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WEATHER CONDITIONS IN THE 2013 -2015 GROWING SEASONS FOR MAIZE IN CROATIA AND BOSNIA AND HERZEGOVINA

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ABSTRACT

Maize is the main field crop on the arable lands in Croatia and Bosnia and Herzegovina (B&H). In the 2001-2010 period, maize was grown on 333,736 ha (average yield 6.50 t ha^{-1}) in Croatia and 195,800 ha (4.42 t ha^{-1}) in B&H. Yield variations among years were from 3.86 to 7.98 t ha^{-1} and from 2.74 to 5.13 t ha^{-1}, respectively. Aim of this study was survey of maize yield and weather data (precipitation and mean air temperature) in Croatia and B&H in the 2013, 2014 and 2015 growing seasons. Average yields of maize were 6.5, 8.1 and 6.5 t ha^{-1} (Croatia), 4.0, 5.0 and 4.1 t ha^{-1} (B&H) in 2013, 2014 and 2015, respectively.

The 2014 growing season was very favorable for maize growth. Precipitation and temperature in April-September period were as follows: 520 mm and 18.2^{o}C (Osijek), 910 mm and 17.2^{o}C (Varazdin), 731 mm and 18.5^{o}C (Bijeljina), 1228 mm and 18.0^{o}C (Banja Luka). These precipitation values are higher by 41% (Osijek), 75% (Varazdin and Bijeljina), and 116% (Banja Luka) compared to averages 1961-1990. In extremely unfavorable 2012 (yield 4.34 and 2.74 t ha^{-1}, in Croatia and B&H, respectively), precipitation and temperature at the same period were 293 mm and 20.0^{o}C (Osijek), 461 mm and 18.8^{o}C (Varazdin), 288 mm and 21.0^{o}C (Bijeljina), 488 mm and 20.1^{o}C (Banja Luka). However, in 2013 and 2015, yields, precipitation and temperature regimes in both countries were more close to average values. Considerable variation of precipitation in the short 2012 -2014 period and higher temperatures are in accordance with climate change.

Key words: *maize, yield, Croatia, Bosnia and Herzegovina, precipitation, temperature, climatic change.*

INTRODUCTION

Maize is the main field crop on the arable lands in Croatia and Bosnia and Herzegovina (B&H). In the 2001-2010 period, maize was grown on 333,736 ha (average yield 6.50 t ha^{-1}) in Croatia and 195,800 ha (4.42 t ha^{-1}) in B&H. In general, the harvested areas of maize among years in both countries are mainly stabile, while annual yield variations in mentioned period were considerable and in ranges from 3.86 to 7.98 t ha^{-1} and from 2.74 to 5.13 t ha^{-1}, respectively (SY 2005, 2010; FAO, 2016). Weather conditions, particularly precipitation quantity and temperature regimes, are responsible for considerable variation maize yields in the mentioned period. With that regard, low yields of maize are in close connection with the lower precipitation and the higher air temperature in summer months (Shaw 1988; Kovacevic *et al.*, 2013). Impacts of weather conditions on maize yield in Croatia in 2001-2010 period were elaborated in previous study (Kovacevic *et al.*, 2012). Majdancic *et al.*, (2016) reported survey of maize growing in Federation of B&H with emphasis on Tuzla Canton in 15-year period 2000-2014, while Iljkic *et al.* (2014) collected data of maize growing in Croatia and B&H in 2008-2012 period. Phenomenon considerable variation of maize yield among years is also associated with recent climatic change which has often adverse influences on field crop yields. Annual global temperatures have increased by about 0.4 ^{o}C since 1980 (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 result of growing season precipitation and temperature variations. Aim of this study was survey of maize yield and weather data (precipitation and mean air temperature) in Croatia and B&H in the 2013, 2014 and 2015 growing seasons.

MATERIAL AND METHODS

FAO database and publications of Croatian Bureau of Statistics were used as sources of arable land, maize harvested areas and yields for the tested period.

Eight meteorological stations (Osijek, Bjelovar, Sisak and Varazdin in Croatia; Bijeljina, Tuzla, Banja Luka and Bihac in B&H: Map 1) were selected for elaboration of weather conditions during maize growing seasons because by they cover majority of growing area of maize in both countries. These towns are situated in northern part of Croatia (Panonian region) and northern Bosnia. Meteorological data were collected by courtesy of State Hydrometerological Service in Zagreb, Federal Hydrometeorological Institute in Sarajevo and Hydrometerological Institute of Republic of Srpska in Banja Luka (permitted access in climatologically lists).

Map 1. Situation of the meteorological stations

Meteorological station	Coordinates and elevation (m) above sea level
Croatia	
Osijek (OS)	45°33′03″ N, 18°41′38″ E; 102 m
Bjelovar (BJ)	45°54′36″ N, 16°50′24″ E; 90 m
Sisak (SI)	45°28′48″ N, 16°21′36″ E; 98 m
Varazdin (VZ)	46°18′15″ N, 16°20′16″ E; 154 m
Bosnia and Herzegovina	
Bijeljina (BJ)	44°45′24″ N, 19°12′57″ E; 91 m
Tuzla (TZ)	44° 32′31″N, 18° 41′06″E; 305 m
Banja Luka (BL)	44°46′32″ N, 17°11′08″ E; 158 m
Bihac (BI)	44° 48′31″N, 15° 51′35″E; 246 m

RESULTS AND DISCUSSION

Average maize harvested area in Croatia in decade 2001-2010 period were 333,736 ha, while in the last three year period 2013-2015 it was 268,300 ha or by 20% lower. Decreasing trend of maize growing area were found also in B&H (195,800 ha and 178,590 ha, respectively) but less strong than in Croatia. Average yields of maize in decade period were 6.24 t ha^{-1} (Croatia) and 4.42 t ha^{-1} (B&H). Maize yield in the 2014 growing season in Croatia was for 30% higher and in B&H by 11% higher compared to the 2001-2010 decade average yields. In the remaining two growing seasons maize yields in Croatia were close to decade average, while in B&H yields were about 10% lower. Degree of arable land utilization is a serious problem of agriculture in both countries because about 40% of arable land is unfarmed (Table 1).Average air temperatures for April-September period in eight selected meteorological stations were 18.2 ^{0}C (2013), 17.7 ^{0}C (2014) and 18.8 ^{0}C (2015) and they are higher in comparison with 1961-1990 average (16-9 ^{0}C). These data are in accordance with climate change toward global warming (Allen et al., 2003; Chi-Chung et al, 2004; FAO, 2007; Jolankai and Birkas, 2013). Precipitation in April-September period of 2013 and 2014 (Table 2) in Bijeljina (373 mm and 731 mm), Tuzla (443 mm and 1021 mm), Banja Luka (370 mm and 1228 mm) and Bihac (479 mm and 1135 mm) are in agreement with this opinion. At the same period, average air temperatures were as follows (^{0}C): 19.1 and 18.5 (Bijeljina), 17.4 and 16.6 (Tuzla), 18.9 and 18.0 (Banja Luka), 17.8 and 17.1 (Bihac), respectively. The higher yields of maize in Croatia and B&H in 2014 and considerable lower yields in 2013 and 2015 (Table 1) could be explained by general opinions regarding impact of weather conditions on maize growth and productivity in Corn Belt of USA (Shaw, 1988) and experiences from Croatia and neighboring countries (Kovacevic *et al.*, 2012, 2013; Iljkic *et al.*, 2014; Majdancic *et al.*, 2016).

Table 1. The harvested area and yields of maize in Croatia and B&H (FAO, 2016; SY, 2005, 2010, 2013, CBS 2016)

Harvested area and yields of maize (maize for grain) in Croatia and B&H							
Croatia				Bosnia and Herzegovina			
2001-2010	2013	2014	2015	2001-2010	2013	2014	2015
Harvested area of maize (ha)				Harvested area of maize (ha)			
333 736	**288 365**	**252 567**	**263 970**	**195 800**	**190 000**	**170 000**	**175 770**
Yield of maize (t ha^{-1})				Yield of maize (t ha^{-1})			
6.24	**6.5**	**8.1**	**6.5**	**4.42**	**4,0**	**5.0**	**4.1**
Annual yield variation in 2001-2010 period: **from 3.86 to 7.98 t ha^{-1}**				Annual yield variation in 2001-2010 period: **from 2.79 to 5.13 t ha^{-1}**			
Index of yield (mean 2001-2010 = 100)				Index of yield (mean 2001-2010 = 100)			
100	**104**	**130**	**104**	**100**	**89**	**111**	**91**
Utilized arable land (ha)				Utilized arable land (ha)			
859 839	**874 863**	**811 067**	**841 939**	**1 013 500**	**1 010 000**	**1 011 000**	**1 029 000**
Total arable land (ha)				Total arable land (ha)			
1 460 000 (SLJ, 2005)				**1 589 000** (FAO, 2009)			
Territory: 56 542 km^2				Territory: 51 197 km^2			

Drought and the higher temperatures are responsible for lower yields of maize in 2013 and 2014. With that regard, the eastern parts of both countries were more affected by weather stress conditions (Tables 2 and 3). For example, precipitation in April-September period of 2015 in Bijeljina was only 302 mm (Bijeljina) and 316 mm (Osijek), while in west situated Varazdin and Bihac precipitation was 555 mm and 634 mm, respectively. At the same period, temperatures were 20.2 ^{0}C (Bijeljina), 19.5 ^{0}C (Osijek), 18.2 ^{0}C (Varazdin) and 18.6 ^{0}C (Bihac). Maize crops were affected by drought and high temperature mainly in August.

Absolute maximal temperatures were recorded at the end of July / beginning of August 2013 (Bihac 42.0 ^{o}C, Varazdin 39.4 ^{o}C, Bijeljina 39.2 ^{o}C and Osijek 38.4 ^{o}C) and in July / August 2015 (Bihac 37.9 ^{o}C, Bijeljina 37.8 ^{o}C, Osijek 37.2 ^{o}C and Varazdin 35.6 ^{o}C). However, in favorable 2014 growing season for maize, absolute maximal temperatures were in range from 31.6 ^{o}C in Varazdin to 34.4 ^{o}C in Osijek and Bijeljina (Table 3).

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

Precipitation and average air-temperatures in 2013-2015 and average 1961-1990 (*61-90*)														
Year	Monthly precipitation (mm)							Monthly average air-temperatures (°C)						
	Apr.	May	June	July	Aug	Sept	Σ	Apr.	May	June	July	Aug	Sept	X
	Bijeljina													
2013	28	182	57	37	18	51	***373***	13.2	17.1	20.7	23.4	24.0	16.4	***19.1***
2014	83	252	67	73	147	109	***731***	13.1	16.1	20.8	22.6	21.4	17.0	***18.5***
2015	57	100	22	11	39	73	***302***	12.5	18.5	21.2	25.7	24.5	18.7	***20.2***
61-90	***68***	***81***	***86***	***68***	***61***	***53***	*417*	***11.0***	***16.3***	***19.8***	***21.7***	***21.1***	***16.8***	*17.8*
	Osijek													
2013	45	119	63	37	33	129	**426**	13.1	16.7	20.2	22.9	22.9	15.9	**18.6**
2014	81	159	91	66	54	69	**520**	13.2	16.1	20.4	21.8	20.8	17.0	**18.2**
2015	13	113	17	26	106	41	**316**	12.1	17.8	20.8	24.6	23.7	17.9	**19.5**
61-90	***54***	***59***	***88***	***65***	***58***	***45***	*368*	***11.3***	***16.5***	***19.5***	***21.1***	***20.3***	***16.6***	*17.6*
	Tuzla													
2013	31	168	74	55	36	79	***443***	12.8	15.7	18.6	20.9	21.6	15.0	***17.4***
2014	187	339	64	112	184	135	***1021***	11.5	14.5	18.5	20.3	19.6	15.6	***16.7***
2015	58	122	93	11	55	81	***420***	10.7	16.6	19.0	23.3	22.9	17.3	***18.3***
61-90	***76***	***92***	***111***	***94***	***84***	***64***	*521*	***10.4***	***14.8***	***17.7***	***19.3***	***18.9***	***15.5***	*16.1*
	Banja Luka													
2013	63	120	54	27	36	70	***370***	13.4	16.6	20.4	23.0	23.5	16.7	***18.9***
2014	214	218	97	139	276	284	***1228***	13.1	15.8	20.3	21.7	20.6	16.4	***18.0***
2015	54	118	61	21	23	75	***352***	11.8	17.4	20.9	25.2	24.0	18.3	***19.6***
61-90	***87***	***98***	***111***	***95***	***93***	***82***	*566*	***10.9***	***15.6***	***18.9***	***20.6***	***19.7***	***15.9***	*16.9*
	Bjelovar													
2013	56	94	53	49	71	103	**426**	13.1	16.5	20.0	23.2	22.4	15.4	**18.4**
2014	*106*	*168*	*80*	*144*	*126*	*204*	***828***	13.0	15.4	20.1	21.6	20.2	16.0	**17.7**
2015	*21*	*145*	*39*	*40*	*51*	*99*	***395***	12.1	17.2	20.8	24.2	23.4	17.3	**19.2**
61-90	***63***	***79***	***96***	***78***	***82***	***65***	*461*	***10.8***	***15.6***	***18.7***	***20.4***	***19.5***	***15.8***	*16.8*
	Sisak													
2013	76	58	35	97	49	149	**464**	13.4	16.5	20.2	23.0	22.3	15.7	**18.5**
2014	124	193	74	153	169	214	**927**	13.1	15.8	20.3	21.7	20.2	16.2	**17.9**
2015	50	171	62	26	117	112	**538**	12.2	17.4	20.8	24.4	23.0	17.0	**19.1**
61-90	***73***	***82***	***91***	***77***	***85***	***76***	*484*	***11.1***	***15.8***	***19.1***	***20.8***	***19.8***	***16.0***	*17.1*
	Varazdin													
2013	62	96	60	34	103	139	***494***	12.2	15.7	19.4	22.4	21.1	15.1	**17.7**
2014	105	109	118	134	153	291	***910***	12.7	15.0	19.3	21.1	19.2	15.8	**17.2**
2015	21	165	79	98	90	102	***555***	11.4	16.4	19.8	23.0	21.9	16.4	**18.2**
61-90	***70***	***84***	***98***	***92***	***98***	***81***	*524*	***10.3***	***15.1***	***18.3***	***19.8***	***18.9***	***15.4***	*16.3*
	Bihac													
2013	88	98	73	36	85	99	***479***	12.5	15.4	19.3	22.0	21.7	15.7	***17.8***
2014	187	199	87	228	105	329	***1135***	12.3	14.9	19.5	20.5	19.8	15.5	***17.1***
2015	91	172	80	44	97	150	***634***	11.6	17.3	20.0	23.8	22.1	17.0	***18.6***
61-90	***115***	***116***	***109***	***107***	***109***	***108***	*664*	***10.7***	***15.1***	***18.9***	***20.0***	***19.2***	***15.9***	*16.6*

Iljkic *et al.*, (2014) reported 5-year data (2008-2012) regarding impact of weather conditions on maize yield in Croatia and B&H. In both countries the lowest maize yields were realized in 2012 (4.30 and 2.90 t/ha in Croatia and B&H, respectively) and they were lower for 48% (Croatia) and 40% (B&H) than in 2008. Precipitation

and mean air temperature in July + August 2012 were as follows: 52 mm and 24.5 ^{o}C (Osijek), 8 mm and 23.5 ^{o}C (Tuzla).

Majdancic *et al.*, (2016) performed 15-year data of maize harvested area and yield in Federation B&H (FB&H) with emphasis on Tuzla Canton. In the 15-year period 2000-2014 maize for grain was grown in FB&H on the area of average 48,208 ha and average grain yield was 3.99 t ha^{-1} with considerable variation among years from 2.18 to 4.92 t ha^{-1}. In three "the poor" years (2000, 2003 and 2012) yield was less than 3.0 t ha^{-1} (average 2.66 t ha^{-1}), while in three "the good" years (2006, 2008 and 2009) it was above 4.5 t ha^{-1} (average 4.74 t ha^{-1}). Precipitation quantity in the April -September period of "the poor" years in Tuzla was 320 mm (3-year average) or 39% of the long-term mean (LTM) 1961-1990, while in "the good" years it was 492 mm. Mean air temperature at the same period of the favorable years was 17.5 ^{o}C or for 1.0 ^{o}C lower than in the unfavorable years.

Table 3. Mean maximal and absolute maximal air temperatures in July and August

Month	Average maximal (AverageM) and absolute maximal (AbsoluteM) air temperature in the 10-days intervals (a = 1- 10; b = 11 – 20; c = 21 – 30/31)											
	Eastern part of the region						Western part of the region					
	AverageM (^{o}C)			AbsoluteM (^{o}C)			AverageM (^{o}C)			AbsoluteM (^{o}C)		
	a	b	c	a	b	c	a	b	c	a	b	c
	The 2013 growing season											
	Osijek						Varazdin					
July	28.9	28.2	32.2	30.5	30.9	38.4	27.9	27.2	32.0	29.4	30.3	37.6
Aug.	34.5	30.2	25.4	38.2	34.3	28.5	33.8	28.0	23.3	39.4	32.6	26.6
	Bijeljina						Bihac					
July	28.9	28.5	32.4	30.2	32.0	39.2	27.4	27.6	33.0	30.6	31.0	39.3
Aug.	35.4	31.0	26.9	39.1	35.8	31.2	35.9	29.3	24.9	42.0	34.2	28.4
	The 2014 growing season											
	Osijek						Varazdin					
July	27.9	28.0	28.0	32.1	31.5	31.7	25.7	28.0	26.2	31.6	31.1	28.9
Aug.	28.0	27.7	24.7	30.2	34.4	28.0	27.6	25.0	23.0	31.1	29.9	25.5
	Bijeljina						Bihac					
July	29.4	28.3	28.8	33.4	32.7	33.0	27.1	26.9	25.4	32.8	33.1	28.6
Aug.	28.3	28.9	26.1	31.4	34.4	29.6	27.4	27.3	24.0	32.5	33.2	27.1
	The 2015 growing season											
	Osijek						Varazdin					
July	31.4	32.2	30.0	37.2	36.4	36.5	29.9	31.0	27.0	34.6	35.6	35.1
Aug.	32.4	31.0	28.7	34.9	36.8	35.2	30.9	28.7	27.2	33.3	35.5	32.5
	Bijeljina						Bihac					
July	32.1	33.5	32.2	37.8	37.6	37.6	31.9	34.3	29.5	37.3	37.9	37.2
Aug.	33.9	32.9	29.1	36.7	37.8	36.3	31.8	28.5	27.7	35.0	35.6	35.0

Alleviation of unfavorable effects of "poor" years for maize yields is possible by irrigation and by adequate soil management practice, as ploughing and addition of majority NPK fertilizers in autumn instead in spring, weed control, growing more drought tolerant hybrids etc. (Kovacevic and Rastija, 2014).

Bancy (2000) reported that in order to counter the adverse effects of climate change in maize production, it might be necessary to use early maturing cultivars and practice early planting. However, under eastern and middle European conditions, appearance of late frost could be limiting factor for wide application of this practice. By late spring frost in night 26th April 2016 (minimal air-temperatures from -2 ^{0}C to -6.0 ^{0}C in northern Croatia) considerably damaged vineyard and orchards and too early sowing of spring crops (CAAS, 2016). For this reason, our recommendation is that majority sowing area of maize could be practiced in the second half of April because early sowing, for example two or three weeks earlier, is accompanied with potential damage caused by late frost. However, combination absence of frost and the earlier sowing is mainly very favorable for maize growth.

CONCLUSION

Weather conditions are considerable factor of maize yield in Croatia and B&H. Lower precipitation and higher temperatures are mainly in connection with lower yields. Alleviation of unfavorable effect of drought for maize yields is possible by irrigation and by correspondingly soil management, for example fertilization, weed control, earlier sowing etc.

REFERENCES

Allen, L.H., Pan D. Jr., Boote K.J., Pickering N.B., Jones J.W. (2003). Carbon dioxide and temperature effects on evapotranspiration and water use efficiency of soybean. Agron. J., 95: 1071-1081.

Bancy, M.M., (2000). The influence of climate change on maize production in semi-humid and semi-arid areas of Kenya. J. Arid. Environ., 46: 333-334.

CAAS (2016): (http://www.savjetodavna.hr/vijesti/53/4717) Croatian Agricultural Adviser Service Zagreb.

CBS (2016). Crop production, 2015, Croatian Bureau of Statistics Zagreb, First release No 1.1.14.; 12 May 2016.

Chi-Chung, C., Mc Carl B. A., Schimmelpfennig D. (2004). Yield variability as influenced by climate: A statistical investigation. Climatic Change, 66: 239-261.

FAO (2007). Climate Change: Climate Change Impacts, Adaptation and Vulnerability. IPCC WG II fourth Assessment Report. (http://www.ipcc.ch/SPM6avr07.pdf).

FAO (2016). http://faostat.fao.org

Iljkic D., Kovacevic V., Markovic M., Basic M., Majdancic M. (2014). Variation of maize yield in Croatia and Bosnia and Herzegovina among years with aspect of climatic changes. Turkish J. of Agricultural and Natural Sciences, Special Issue 1: 789-792.

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

Jolankai M, Birkas M. (2013). Precipitation impacts on yield quantity and quality of wheat crop. In: Proceedings, of the 48th Croatian & 8th International Symposium on Agriculture 17.-22. February 2013 Dubrovnik (Maric S. and Loncaric Z. Editors), Faculty of Agriculture, University J.J. Strosmayer in Osijek, p. 489-493.

Kovacevic V., Kovacevic D., Pepo P., Markovic M. (2013). Climate change in Croatia, Serbia, Hungary and Bosnia and Herzegovina: comparison the 2010 and 2012 maize growing seasons. Poljoprivreda / Agriculture 19 (2): 16-22.

Kovacevic V., Rastija M. (2014). The Cereals (university textbook). University J. J. Strossmayer in Osijek, Faculty of Agriculture in Osijek.

Kovacevic V., Rastija M., Josipovic M. (2012). Precipitation and temperature regimes and yield of maize in Croatia. In: Proceedings, Third Intern. Scientific Symposium „Agrosym Jahorina 2012“. 15.-17. Nov. 2012. Jahorina, B&H (Kovacevic D. and Milic V. Editors), University of East Sarajevo, Faculty of Agriculture, p. 81-86.

Majdancic M., Basic M., Salkic B., Kovacevic V., Jovic J. (2016). Weather characteristics and yields of maize in Federation of Bosnia and Herzegovina with emphasis on Tuzla Canton. Works of the Faculty of Agriculture and Food Sciences University of Sarajevo LXI (66/1): 303-307.

Lobell D., Field C. (2007). Global scale climate-crop yield relationships and the impacts of recent warming (http://digitalcommons.unl.edu/publichealthresources/152).

Shaw, R. ,H. (1988). Climate requirement. In: Corn and Corn Improvement, Agronomy Monograph No 18, ASA-CSSA-SSSA, Madison, Wisconsin, USA , p.609-638.

SY (2005, 2010, 2013). Statistical Yearbook of Croatia, Croatian Bureau of Statistics, Zagreb.