

WEATHER CONDITIONS IN BOSNIA AND HERZEGOVINA FROM 2011 TO 2015 PERIOD WITH ASPECT OF MAIZE GROWTH AND CLIMATIC CHANGE

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Abstract

Maize is main field crop on the arable lands of Bosnia and Herzegovina (B&H). In the 2011-2015 period, maize was grown on average 189 137 ha or close to 20% of arable land. The majority of maize growing area was situated in the northern lowland region and in Republic of Srpska (RS). Considerable variation of the yearly yield was found in this period from 2.7 t ha⁻¹ (2012) to 4.7 t ha⁻¹ (2014), mainly under influence of weather conditions. With that regard, precipitation and temperature regimes, particularly in July and August, had considerable effects. 2011, 2013 and 2015 growing seasons were more close to usual values. However, 2012 and 2014 were considerably deviated and characterized by drought and hot stress (2012) and excessive, but for maize more favorable, precipitation and the lower temperature (2014). Six meteorological stations were selected for weather characterization as follows: Bijeljina (BI), Tuzla (TZ), Gradacac (GR), Banjaluka (BL), Prijedor (PR) and Bihac (BH). Precipitation and mean air temperatures in the period 2011-2015 were compared to the long-term means 1961-1990 (LTM). In general, precipitation in the April-September period (LTM) was lower and temperatures higher in the eastern part (BI: 417 mm and 17.8 °C) than in western part (BI: 664 mm and 16.6 °C) of the country. These values for two deviated growing seasons were as follows: 288 mm and 20.0 °C in BI, 693 mm and 18.9 °C in BH (2012), 731 mm and 18.5 °C in BI, 1135 mm and 17.1 °C in BH (2014).

Keywords: *precipitation, temperature, maize yield, climatic change.*

Introduction

Maize is main field crop on the arable lands of Bosnia and Herzegovina (B&H). In the 2011-2015 period, maize was grown on average 189 137 ha or close to 20% of arable land capacity. The majority of maize growing area was situated in the northern lowland region of the country and in entity Republic of Srpska (RS). Average yield in the mentioned period was 3.92 t ha⁻¹ (AS, from 2012 to 2016) and it is low with the aspect of possibilities, the existence of high-yielding hybrids and environmental conditions under different systems of soil tillage (Jug et al., 2014). Weather conditions are also important factors of maize yield and weather excess accompanied with drought and high air temperature, particularly in July and August, are often in connection with low yields (Kovacevic et al., 2013, 2016; Kovacevic and Rastija, 2014; Majdancic et al., 2016).

Material and methods

The FAO database (FAO), releases of Agency for Statistics (AS) of Bosnia and Herzegovina (Agriculture, Environment and Regional Statistics: harvested area, total production and yield of main crops), statistical yearbooks Republic of Srpska (SYRS) and Federation of B&H (SYFB&H) were used as source of the arable land, harvested area and maize yield data. Publications of Hydrometeorological Institute of the Republic of Srpska in Banja Luka and Federal Hydrometeorological Institute in Sarajevo were perused for used the meteorological data as follows: monthly values of precipitation and mean air temperature, means of minimal and maximal air temperatures and their absolute values. B&H is administratively divided into two political entities (Federation of B&H or FB&H and Republic of Srpska or RS) and Brcko district.

Six meteorological stations (MS) situated in the northern part of the country - three from RS and three from FB&H - were selected for analyzing of weather data with the aspect of maize growth (Fig 1). The most western and the most eastern positions of Bihac and Bijeljina are air-distanced 320 km. Choice of this part of B&H is resulted by the fact that by these localities are covered majority growing area of maize in B&H.

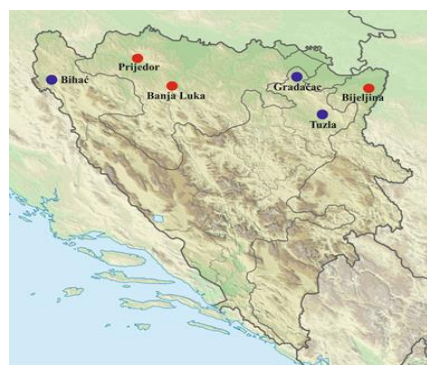


Fig. 1. Situation of MS in B&H

Results and discussion

B&H has on disposal about 1 million ha of arable land and gardens and even close to 50% are fallow and uncultivated land. Maize harvested area in the 2011-2015 period was average 189 137 ha and close to decade 2000-2010 average. However, average maize yield 3.92 t ha⁻¹ is about 12% lower compared to the decade average. About 70% of maize harvested area are situated in RS. High variation of yields are mainly affected by weather conditions (Table 1).

Table 1. The harvested area and yields of maize in B&H and in level of the entities

Statistical data from 2011 to 2015 (FAO, AS, SYRS and SYFB&H)							
	Average	Year					Average
	2001-2010	2011	2012	2013	2014	2015	2011-2015
Arable land and gardens (000 ha): total, fallow and unfarmed land							
Total	1 009	1 006	998	1 011	1 029	1 010	1 010
Fallow and unfarmed	478	476	478	508	510	490	490
Harvested area (ha) and yields of maize for grain (t ha ⁻¹)							
Bosnia and Herzegovina							
ha	195 887	195 970	196 504	189 554	169 948	193 707	189 137
t ha ⁻¹	4.42	3.9	2.7	4.2	4.7	4.1	3.92
The entity Republic of Srpska (RS)							
ha	142 053	142 273	142 742	135 143	120 901	138 824	135 977
t ha ⁻¹	4.60	3.80	2.70	4.10	4.80	4.00	3.90
Federation of B&H (FB&H)							
ha	48 490	48 620	48 558	49 497	43 866	48 154	47 568
t ha ⁻¹	4.22	4.20	2.90	4.60	4.01	3.90	4.02
Yield variations in B&F (2001 - 2015): from 2.7 t ha ⁻¹ (2012) to 5.1 t ha ⁻¹ (2004 and 2005)							

Precipitation in April-September of 2011-2015 (average of six MS) in amount 535 mm was at the level of 1961-1990 average (529 mm), but it was characterized by extreme variation from 352 mm in 2001 to 1000 mm in 2014 (Table 2).

Table 2: Precipitation, geographical coordinates and elevation (el.) above sea level

Precipitation in 2011-2015 period and long-term mean (LTM: 1961-1990)														
Year	Monthly precipitation (mm)							Monthly precipitation (mm)						
	Apr.	May	June	July	Aug	Sept	Σ	Apr.	May	June	July	Aug	Sept	Σ
	Bijeljina 44°45'24" N, 19°12'57" E; el. 91 m							Tuzla 44°32'17"N, 18°40'34"E; el. 239 m						
2011	32	78	51	86	1	16	267	29	86	74	147	13	14	363
2012	91	97	44	36	0	19	287	92	137	55	8	0	27	319
2013	28	182	57	37	18	51	373	31	168	74	55	36	79	443
2014	83	252	67	73	147	109	731	187	339	64	112	184	135	1021
2015	57	100	22	11	39	73	302	58	122	93	11	55	81	420
LTM	68	81	86	68	61	53	417	76	92	111	94	84	64	521
	Gradacac 44°53'00" N; 18°26'00" E; el. 129 m							Banjaluka 44°46'32" N, 17°11'08" E; el. 158 m						
2011	26	44	61	97	9	18	255	38	63	37	113	9	26	286
2012	111	121	90	45	1	36	404	103	168	70	53	2	92	488
2013	55	175	87	36	26	60	439	63	120	54	27	36	70	370
2014	145	301	72	80	194	129	921	214	218	97	139	276	284	1228
2015	50	124	43	6	72	113	408	54	118	61	21	23	75	352
LTM	73	92	99	86	74	65	488	87	98	111	95	93	82	566
	Prijedor 44°46'32" N, 17°11'08" E; el. 158 m							Bihac 44°48'49.7"N, 15°52'19.7"E; el. 231m						
2011	244	39	53	138	20	30	524	52	101	80	100	25	60	418
2012	87	116	64	35	1	64	367	128	155	74	104	39	193	693
2013	72	73	54	18	64	63	344	88	98	73	36	85	99	479
2014	164	219	78	127	142	237	967	187	199	87	228	105	329	1135
2015	49	115	85	24	104	124	501	91	172	80	44	97	150	634
LTM	84	90	89	98	80	79	520	115	116	109	107	109	108	664

However, the mean air temperature in 2011 -2015 period (April-September) was 18.9 °C or for 1.9 °C higher than in 1961-1990 with variation among years from 17.8 °C in 2014 to 19.7 °C in 2012 (Table 3). In general, precipitation quantities have increasing trend and temperature decreasing trend in the direction from the east toward the west (1961-1990: Bijeljina 417 mm and 17.8 °C and Bihac 664 mm and 16.6 °C).

Average minimal and average maximal temperature in the 2011-2015 period (Table 4) was 13.4 °C and 25.6 °C in Bijeljina, 11.9 °C and 24.9 °C in Bihac (averages 1961-1990: 13.7 °C and 24.4 °C, 10.5 °C and 22.8 °C, for Bijeljina and Bihac, respectively). Absolute minimal air temperature in 2011-2015 period (Table 5) was recorded in April of 2012 (Bijeljina -2.8 °C and Bihac -4.0 °C (1961-1990: Bijeljina -0.6 °C and Bihac -4.6 °C), while values for absolute maximal temperature were for 2011-2015 period were recorded in August of 2012 (Bijeljina 40.3 °C) and 2013 (Bihac 42.0 °C). Comparison these values with 1961-1990 period (34.7 °C in Bijeljina and 38.6 °C in Bihac) indicating global warming (Chiu et al., 2004, FAO, 2007)

The 2012 growing season was unfavorable for maize growth because of lower precipitation and the higher temperature in April-September period (means of 6 stations: 427 mm and 19.8 °C). Especially unfavorable weather conditions were observed in August for all tested sites with exception Bihac (from 0 to 2 mm precipitation and mean air temperature between 24.1 °C in Prijedor to 25.8 °C in Gradacac; Bihac 39 mm and 22.9 °C: Tables 1-2). Absolute maximal air temperature in Bijeljina was in three 10-day periods of August 2012 from 35.6 °C to 40.3 °C and by these stress conditions was also exposed maize in the eastern parts of Croatia and

Hungary, as well as in the northern part of Serbia in Vojvodina province (Table 6). As affected by these conditions maize yields in 2012 were low in B&H (2.74 t ha⁻¹), in the neighbouring Croatia (4.34 t ha⁻¹) and Serbia (2.78 t ha⁻¹), as well as in Hungary (3.98 t ha⁻¹) and yield decrease in 2012 compared to normal weather conditions in 2010 were between 38% (Croatia and Hungary: in B&H 40%) and 53% in Serbia (Kovacevic et al., 2013).

Table 3. Monthly mean air temperatures

Year	Air temperatures in 2011-2015 and long-term mean (LTM: 1961-1990)													
	Mean air temperature (°C)							Mean air temperature (°C)						
	Apr.	May	June	July	Aug	Sept	X	Apr.	May	June	July	Aug	Sept	X
	Bijeljina							Tuzla						
2011	13.6	16.8	21.4	23.3	23.4	20.6	19.9	12.1	14.3	19.2	21.2	22.0	19.4	18.0
2012	12.7	16.1	23.0	25.2	24.2	18.9	20.0	11.5	14.8	21.4	23.9	23.3	18.3	18.9
2013	13.2	17.1	20.7	23.4	24.0	16.4	19.1	12.8	15.7	18.6	20.9	21.6	15.0	17.4
2014	13.1	16.1	20.8	22.6	21.4	17.0	18.5	11.5	14.5	18.5	20.3	19.6	15.6	16.7
2015	12.5	18.5	21.2	25.7	24.5	18.7	20.2	10.7	16.6	19.0	23.3	22.9	17.3	18.3
<i>LTM</i>	11.0	16.3	19.8	21.7	21.1	16.8	17.8	10.4	14.8	17.7	19.3	18.9	15.5	16.1
	Gradacac							Banjaluka						
2011	13.8	16.5	21.1	22.6	24.0	21.6	19.9	13.0	16.0	21.2	23.1	23.7	20.2	19.5
2012	13.3	16.8	22.8	25.2	25.8	20.1	20.7	12.7	16.1	23.0	25.2	24.2	18.9	20.0
2013	14.1	16.6	20.4	23.6	23.7	16.9	19.2	13.4	16.6	20.4	23.0	23.5	16.7	18.9
2014	12.9	15.8	20.4	21.8	21.1	16.7	18.1	13.1	15.8	20.3	21.7	20.6	16.4	18.0
2015	12.8	17.7	20.7	25.0	24.4	18.8	19.9	11.8	17.4	20.9	25.2	24.0	18.3	19.6
<i>LTM</i>	11.3	15.9	19.0	20.9	20.3	16.9	17.4	10.9	15.6	18.9	20.6	19.7	15.9	16.9
	Prijedor							Bihac						
2011	11.2	14.1	18.4	20.3	21.0	18.4	19.3	12.5	15.2	19.8	22.0	21.8	19.1	18.4
2012	12.4	16.5	22.8	24.8	24.1	18.5	19.9	12.2	15.3	22.4	23.5	22.9	17.0	18.9
2013	13.5	16.7	20.4	23.1	23.1	16.4	18.9	12.5	15.4	19.3	22.0	21.7	15.7	17.8
2014	13.5	16	20.6	21.8	20.7	16.6	18.2	12.3	14.9	19.5	20.5	19.8	15.5	17.1
2015	11.8	17.7	20.6	24.4	23.1	17.2	19.1	11.6	17.3	20.0	23.8	22.1	17.0	18.6
<i>LTM</i>	11.1	15.8	19.1	20.8	21.0	16.4	17.4	10.7	15.1	18.9	20.0	19.2	15.9	16.6

Table 4. Mean minimal and mean maximal air temperatures in Bijeljina and Bihac

Month	Air temperatures in 2011-2015 and long-term mean (LTM: 1961-1990)											
	Bijeljina						Bihac					
	2011	2012	2013	2014	2015	LTM	2011	2012	2013	2014	2015	LTM
	Mean minimal air temperature (°C)						Mean minimal air temperature (°C)					
Apr.	7.6	6.6	6.7	8.2	5.8	5.5	6.0	7.0	5.9	7.6	6.0	5.1
May	10.6	10.9	11.6	10.4	12.3	10.1	8.4	8.7	10.3	9.2	11.7	9.1
June	15.3	16	14.6	14.7	14.5	13.6	13.3	15.2	12.7	13.3	13.0	12.2
July	17.1	18.3	15.9	16.9	17.9	14.8	15.5	16.0	14.4	14.8	16.1	13.3
Aug	16.5	15.8	16.8	16.2	17.6	14.2	14.7	14.3	14.7	14.4	16.1	13.0
Sept.	13.7	13.1	11.2	13.3	13.9	11.0	12.0	12.0	10.0	12.3	12.9	10.3
Mean	13.5	13.5	12.8	13.3	13.7	11.5	11.7	12.2	11.3	11.9	12.6	10.5
	Mean maximal air temperature (°C)						Mean maximal air temperature (°C)					
Apr.	19.5	19.5	20.1	18.8	17.1	17.8	19.0	17.8	18.5	17.8	18.0	16.3
May	20.3	22.8	23.6	21.9	24.3	22.8	22.7	22.0	21.5	20.9	23.3	21.0
June	27.6	30.4	26.2	26.8	27.9	25.7	26.2	29.1	25.6	26.3	27.1	24.2
July	29.4	32.8	30.0	28.8	24.9	27.9	28.8	30.8	29.4	26.4	31.8	26.7
Aug	31.3	33.6	30.9	27.7	27.9	27.9	30.4	32.3	29.9	26.1	29.3	26.2
Sept.	28.9	27	23.4	22.4	21.6	24.3	27.2	23.4	22.8	20.3	22.2	22.6
Mean	26.2	27.7	25.7	24.4	24.0	24.4	25.7	25.9	24.6	23.0	25.3	22.8

Table 5. Absolute minimal and absolute maximal temperature in Bijeljina and Bihac

Air temperatures in 2011-2015 and long-term mean (LTM: 1961-1990)												
Month	Bijeljina						Bihac					
	2011	2012	2013	2014	2015	LTM	2011	2012	2013	2014	2015	LTM
Absolute minimal air temperature (°C)						Absolute minimal air temperature (°C)						
Apr.	3.0	-2.8	0.4	2.0	-0.4	-0.6	-0.4	-4.0	-0.3	1.1	-1.1	-4.6
May	1.4	5.7	5.2	4.0	5.4	3.9	0	0.7	3.4	2.2	4.5	-2.4
June	9.8	8.1	9.6	9.2	9.3	7.9	8.2	9.2	5.1	7.0	6.0	2.4
July	9.3	12.3	10.6	12.7	11.0	9.9	7.5	8.8	10.5	8.4	9.8	4.4
Aug	10.2	9.7	11.7	9.2	12.0	8.8	6.9	8.9	8.8	8.2	10.2	3.6
Sept.	8.0	5.4	5.8	6.2	6.0	4.8	6.7	2.9	3.4	4.0	5.0	-2.4
Mean	7.0	6.4	7.2	7.2	7.2	5.8	4.8	4.4	5.2	5.2	5.7	0.2
Absolute maximal air temperature (°C)						Absolute maximal air temperature (°C)						
Apr.	25.2	29.6	31.1	24.6	27.3	26.2	26.1	30.0	29.9	25.5	25.5	30.8
May	30.6	32.2	31.8	29.8	32.4	30.2	29.9	31.1	31.2	29.6	32.8	32.6
June	34.6	36.6	36.1	33.3	34.3	32.9	32.9	37.0	35.8	34.6	32.7	34.6
July	37.2	38	39.2	33.4	37.8	34.7	39.6	38.0	39.3	33.1	37.9	38.6
Aug	38.0	40.3	39.1	34.4	37.8	33.4	38.1	40.0	42.0	33.2	35.6	37.4
Sept.	35.4	34.6	29	28.6	38.8	31.6	36.1	29.6	29.3	28.1	34.4	35.0
Mean	33.5	35.2	34.4	30.7	34.7	31.5	33.8	34.3	34.6	30.7	33.2	34.8

Table 6. Mean maximal and absolute maximal temperature in the 2012 growing season (Kovacevic et al., 2013)

Month	The 2012 growing season: average (AverageM) and absolute (AbsoluteM) maximal air temperature in the 10-days intervals (a = 1-10; b = 11-20; c = 21-30/31)											
	AverageM (°C)			AbsoluteM (°C)			AverageM (°C)			AbsoluteM (°C)		
	a	b	c	a	b	c	a	b	c	a	b	c
Osijek (Croatia)						Novi Sad (Serbia)						
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 (Hungary)						Bijeljina (B&H)						
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
Precipitation (mm): in bracket = LTM:1961-1990												
Osijek			Debrecen			Novi Sad			Bijeljina			
July	48 (65)		49 (66)		48 (61)		36 (72)					
August	4 (58)		13 (61)		4 (55)		0 (66)					
April-Sept.	293 (368)		250 (346)		227 (339)		288 (436)					

Alleviation of unfavorable weather stress for maize growth is possible by application corresponding soil and crop management practice, for example, soil ploughing in autumn instead of spring and incorporation before ploughing phosphorus and particularly potassium mineral fertilizer according soil test, liming of acid soils and growing of drought more tolerant hybrids (Kovacevic and Rastija, 2014; Komljenovic et al., 2010, 2015; Kovacevic and Loncaric, 2014; Markovic et al., 2008).

Conclusions

Weather conditions, particularly long drought period and high air temperature adversely affected on maize yields. With that regards, the 2012 and 2014 growing season are typical examples of recent climatic change characterizing by global warming and extremely oscillation of weather in short period. The first mentioned year was unfavorable and the second mentioned

year very favorable for maize growth. By adequate soil and crop management is possible to alleviate stress provoked by weather and stabilizing yields of maize among years.

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