July	27.0	22.6	22.5	36.2	37.4	34.1	26.3	20.6	20.9	35.0	33.9	32.8
August	25.6	22.3	23.5	39.3	35.1	40.0	23.6	20.3	22.1	32.6	34.4	37.5

The 2010 and 2012 growing seasons considerably differed regarding precipitation and temperature regimes (Tables 2 - 4) and for this reason differently favorable for the field crops growing, especially for maize (mean yields 7.0 and 4.3 tha^{-1}, for 2010 and 2012, respectively). Particularly unfavorable conditions were in August of 2012. Absolute maximal air-temperature in Osijek and Slavonski Brod were above 40 °C. In general, weather conditions in 2012 were very unsuitable in the eastern part of the region (Tables 2-4).

Table 4. Values of the Rain factor according to Gračanin

Rain factor monthly values (RFm) according to Gračanin (1950) in July and August of 2010, 2012 and the long-term means (30-year averages 1961-1990)*								
Year	Osijek (OS)		Slav. Brod (SB)		Sisak (SI)		Varazdin (VZ)	
	July	Aug.	July	Aug.	July	Aug.	July	Aug.
2010	1.4a	5.1sh	1.9a	2.0a	2.8a	7.5h	3.1a	10.8h
2012	1.9a	0.2a	0.8a	0.5a	1.4a	0.6a	3.6sa	0.5 ph
LTM	*3.1a*	*2.9a*	*4.0sa*	*3.7sa*	*3.7sa*	*4.3sa*	*4.6sa*	*5.2sh*
* the legend: a = arid, sa = semiarid, sh =semihumid, h = humid, ph = perhumid								

Conclusions

Extreme variation of precipitation and temperature regimes among years during the spring crops growing seasons in Croatia are typical example of recent climatic changes. Regarding drought and the high temperature stresses, possible solutions for alleviation their negative effects are first of all irrigation, than growing more tolerant genotypes and adaptation of soil and crop management practice.

References

Gračanin M. (1950): Mjesečni kišni factor i njihovo značenje u pedološkim istraživanjima. Poljoprivredna znanstvena smotra 12, 51.

IPCC (Intergovernmental Panel on Climate Change Working Group 2) (2001): Climate Change 2001: Impacts, Adaptation and Vulnerability IPCC Working Group 2.

Josipovic M., Kovacevic V., Petosic D. and Sostaric Jasna (2005): Wheat and maize yield variations in the Brod-Posavina area. Cereal Research Communications 33 (1):229-233.

Kovacevic V. ,Kaucic D.(2006): Weather characteristics impacts on yields of the spring crops in Croatia. In: Proceednings, 41 Croatian & 1st International Symposium on Agriculture, (S. Jovanovac and V. Kovacevic Eds.), 13-17. February 2006, Opatija, Croatia, Faculty of Agriculture, University J. J. Strossmayer in Osijek, p. 421-422.

Kovacevic V., Josipovic M., Kaucic D., Iljkic D. (2010): Weather impacts on yields of maize, sugar beet, soybeans and sunflower. In: Proceedings of 45th Croatian and 5th International Symposium of Agriculuture, Opatija 15-19 February 2010 (Maric S. and Loncaric Z. Editors), Faculty of Agriculture in Osijek, p. 796-800.

Kovacevic V., Kovacevic D., Pepo P., Markovic M. (2013): Climate change in Croatia, Serbia, Hungary and Bosnia and Herzegovina. Poljoprivreda / Agriculture 19 (2): - in press.

Kovacevic, V. (2004): Precipitation influences on maize yields in eastern Croatia. Proceedings of the Third Alps-Adria Scientific Workshop (Gyuricza C. Editor), March 1-6, 2004, Dubrovnik. Hungarian Academy of Sciences, Crop Production Committee, Soil Science and Agrochemistry Committee, Plant Protection Committee, pp. 295-299.

Kovacevic V., Josipovic M. (1998): Weather and soil limitations for maize growing in the Eastern Croatia. Fifth Congress of ESA (European Society for Agronomy), Short Communications (Vol. II), Zima M. and Bartosova M. L. – Editors, June 28 – July 2, 1998, Nitra, The Slovak Republic p.157-158.

Lobell D., Field C. (2007): Global scale climate–crop yield relationships and the impacts of recent warming. PublicHealth Resources.Paper 1.

http://digitalcommons.unl.edu/publichealthresources/152

SYB (2012): Statistical Year Book, State Bureau for Statistics, Zagreb.

SR (2012): Statistical Report, Agriculture 2012, State Bureau for Statistics, Zagreb.