REVIEW ARTICLE

Impact of climate change on wheat, barley and rapeseed yields in Croatia

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Abstract

In Croatia winter wheat is main winter crop and the second most important field crop after maize. With barley and rapeseed they occupy about 27.4% of the used arable land in the country. For 5-year period (2008–2012) average harvest area of winter wheat in Croatia was 168433 ha year^{-1}, while remaining two winter crops covered 56574 ha year^{-1} (barley) and only 16978 ha (rapeseed) year^{-1} (FAO, 2013). This study observed weather (precipitation and air–temperatures) and crop yield interactions of three winter crops (wheat, barley and rapeseed) in Croatia for period of 5 years (2008–2012). The ranges of yield variations between years in the mentioned period were from 4.04 to 5.48 t ha^{-1} (wheat), from 3.27 to 4.26 t ha^{-1} (barley) and from 2.02 to 2.82 t ha^{-1} (rapeseed). Growing season 2009/2010 stands out as unfavorable for all three winter crops since the lowest yields were obtained in unfavorable weather conditions. During winter period (Dec.–Febr.) precipitation were higher for 76% in Osijek, 77% in Slavonski Brod, 68% in Sisak and 48% in Varazdin (139, 151, 170 and 148 mm of long–term mean, respectively). Also, excessive amount of precipitation during harvest in 2010 may cause yield reduction. At the same period mean air temperature was higher in comparison to LTM.

Key words: Climate change, precipitation, air–temperature, winter crops, grain yield, Croatia

Introduction

Winter wheat is main winter crop in Croatia. According to data of FAO (2013) in the 5–year period 2008–2012 average harvested areas of winter wheat was 168433 ha year^{-1}. Remaining main winter crops in Croatia are barley (56574 ha; average yield 3.95 t ha^{-1}) and rapeseed (16 978 ha; average yield 2.62 t ha^{-1}) with emphasis that a smaller part of barley area is covered by spring barley.

Yield variations of field crops between the years in such short period are mainly affected by weather conditions during individual growing season. In regard of that, global warming and unfavorable precipitation regime had mainly negative effects on the field crop 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). Meteorological record of annual temperatures over Europe show increase in temperature at a rate of between 0.1 and 0.4°C decade^{-1} (Olesen and Bindi, 2002). Warming is expected to lead to a northward expansion of suitable cropping areas and a reduction of the growing period of cereals in Europe (Trnka, 2012).

The aim of this study was to investigate yield and weather (precipitation and air–temperatures) variations of winter wheat, barley and rapeseed for the 5–years period (2008–2012) in Croatia. In previous studies (1961 to 1990 and 1996 to 2007) the results were elaborated regarding yields and weather characteristics for winter wheat (Kovacevic 2005; Kovacevic et al., 2009; Marijanovic et al., 2010; Iljkić et al., 2010).

Material and methods

To gather information of winter wheat harvested area and yield data in the 2008–2011 period, FAO (2013) Statistical Yearbooks were used, while for 2012 data were obtained from State Bureau for Statistics (SR, 2013). Source of the meteorological data, precipitation and mean air–temperatures: Osijek, Slavonski Brod, Sisak and Varazdin was State Hydrometeorological Institute in Zagreb. These four locations represent the main Croatian crop production area.

Results and discussion

In the observed period (2008-2012) winter wheat as main winter crop on arable land in Croatia covered 168433 ha or close to 20% of total used arable land in the country. Barley was grown on considerably smaller area, 56574 ha or about 6% and rapeseed on only about 17000 ha or 2% of total used arable land. In 5–year period main yield of wheat was 5.06 t ha^{-1}, barley 3.95 t ha^{-1} and rapeseed 2.62 t ha^{-1} (Table 1). However, the ranges of yield variations among years in the mentioned period were from 4.04 to 5.48 t ha^{-1} (wheat), from 3.27 to 4.26 (barley) and from 2.02 to 2.82 (rapeseed). These variations are result of specific weather characteristic to each growing season.

Table 1. The harvest area and yields of winter crops in Croatia 2008–2012 (FAO, 2013)

		The harvest area (ha) and yields (t ha $year^{-1}$) for 2008–2012 period in Croatia					
The arable crop		2008	2009	2010	2011	2012	Average
Wheat	ha	156536	180376	168507	149797	186949	168433
	t ha^{-1}	5.48	5.19	4.04	5.22	5.35	5.06
Barley	ha	65538	59584	52524	48318	56905	56574
	t ha^{-1}	4.26	4.09	3.27	4.01	4.14	3.95
Rapeseed	ha	22372	28723	16339	17563	9900	16978
	t ha^{-1}	2.81	2.80	2.02	2.82	2.67	2.62
		Used arable land (ha) and share of individual crop (% of arable land)					
Arable lands (ha)		855 416	863 023	899 594	892 221	903 508	882 752
Wheat (%)		18.3	20.9	18.7	16.8	20.7	19.1
Barley (%)		7.7	6.9	5.8	5.4	6.3	6.4
Rapeseed (%)		2.6	3.3	1.8	2.0	1.1	1.9

From 2008 to 2012 winter air–temperatures (Dec.–Febr.) were variable for winter wheat, barley and rapeseed (Table 2). The growing season 2009/2010 is separated from remaining four tested growing season because of the lowest achieved yield of all three winter crops. The possible main reason are different weather conditions. In the remaining four years the annual yields of wheat, barley and rapeseed were similar. During winter period (Dec.–Febr.) precipitation was 76% higher in Osijek, 77% in Slavonski Brod, 68% in Sisak and 48% in Varazdin (139, 151, 170 and 148 mm LTM, respectively). In general, low yields of wheat are in close connections with excessive precipitation, especially during the autumn/winter period (Josipovic et al., 2005). In 2010 yield reduction is partly caused by 55% and 53% higher precipitation compare to LTM in May and June which negatively affected at the harvest. Sprauge et al. (2014) reported that winter rapeseed achieved grain yields of 2.6–5.8 t ha^{-1} in areas with annual precipitation around 600 mm.

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

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): 45°33′ N, 18°41′ E; 102 m											
Oct.	93	30	55	67	29	*41*	10.3	13.0	11.5	9.1	10.6	*11.2*
Nov.	103	48	68	56	0	*57*	4.0	7.5	8.2	8.9	2.3	*5.4*
Dec.	48	41	101	73	69	*52*	0.1	3.8	3.1	0.3	3.4	*0.9*
Jan.	33	60	84	24	28	*47*	1.5	-1.1	-0.8	1.1	2.2	*-1.2*
Febr.	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*
	Slavonski Brod (SB): 45°16′ N, 18°00′ E; 88 m											
Oct.	120	44	45	58	32	*54*	10.0	12.2	11.0	8.9	10.2	*10.6*
Nov.	76	65	68	72	4	*61*	3.7	7.3	7.8	8.1	2.5	*5.3*
Dec.	67	47	106	69	71	*58*	0.3	3.8	3.4	0.3	2.8	*0.9*
Jan.	34	63	80	27	29	*50*	1.7	-1.6	0.0	0.8	1.7	*-1.2*
Febr.	7	26	82	17	43	*43*	5.1	2.9	1.8	1.0	-2.9	*1.7*
March	99	41	50	36	1	*50*	7.6	7.1	6.8	6.4	9.1	*6.2*
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*
Σ (X)	*630*	*447*	*822*	*388*	*420*	*533*	*8.9*	*9.3*	*8.8*	*8.4*	*8.3*	*7.7*
	Sisak (SI): 45°50′ N, 16°36′ E; 106 m											
Oct.	141	88	88	65	80	*64*	9.7	12.6	11.3	9.1	10.1	*10.8*
Nov.	97	86	102	140	2	*90*	4.7	7.5	8.4	9.1	2.7	*5.6*
Dec.	73	101	95	63	75	*68*	0.4	3.6	3.5	0.7	3.7	*1.0*
Jan.	31	113	105	15	27	*52*	2.2	-1.4	-0.6	2.1	2.1	*-0.7*
Febr.	8	40	89	14	54	*50*	5.2	3.2	1.8	1.1	-2.4	*1.9*
March	115	54	66	21	10	*58*	7.8	7.6	7.4	7.3	9.4	*6.3*
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*
Σ (X)	*704*	*710*	*907*	*506*	*516*	*628*	*9.0*	*9.6*	*9.0*	*9.0*	*8.6*	*7.9*
	Varazdin (VZ): 46°18′ N, 16°20′ E; 154 m											
Oct.	97	66	40	61	84	*69*	9.3	11.8	10.8	8.1	9.6	*10.1*
Nov.	43	38	75	116	1	*83*	4.7	6.8	7.7	8.1	2.4	*4.9*
Dec.	50	83	79	67	78	*58*	0.3	2.8	2.6	-0.2	3.5	*0.5*
Jan.	6	105	73	11	22	*45*	2.7	-1.3	-1.7	1.5	2.0	*-1.3*
Febr.	8	49	67	12	21	*45*	4.8	2.4	1.6	0.4	-2.4	*1.3*
March	87	59	41	15	1	*55*	6.9	6.8	6.1	6.4	8.5	*5.4*
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*
Σ (X)	*492*	*611*	*685*	*401*	*457*	*607*	*8.6*	*8.8*	*8.2*	*8.2*	*8.2*	*7.2*

In sowing period of winter wheat and barley there was enough precipitation to allow the critical transition phases of germination and emergence (Table 2). The exception is 2012 when rapeseed sowing date (the end of Aug.–beginning of Sept.) was delayed because of lack of precipitation in August (average of 9.9 mm).
In average air–temperatures in December for all observed years were higher for 1.34°C in western part (SI and VZ) and for 1.23°C in eastern part (OS and SB) of Croatia compared to LTM temperatures. Kovacevic et al. (1995) concluded that weather conditions for crop production are more favorable in western part than in the eastern part of Croatia.
In observed 5–year period mean air–temperatures in vegetation period (Oct.–June) were above LTM for 0.9°C in OS, 0.3°C in SB, 1.1°C in SI and 1.2 °C in VZ. Followed by higher temperatures in spring (on average 1.4°C in March, 2.0°C in April and 1.1°C in May above LTM), lack of precipitation especially in March 2012 could not support early vegetative growth in spring and yields were partly limited by drought. Olesen and Bindi (2002) reported that temperature increase can shorten the length of the growing period and reduce yields. Trnka et al. (2012) reported that increase in the mean temperature by 1°C (1961–2007) leads to yield decreases of up to 11% for winter wheat and up to 10% for spring barley.
Lower absolute minimal air–temperatures during the winter period particularly in the period from December 11 to February 20 (Table 3) probably contributed to the lower yields of the winter crops in the 2009/2010 growing season.

Table 3. Mean minimal and absolute minimal air–temperatures during 3–month winter period

Month	Average minimal (AverageMin) and absolute minimal (AbsoluteMin) air–temperature in the 10–days intervals in December–February period (a=1.–10.; b=11.–20.; c=21.–30./31.)											
	AverageMin (°C)			AbsoluteMin (°C)			AverageMin (°C)			AbsoluteMin (°C)		
	a	b	c	a	b	c	a	b	c	a	b	c
	The 2009/2010 growing season											
	Osijek (OS)						Varazdin (VZ)					
Dec.	4.7	-5.9	1.9	3.1	-17.5	-17.0	2.4	-6.4	1.7	-2.6	-21.6	-2.5
Jan.	0.2	-0.9	-8.2	-4.0	-2.3	-16.1	-1.7	-2.2	-7.7	-6.6	-4.6	-12.8
Febr.	-5.7	-2.8	2.9	-15.0	-10.7	-1.0	-6.1	-3.8	3.1	-12.1	-9.8	-0.9
	The 2010/2011 growing season											
	Osijek (OS)						Varazdin (VZ)					
Dec.	1.4	-6.2	-3.5	-3.5	-14.0	-10.7	-1.8	-8.6	-2.6	-10.1	-18.1	-8.2
Jan.	-2.9	1.0	-3.5	-8.0	-0.6	-7.7	-1.2	3.6	-3.3	-9.4	-2.9	-6.7
Febr.	-3.4	0.2	-5.0	-7.0	-5.0	-10.9	-3.7	-0.5	-6.0	-6.6	-3.4	-10.0

Conclusions

This paper presents a review of five year vegetation conditions of winter crops. The variation in the results show initial change of climate conditions in Croatian which has consequences on crop production. In 5–year period mean air–temperatures in winter crops growing season (Oct.–June) were above the long–term mean which is in relation to European meteorological records. According to our data, weather conditions, particularly excessive amount of precipitation during winter period had adverse effect on yield of main winter crops in Croatia.

References

Iljkic, D., Kovacevic, V., Kovacevic, J., Lalic, A., Drezner, G. (2010): Weather impacts on yields of wheat and barley. In: Proceedings of 45th Croatian and 5th International Symposium of Agriculuture, Marić, S., Lončarić, Z. (ur.). Osijek : Poljoprivredni fakultet Sveučilišta J.J. Strossmayera u Osijeku. 737-740.

Josipovic, M., Kovacevic, V., Petosic, D., Sostaric, J. (2005): Wheat and maize yield variations in the Brod-Posavina area. Cereal Res. Commun., 33, 229–233.

Kovacevic V. (2005): Wheat yield variations among the years in the Eastern Croatia. In: Proceedings of the XL Croatian Symposium on Agriculture with International Participation (Kovacevic V. and Jovanovac Sonja Eds.), 15-18 February 2005, Opatija, Croatia, p. 453-454.

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., Josipovic M. (1995): Winter wheat (*Triticum aestivum* L.) yield variations in Croatia from 1960 to 1994. Fragmenta Agronomica 46(2):28–29.

Kovacevic V., Josipovic M., Sostaric J., Iljkic D., Markovic M. (2009):Wheat yield variations among years in eastern Croatia with emphasis on Vukovar-Syrmium area. In: Proceedings of 2nd International Scientific/Professional Conference„Agriculture in Nature and Environment Protection“, Vukovar 4th – 6th June 2009,p.115-121.

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

Marijanovic M., Markulj A., Tkalec M., Jozic A., Kovacevic V. (2010): Impact of precipitation and temperature on wheat (*Triticum aestivum* L.) yields in eastern Croatia. Acta Agriculturae Serbica, Vol. XV, 29: 117-123.

Pepo P., Kovacevic V. (2011): Regional analysis of winter wheat yields under different ecologicakl conditions in Hungary and Croatia. Acta Agronomica Hungarica, 59(1):23–33.

Olesen, L.E., Bindi, M. (2002): Consequences of climate change for European agricultural productivity, land use and policy. European Journal of Agronomy 16(4):239–262.

Sprague, S.J., Kirkegaard, J.A., Graham, J.M., Dove, H., Kelman, W.M. (2014): Crop and livestock production for dual-purpose winter canola (*Brassica napus*) in the high–precipitation zone of south–eastern Australia. Field Crops Research 156:30–39.

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

Trnka, M., Brázdil, R., Olesen, J.E., Eitzinger, J., Zahradníček, P., Kocmánková, E., Dobrovolný, P., Štěpánek, P., Možný, M., Bartošová, L., Hlavinka, P., Semerádová, D., Valášek, H., Havlíček, M., Horáková, V., Fischer, M., Žalud, Z. (2012): Could the changes in regional crop yields be a pointer of climatic change? Agricultural and Forest Meteorology 166–167:62–71.

***FAO (2013): faostat.fao.org/crops (12.12.2013.)