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Variation of winter wheat yields in Croatia and Bosnia and Herzegovina among years with aspect of climatic changes

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Abstract

The used arable land covering in Croatia 882752 ha and in Bosnia and Herzegovina (B&H) 447181 ha (average 2008-2012) or 15.60% (Croatia) and 8.75% (B&H) of the state territory. Main field crops (average 2008-2012) are maize for grain (302266 ha and 189 557 ha and winter wheat (168433 ha and 57480 ha). Annual yields of wheat in the mentioned period were from 4.00 to 5.50 t/ha (Croatia) and from 2.63 to 3.80 t/ha (B&H). Global warming and increasingly experiencing with extreme weather conditions around the globe affecting often adversely on field crop yields. Annual temperature over Europe increased between 0.1 and 0.4% /decade. In our study, average air temperature in 2008-2012 (October-June) were higher from average (1961-1990) for 0.9 °C (Osijek), 1.5 °C (Zagreb), 0.8 °C (Tuzla) and 1.2 °C (Banja Luka).

As both in Croatia and B&H are dominant less permeable soils, the low yields of wheat in the growing season 2009/2010 (4.04 t/ha in Croatia and 2.67 t/ha in B&H: average of the remaining four years 5.30 t/ha and 3.74 t/ha, respectively) are in close connection with excessive precipitation. Precipitation in December-February (mm) were 244 (Osijek), 230 (Zagreb), 296 (Tuzla) and 414 (Banja Luka) or the higher for the referent values (1961-1990) for 76%, 57%, 59% and 90%, respectively. Also, loss of yield is partly caused by excess of precipitation in May and June (350 mm in Osijek, 434 mm in Tuzla and 383 mm in Banja Luka (average 1961-1990: 147 mm, 203 mm and 209 mm, respectively).

Key words: climate changes, precipitation, air temperature, wheat yield, year effects

Introduction

Winter wheat is main winter crop in Croatia and Bosnia and Herzegovina (B&H). In the 5–y period 2008-2012 mean harvested areas of winter wheat in Croatia was 168433 ha year^{-1} and in B&H 57 480 ha year^{-1}. Annual yield variations of wheat in this period were from 4.00 to 5.50 t/ha in Croatia and from 2.63 to 3.80 t/ha in B&H (FAO, 2013; SG,2013; SG/LJ, 2013; SLJ, 2013).

As soil and crop management practice, as well as cultivars in this short period were similar, differences of yield among the years are mainly result of weather characteristics during the individual growing season. With that regards, climatic changes characterizing global warming and more frequency either drought or oversupplies of precipitation have correspondingly mainly negative effects on wheat yields. Lobell and Field (2007) found that 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. Olesen and Bindi (2002) reported that meteorological record of annual temperatures over Europe showing warm at a rate of between 0.1 and 0.4°C decade^{-1}. Trnka et al. (2012) reported that increase the mean temperature by 1°C (1961–2007) led to yield decreases of up to 11% for winter wheat.

Aim of this study was testing impacts of weather characteristics on yields of winter wheat in two neighboring countries, Croatia and B&H based on 5-year period from 2008 to 2012. In the previous studies, the periods from 1961 to 1990 and from 1996 to 2007 were elaborated regarding impacts of precipitation and temperature impacts on wheat yields in Croatia (Josipovic et al., 2005; Kovacevic 2005; Kovacevic and Josipovic, 1995; Kovacevic et al., 2009; Marijanovic et al., 2010; Iljkić et al., 2010).

Material and methods

The data of State Hydrometerological Service in Zagreb, Federal Hydrometerological Service in Sarajevo and Hydrometeorological Service of Republic of Srpska in Banja Luka were used for weather and climate data. Four sites were selected for weather and climate characterization as follows: Osijek (OS) and Zagreb (ZG) in Croatia, Tuzla (TZ) and Banja Luka (BL) in B&H. Sources of arable land capacities, harvested area of crops and yield data were FAO (2013) database and statistical yearbooks (SG, 2013; SG/LJ, 2013; SLJ, 2013).

Results and discussion

Total arable land areas in Croatia is close to 1.5 and in B&H close to 1.0 million hectares. However, 40% arable land in Croatia and 54% in B&H is out of using. Maize and winter wheat are main arable crops in both countries with contribution of 53% (Croatia) and 57% used arable land. By remaining six mentioned field crops are covered additional 20% and 10% used arable lands (Table 1).

Grain yield variation of the crops among years is considerable in both countries because the lowest annual yields were for 46% lower (maize) and close to 30% lower (wheat) compared to the highest annual yields in the mentioned 5-year period. In general, yields of both maize and wheat in B&H is about third part lower compared to those in Croatia. Dominant arable crop in the both countries is maize with contribution of 34% (Croatia) and 44% (B&H) of used arable land, while contribution of the second-ranked wheat is 19% and 14%, respectively (Table 1).

Table 1. The harvested area and yields of main field crops in Croatia and B&H (FAO, 2013; SG,2013; SG/LJ, 2013; SLJ, 2013)

Field crop	Harvested area and yields of main field crops for 5-year period 2008 - 2012											
	Croatia						Bosnia and Herzegovina					
	2008	2009	2010	2011	2012	Mean	2008	2009	2010	2011	2012	Mean
	Harvested area (000 ha)						**Harvested area** (000 ha)					
Maize	314	296	297	305	299	*302*	204	189	189	196	197	*195*
Wheat	157	180	169	150	187	*168*	64	68	55	58	61	*61*
Barley	66	60	53	48	57	*57*	23	22	19	21	20	*21*
Soybeans	36	44	56	59	54	*50*	4.2	3.8	4.0	3.9	5.3	*4.2*
Sunflower	39	27	26	30	34	*31*	0.25	0.21	0.41	0.29	0.35	*0.30*
Oats	20	21	19	25	29	*23*	15	13	10	10	10	*12*
Rapeseed	22	29	16	18	10	*17*	0.85	0.68	0.63	0.77	0.31	*0.65*
Rye	1.37	1.10	1.04	0.87	0.85	*1.05*	3.7	3.8	2.9	3.3	3.5	*3.4*
	Yield (t ha^{-1})						**Yield** (t ha^{-1})					
Maize	7.98	7.35	6.97	5.68	4.34	*6.46*	4.92	5.10	4.52	3.90	2.75	*4.24*
Wheat	5.48	5.19	4.04	5.22	5.35	*5.06*	3.74	3.78	2.67	3.60	3.31	*3.42*
Barley	4.26	4.09	3.27	4.01	4.14	*3.95*	3.42	3.44	2.70	3.17	3.19	*3.18*
Soybeans	3.01	2.60	2.72	2.50	1.78	*2.52*	2.01	2.15	1.98	1.74	1.26	*1.83*
Sunflower	3.10	3.00	2.34	2.83	2.68	*2.79*	1.20	0.88	0.83	1.55	4.73	*1.84*
Oats	3.29	2.98	2.50	3.05	3.32	*3.03*	2.65	2.66	1.99	2.70	2.61	*2.52*
Rapeseed	2.81	2.80	2.02	2.82	2.67	*2.62*	2.33	2.70	1.83	1.98	1.78	*2.12*
Rye	2.98	2.87	2.42	3.38	2.87	*2.93*	2.98	3.16	2.52	2.93	3.11	*2.94*
	Used arable land (000 ha)						**Used arable land** (000 ha)					
Used	860.7	863.3	904.4	896.7	903.2	*885.7*	425.6	446.6	467.5	443.3	452.8	*447.2*
Total	1 460 (SL, 2005)					*1 460*	987.0	975.4	981.8	971.2	978.3	*978.7*

Table 2. Precipitation and mean air–temperatures

The month	Year* of harvest (LTM=the long–term mean 1961–1990)											
	2008	2009	2010	2011	2012	LTM	2008	2009	2010	2011	2012	LTM
	Precipitation (mm)						**Mean air–temperature** (°C)					
	Osijek (OS): the geographical coordinates 45°33′ N, 18°41′ E; elevation 102 m											
October	93	30	55	67	29	***41***	10.3	13.0	11.5	9.1	10.6	***11.2***
November	103	48	68	56	0	***57***	4.0	7.5	8.2	8.9	2.3	***5.4***
December	48	41	101	73	69	***52***	0.1	3.8	3.1	0.3	3.4	***0.9***
January	33	60	84	24	28	***47***	1.5	-1.1	-0.8	1.1	2.2	***-1.2***
February	5	29	59	18	54	***40***	4.9	2.3	1.4	0.7	-4.1	***1.6***
March	85	27	22	37	1	***45***	7.5	6.8	6.8	6.4	8.7	***6.1***
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***
Σ (X)	***560***	***356***	***815***	***426***	***390***	*483*	***8.9***	***9.4***	***8.8***	***8.6***	***8.3***	*7.9*
	Zagreb – Maksimir (ZG): the geographical coordinates 45°15′ N, 15°30′ E; elevation 112 m											
October	105	78	69	36	73	***69***	10.4	12.6	11.7	9.4	10.4	***10.5***
November	59	66	88	113	1	***81***	4.9	7.6	8.0	8.8	3.0	***5.3***
December	54	95	79	61	85	***58***	0.5	3.4	2.8	0.1	3.7	***0.9***
January	11	82	84	12	19	***46***	2.3	-1.1	-0.4	2.1	2.5	***-0.8***
February	9	44	67	12	26	***42***	5.3	2.9	2.3	1.3	-1.9	***1.8***
March	109	43	46	36	5	***56***	7.2	7.6	6.8	7.3	9.4	***5.9***
April	40	52	63	42	51	***64***	12.0	14.5	12.0	13.4	12.5	***10.6***
May	44	49	98	70	82	***79***	17.4	18.4	16.6	16.9	16.7	***15.3***
June	*103*	*68*	*104*	*68*	*128*	***100***	20.9	19.8	20.4	21.1	22.0	***18.5***
Σ (X)	***431***	***577***	***698***	***450***	***470***	*595*	***9.0***	***9.5***	***9.2***	***8.9***	***8.7***	*7.6*
	Tuzla (TZ): the geographical coordinates 44°32′ N, 18°40′ E; elevation 231 m											
October	114	47	136	65	45	***56***	9.5	12.2	10.3	8.7	9.6	***10.6***
November	88	79	72	57	15	***71***	3.2	7.8	8.2	9.6	2.8	***5.6***
December	54	63	136	68	61	***72***	-0.3	4.1	3.3	1.3	3.0	***0.9***
January	30	62	86	32	75	***59***	2.7	-1.3	-0.3	0.9	0.6	***-0.8***
February	14	44	74	37	79	***55***	4.7	1.7	1.8	0.9	-4.2	***1.7***
March	96	99	55	14	11	***61***	7.0	6.2	6.3	6.1	8.4	***5.7***
April	54	32	102	29	92	***76***	11.8	13.0	11.2	12.1	11.5	***10.4***
May	100	56	177	86	137	***92***	16.4	17.3	15.1	14.8	14.8	***14.8***
June	113	160	257	74	56	***111***	20.1	18.5	19.0	19.2	21.4	***17.7***
Σ (X)	***663***	***642***	***1095***	***462***	***571***	*653*	***8.3***	***8.8***	***8.3***	***8.2***	***7.5***	*7.4*
	Banja Luka (BL): the geographical coordinates 44°46′ N, 17°11′ E; elevation 164 m											
October	146	69	73	84	62	***72***	9.9	13.6	11.4	9.4	11.0	***10.8***
November	128	78	82	74	5	***91***	4.3	8.0	8.7	8.9	3.1	***5.9***
December	99	66	180	88	121	***86***	0.6	4.4	4.6	1.5	3.9	***1.2***
January	39	73	132	52	68	***69***	2.3	-0.7	0.2	1.9	2.0	***0.7***
February	12	51	102	29	68	***63***	5.4	2.7	2.4	1.7	-2.8	***1.9***
March	158	71	114	34	5	***79***	7.9	7.6	7.5	7.1	9.3	***6.1***
April	103	40	71	38	103	***87***	12.6	14.2	12.0	13.0	12.7	***10.9***
May	71	49	148	63	168	***98***	17.6	18.9	16.5	16.0	16.1	***15.6***
June	80	153	235	37	70	***111***	21.5	20.0	20.4	21.2	23.0	***18.9***
Σ (X)	***836***	***650***	***1137***	***499***	***670***	*756*	***9.1***	***9.9***	***9.3***	***9.0***	***8.7***	*8.0*

* Oct. + Nov. + Dec. = the previous year

Similar finding regarding precipitation impacts on wheat yield in the eastern Croatia were found for the period 1961-1990 because the growing season characterized by excessive precipitation in autumn/winter period was less favorable for wheat growth (Kovacevic and Josipovic, 1995; Marijanovic et al., 2010). For example, in three more favorable seasons (MFS=year of harvest 1984, 1988 and 1989) mean wheat yield in the region was 5.53 t/ha, while in three less favorable seasons (LFS= year of harvest 1978, 1980 and 1982) it was 4.22 t/ha or 24% lower. Precipitation (a = Oct.-June; b = Nov. + Dec. of the previous year: 3-year means in Osijek) were higher in the LFS, especially for Nov. + Dec. period (a =522 and 463 mm, b = 146 mm and 79 mm, for the LFS and MFS, respectively).However, more reliable findings regarding precipitation impacts on wheat yield is possible have based on more precise testing of precipitation regime, for example by observations of their 10-day interval values. The growing season 2009/2010 is separated from remaining four tested growing season because of the lowest achieved yield of wheat (4.04 t ha^{-1} in Croatia and 2.67 t ha^{-1} in B&H). In four remaining tested years yields of wheat were similar with differences among years from 5.19 to 5.48 t ha^{-1} in Croatia and from 3.31 to 3.78 t ha^{-1} in B&H.

Degree of yield variation among years is relative high because in this short 5-year period the lowest annual yield is lower for 26% in Croatia and for 29% in B&H. In our earlier study (Kovacevic and Josipovic, 1995) was found increased trend of decade yields of wheat in the eastern Croatia for 1961-1990 period (2.81 t ha^{-1}, 4.09 t ha^{-1} and 5.26 t ha^{-1}, for the decade of 60-ies, 70-ties and 80-ties, respectively) with variation of yields among years in individual decades from2.08 to 3.68 t ha^{-1}, from 3,42 to 4.93 t ha^{-1} and from 4.03 to 6.50 t ha^{-1}. As both in Croatia and B&H are dominant less permeable soils, the low yields of wheat in the growing season 2009/2010 are in close connection with excessive precipitation (Table 2). Precipitation in Dec.-Febr. (mm) were 244 (Osijek), 230 (Zagreb), 296 (Tuzla) and 414 (Banja Luka) or the higher for the referent values (1961-1990) for 76%, 57%, 59% and 90%, respectively.

Also, loss of yield is partly caused by excess of precipitation in May and June (350 mm in Osijek, 434 mm in Tuzla and 383 mm in Banja Luka (average 1961-1990: 147 mm, 203 mm and 209 mm, respectively). Additional adversely effects on wheat yields in unfavorable 2009/2010 growing season had lower minimal air–temperatures during the winter period particularly in January and February (absolute minimum in Osijek: -17.5 ^{o}C) probably contributed to the lower yields of wheat in the 2009/2010 growing season (SHS, 2010; Iljkic et al., 2014).

Global warming and increasingly experiencing with extreme weather conditions around the globe affecting often adversely on field crop yields. Annual temperature over Europe increased between 0.1 and 0.4% /decade. In our study (Table 2), average air temperature in 2008-2012 (October-June) were higher from average (1961-1990) for 0.9 ^{o}C (Osijek), 1.5 ^{o}C (Zagreb), 0.8 ^{o}C (Tuzla) and 1.2 ^{o}C (Banja Luka). Pepo and Kovacevic (2011) compared variations in winter wheat yields over years in four counties in the eastern Hungary and five in the eastern Croatia with emphasis on the impacts of precipitation and mean air temperature regimes. In general, the result shoved that precipitation in growing season is much higher in the eastern Croatia than in the eastern Hungary, so drought stress is more pronounced environmental problem for wheat in Hungary.

Conclusions

There is considerable variation of what yields among years and they are mainly result of weather impacts, particularly precipitation quantities and their distribution as well as temperature regimes. However, precise connections are impossible to explain based on their monthly values only although there are indications that the higher precipitation and the lower temperatures during winter period could be negative influencing factors.

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