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ANALYSIS OF CLIMATE ELEMENTS IN THE NORTHEASTERN REGION OF CROATIA FOR THE PURPOSE OF DETERMINING IRRIGATION REQUIREMENTS OF MAIZE AND SOYBEAN ON DRAINED SOIL

SUMMARY

The aim of this research was to determine crop water requirements (soil water deficit) in years with average precipitation amounts and dry years in order to estimate the decline in maize and soybean yields in such years, as well as to determine the actual yields of maize and soybean in years with/almost average precipitation amount and both in dry and wet years.

In the examined 20-year period, annual air temperature in the northeastern region of Croatia increased by 1.7^{o} C, while a very slight negative trend in annual precipitation amount, -0.18 mm/20 yrs, has been identified. The determined soil water deficit in the years with multi–annual mean of precipitation amount ranged from 139.3 mm (soybean) up to 152.7 mm (maize), while in the dry years, water deficit ranged from 299.7 mm (soybean) up to 316.3 mm (maize). The estimation of yield decline (%) in the years with multi–annual mean of precipitation amount ranged from 21.5% (soybean) up to 33.9% (maize), while in the dry years it ranged from 40.5% (soybean) up to 65.0% (maize). In the 5–year period, the lowest yields of both crops were in the year with the lowest annual precipitation amount (maize 5,175 t.ha^{-1} and soybean 2,153 t.ha^{-1}), while the highest crop yields were when the annual precipitation amount was on a par with the average value (maize 9,652 t.ha^{-1} and 9,817 t.ha^{-1} and soybean 3,454 t.ha^{-1} and 3,584 t.ha^{-1}). In the year with the highest precipitation amount, crop yields ranged between the value of the yield aged in the drought and the year with the average precipitation amount (maize 8,875 t.ha^{-1} and 8,929 t.ha^{-1} and soybean 3,188 t.ha^{-1} and 3,202 t.ha^{-1}).

Yield decline problem in the northeastern region of Croatia in dry years can be largely solved through irrigation (need to build/expand the irrigation

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system) and better maintenance of the existing drainage system because the problem can appear during the period with heavy rains.

Keywords: climate elements, irrigation requirements, maize, soybean

INTRODUCTION

Climate change in recent decades is the topic and the major global problem and therefore solutions are being sought to mitigate/prevent its consequences. Climate change can be manifested as a change in climate elements relative to average values or as a change in the distribution of climate events relative to average values. The consequence of that causes more frequent occurrences of floods and droughts which can cause major damage to agriculture and the environment. Climate characteristics and soil water regime, as well as their variable and complex interrelations, define the efficiency of plant production (Šimunić *et al.*, 2007). According to Beltrão *et al.* (1996), the highest yields are obtained at the time of the most favourable air–water ratio in the soil, mainly in the critical periods for each crop. The yields of agricultural crops fluctuate over many years and are influenced by many abiotic and biotic factors. A large number of studies indicate that crop yields primarily vary as a result of extreme climate conditions, although other factors, such as soil fertility, the applied agro–technology measures and plant species may also affect crop yields (Kovačević and Josipović, 2015). Agricultural production is very risky in underdeveloped agricultural areas, especially when surplus and/or deficit of precipitation occurs before or during the growing season. Such conditions make production planning very difficult and/or almost impossible because production and hence yields are dependent on weather conditions, making field crop yields and their quality highly variable (Šimunić, 2016). In Croatia prevention/mitigation of the consequences of climate change in agriculture focuses on the existing (built) hydro–technical facilities, surface and underground drainage systems, as well as irrigation systems that should be adequately used and maintained and the activities for the construction of new hydro–technical facilities and drainage and irrigation systems need to be continued (Šimunić *et al.*, 2020).

The aim of the research was:

– to determine crop water requirements (soil water deficit) in years with average annual precipitation amount and dry years,

– to estimate a decline in yields of maize and soybean in such years,

– to determine actual maize and soybean yields in years with/almost average annual precipitation amount, as well as in dry and wet years.

MATERIAL AND METHODS

For the northeastern region of Croatia, the climate data series from the climatological station Našice (φ=45^{o} 49' N, λ=18^{o} 09' E, 150 m above mean sea level) for the 20–year period (2001– 2020) was used.

Based on the climate data, a reference evapotranspiration was calculated for an average and a dry year (probability of precipitation occurrence in 25% cases). The reference evapotranspiration was calculated using the Penman–Monteith method through "Cropwat" software, version 8 (Smith, 1992).

Crop water requirements were determined by soil water balance using the Palmer method, corrected according to Vidaček, using "Hidrokalk" computer program (Širić & Vidaček, 1988). For soil water balance calculation, the corresponding values of effective precipitation for an average and a dry year were used, which was calculated by USDA, SCS method.

The values of soil water constants were taken into account as the average of the values of the represented soil type: drained hypogley soil by means drainage pipes (Husnjak, 2014). The soil studied had the following characteristics: field water capacity was 44 vol% and wilting point was 22 vol%, clay–loam texture in the arable layer. Pipe drainage spacing is 25 m and average depth is 1 m. Drainpipe discharged directly into open channels. The total drained area is 4,800 ha.

Crop water requirements and yield decline were related to two types of crops: maize and soybean. The root depth for the calculation of soil water balance was 0.3 m. Concerning the previously mentioned crops, the vegetation period was considered and phenological phases and their duration were determined. Each phenological phase was corrected by the crop coefficient. Crop yield decline was determined according to the Doorenbos and Kassam method:

$$(1-\frac{Ya}{Ym})=\mathrm{ky}\,(1-\frac{ETa}{ETc}) \qquad (1)$$

Ya– Actual yield
Ym–Maximum possible yield
ky – Yield response factor
ETa – Actual evapotranspiration
ETc– Crop (maximum) evapotranspiration

The actual yields for both crops were determined after harvesting and drying up to moisture 13%. Vegetation period for both crops during the research were from the beginning of April to the end of September.

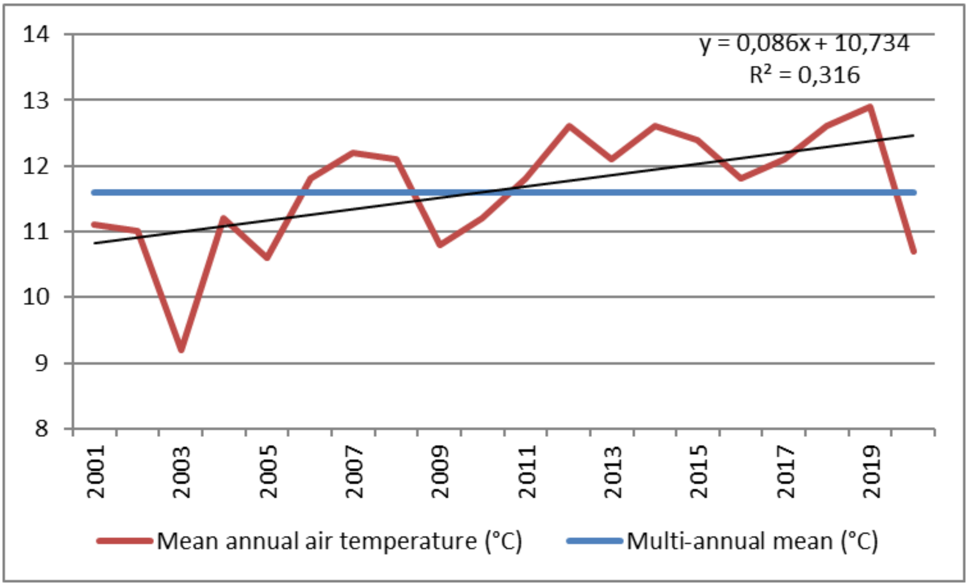
Analysis of variance (ANOVA) was used to test crop yields, while Duncan's Multiple Range test was used to compare the mean values of crop yields depending on the year.

RESULTS AND DISCUSSION

The results obtained have been presented in the following tables and graphs.

Analysis of climate elements

Mean annual air temperature, annual precipitation amounts and corresponding trends for climatological station (CS) Našice have been presented in Graphs 1 and 2 and annual courses of mean, maximum and minimum monthly precipitation amounts have been presented in Graph 3.

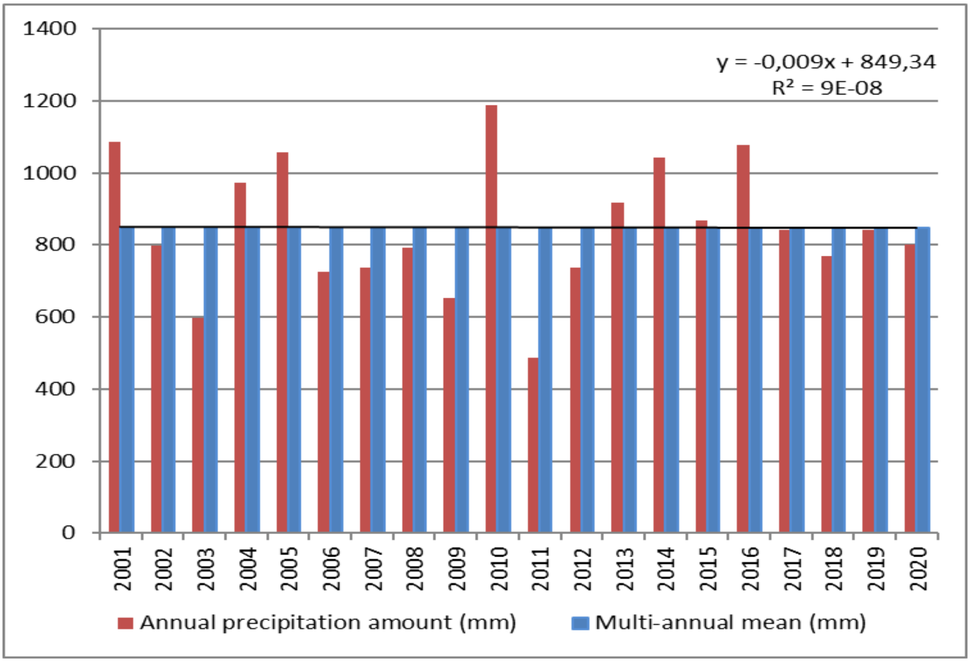


Graph 1. Mean annual air temperature (°C), multi–annual mean (°C) and corresponding linear trend of mean annual air temperature for CS Našice

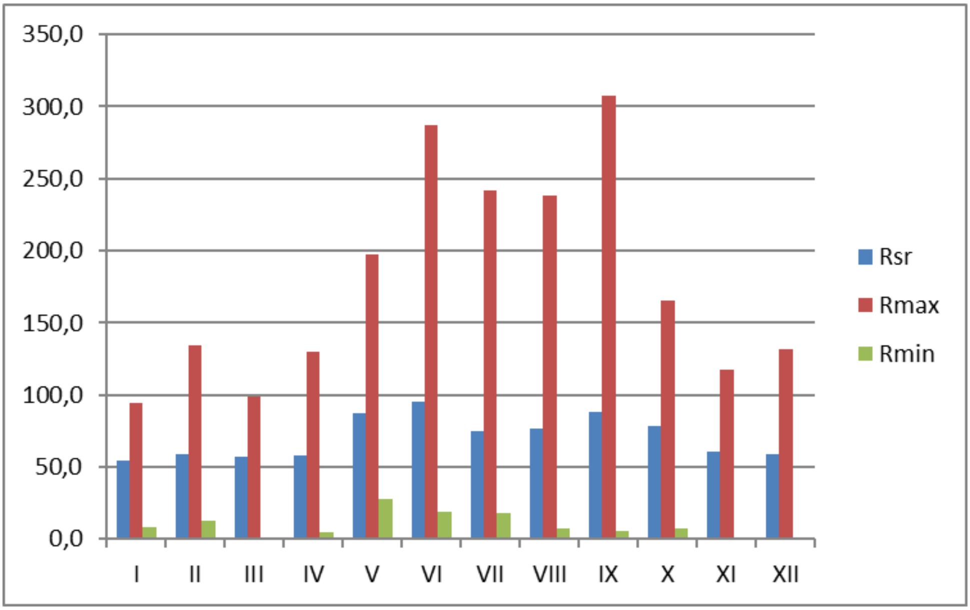
During the analysed period in the northeastern region of Croatia, mean annual air temperatures ranged from 9.2°C to 12.9°C, while the multi–annual mean air temperature was 11.6° C. The corresponding linear trend of mean annual air temperature is 1.7°C/20 yrs, which is evident from Graph 1. During the examined 20-year period, the positive air temperature trend is evident with some inter–annual variations and could be an indicator of climate change. According to Kutilek and Nielsen (2010), the average temperature increased by 1.1–1.3° C in 100 years in Central Europe. The effects of climate change have become increasingly evident over the past decades (Patt and Schröter, 2008). Positive trends of air temperature and precipitation amounts in their research have been quoted by Šimunić *et al.* (2013 and 2019) and Miseckaite *et al.* (2018).

The precipitation regime is one of the most variable climate characteristics of some area, both spatially and temporally (Meteorological and Hydrological Service and Croatian Meteorological Society, page 85, Gajić–Čapka, 2003). This can also be seen in the northeastern region of Croatia.

As shown in Graph 2 for the northeastern region of Croatia, annual precipitation amounts were within the range from 487.3 mm (2011) to 1,188.1 mm (2010), while multi–annual mean of annual precipitation amounts was 855.1 mm. Within the examined 20–year period the difference between the maximum and the minimum value of annual precipitation amount was 700.8 mm.



Graph 2. Annual precipitation amount (mm), multi–annual mean (mm) and corresponding linear trend of annual precipitation amount for CS Našice



Graph 3. The annual courses of mean, maximum and minimum monthly precipitation amounts. The multi–annual mean of annual precipitation amounts is 855.1 mm, CS Našice (2001–2020)

Monthly precipitation amounts can vary significantly from year to year (Graph 3). The variability of monthly precipitation amounts expressed by the coefficient of variation (cv) is larger during the summer months (July, August, September; cv=0.7) than in the cold part of the year (January, November; cv=0.4). The annual course of monthly precipitation amounts in Croatia can be divided into two types (Zaninović *et al*., 2008), depending on the time of the year when the month with the lowest precipitation amount occurs: the maritime type of annual course, with the lowest precipitation amount occurring during the warm period of the year (April to September), and the continental annual course, with the lowest precipitation amount occurring during the cold half of the year (October to March). The annual course of monthly precipitation amount for the northeastern region of Croatia has the characteristics of the continental precipitation regime. From Figure 2 it is evident that there are some differences in annual precipitation amounts from year to year, which is described by the coefficient of variation. In addition, there is a slight negative trend in annual precipitation amounts, –0.18 mm/20 yrs. The trends of precipitation extremes in Europe vary greatly and depend not only on the region, but also on the indicator used to describe an extreme (Groisman *et al.*, 2005). Changes in precipitation are the prime drivers of change in the availability of both surface water and groundwater resources (Beare and Heaney, 2002). Changes in precipitation amount and its distribution have a direct influence on soil water content and affect crop cultivation (Šimunić *et al.*, 2013).

The relationship between reference evapotranspiration and effective precipitation

Reference evapotranspiration that integrates the effects of climate elements and indicates the overall evaporation has been presented in Table 1 and 2, and the relationship between reference evapotranspiration and effective precipitation, both for multi–annual mean and dry year has been presented in Table 3.

Tables 1 and 2 show that multi–annual mean reference evapotranspiration was 2.6 mm.day^{-1} and it was lower than reference evapotranspiration based on the frequency of the occurrence of climate elements upon 25% precipitation probability (2.8 mm.day^{-1}). Moreover, with a multi–annual mean of climate elements, the daily evapotranspiration is lower during the vegetation period than in the year with the frequency of the occurrence of climate elements upon 25% precipitation probability. In relation to effective precipitation for the multi–annual mean and reference evapotranspiration calculated on the basis of multi–annual climate elements, Table 3 shows that the difference in water shortage is smaller than in effective precipitation at the frequency of occurrence in 25% of cases and reference evaporation calculated on the basis of associated climatic elements. In both cases, precipitation deficit occurs throughout the growing season. The exact crop water deficit in the focus of this research can be determined by the soil water balance.

Table 1. Reference evapotranspiration based on multi–annual mean of climate elements

Month	Tmin	Tmax	Humidity	Wind	Sun	Radiation	ETo
	^oC	^oC	%	$km.day^{-1}$	$h.day^{-1}$	$MJ.m^{-2}.day^{-1}$	$mm.day^{-1}$
Jan	-2,3	5,0	82	233	2,1	4,4	0,6
Feb	-0,8	6,9	79	242	3,1	6,9	0,9
Mar	2,3	12,8	72	268	4,8	11,3	1,8
Apr	6,7	18,4	69	250	6,8	16,7	2,9
May	10,8	22,8	72	276	7,7	20,0	3,9
June	14,7	26,5	72	259	8,9	22,5	4,7
July	16,3	28,7	69	250	9,7	23,0	5,2
Aug	15,9	28,6	71	233	9,1	20,3	4,6
Sep	11,6	23,0	77	250	6,3	13,9	2,9
Oct	7,5	17,9	80	233	4,8	9,2	1,7
Nov	3,4	11,8	84	216	2,9	5,3	0,9
Dec	-0,8	6,1	84	225	1,8	3,7	0,6
Mean	7,1	17,4	76	245	5,7	13,1	2,6

Table 2. Reference evapotranspiration based on the frequency of the occurrence of climate elements upon 25% probability precipitation

Month	Tmin	Tmax	Humidity	Wind	Sun	Radiation	ETo
	^oC	^oC	%	$km.day^{-1}$	$h.day^{-1}$	$MJ.m^{-2}.day^{-1}$	$mm.day^{-1}$
Jan	2,5	11,9	71	302	3,4	5,2	1,3
Feb	2,5	11,3	74	216	3,3	7,1	1,2
Mar	3,6	13,6	75	216	4,7	11,2	1,7
Apr	6,0	20,1	67	216	9,7	20,3	3,4
May	11,8	24,2	69	233	7,8	20,2	4,0
June	15,6	28,7	68	233	9,6	23,4	5,2
July	15,6	31,2	59	233	10,8	24,5	6,0
Aug	15,6	28,9	70	233	8,7	19,8	4,7
Sep	9,5	20,8	75	233	6,2	13,8	2,8
Oct	5,8	14,5	80	190	3,8	8,3	1,4
Nov	3,4	11,9	83	207	2,6	5,1	0,9
Dec	-0,9	6,1	83	216	1,0	3,2	0,6
Mean	7,6	18,6	73	227	6,0	13,5	2,8

Crop water requirements in a year with average precipitation amount and in a dry year

The water requirements of maize and soybeans in a year with an average amount of precipitation and a dry year are determined by soil water balance (Tables 4, 5, 6 and 7)

Table 3. Relationship between effective precipitation, multi–annual mean and dry year and reference evapotranspiration based on multi–annual mean of climate elements and based on the frequency of the occurrence of climate elements upon 25% precipitation probability

Month	Multi–annual mean (mm)		Difference	Dry year (mm)		Difference
	Effective precipitation	ETo		Effective precipitation	ETo	
Jan	49.9	18.6	31.3	31.7	40.3	-8.6
Feb	53.1	25.2	27.9	52.2	33.6	18.6
Mar	51,9	55.8	-3.9	75.8	52.7	23.1
Apr	52,2	87.0	-34.8	14.1	102.0	-87.9
May	75.3	120.9	-45.6	74.0	124.0	-50.0
June	80.8	141.0	-60.2	24.0	156.0	-132.0
July	65.9	161.2	-95.3	33.1	186.0	-152.9
Aug	67.5	142.6	-75.1	69.2	145.7	-76.5
Sep	75.6	87.0	-11.4	74.2	84.0	-9.8
Oct	68.6	52.7	15.9	101.2	43.4	57.8
Nov	54.8	27.0	27.8	56.2	27.0	29.2
Dec	53.3	18.6	34.7	49.3	18.6	30.7
Total	749.0	937.6	-188.6	645.3	1.013.3	-368.0

Table 4. The soil water balance for maize for multi–annual mean of precipitation

Month	P	ETo/ETc	L1	L2	R	Roff	AE	S1	S2	S=S1+S2	Deficit
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
Jan	44,9	19	0,0	0,0	0,0	26,3	18,6	22,0	44,0	66,0	0,0
Feb	53,1	25	0,0	0,0	0,0	27,9	25,2	22,0	44,0	66,0	0,0
Mar	51,9	56	3,9	0,0	0,0	0,0	55,8	18,1	44,0	62,1	0,0
Apr	52,2	87	18,1	5,6	0,0	0,0	75,9	0,0	38,4	38,4	11,1
May	75,3	36	0,0	0,0	27,6	11,5	36,3	22,0	44,0	66,0	0,0
June	80,8	99	17,9	0,0	0,0	0,0	98,7	4,1	44,0	48,1	0,0
July	65,9	169	4,1	33,1	0,0	0,0	103,1	0,0	10,9	10,9	66,2
Aug	67,5	150	0,0	6,8	0,0	0,0	74,3	0,0	4,1	4,1	75,4
Sep	75,6	70	0,0	0,0	6,0	0,0	69,6	6,0	4,1	10,1	0,0
Oct	68,6	53	0,0	0,0	15,9	0,0	52,7	21,9	4,1	26,0	0,0
Nov	54,8	27	0,0	0,0	27,8	0,0	27,0	22,0	31,8	53,8	0,0
Dec	53,3	19	0,0	0,0	12,2	22,5	18,6	22,0	44,0	66,0	0,0
Year	744	808	44	45	89	88	656				**152,7**

*Palmer's method (1965), calibrated and corrected by Vidaček (1988)

Legend:

P–effective precipitation (mm)
ETo–reference evapotranspiration (mm)
ETc–crop evapotranspiration (mm)
L1–loss of water from the surface layer (0-10 cm)
L2–loss of water from the subsurface layer (10-30 cm)
R–water recharge (mm)
Roff–water runoff (mm)
AE–actual evapotranspiration (mm)
S1–water storage in the surface layer (mm)
S2–water storage in the subsurface layer (mm)
S – total water storage (mm)

Table 5. The soil water balance for soybean for multi–annual mean of precipitation

Month	P	ETo/ETc	L1	L2	R	Roff	AE	S1	S2	S=S1+S2	Deficit
	Mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
Jan	44,9	19	0,0	0,0	0,0	26,3	18,6	22,0	44,0	66,0	0,0
Feb	53,1	25	0,0	0,0	0,0	27,9	25,2	22,0	44,0	66,0	0,0
Mar	51,9	56	3,9	0,0	0,0	0,0	55,8	18,1	44,0	62,1	0,0
Apr	52,2	87	18,1	5,6	0,0	0,0	75,9	0,0	38,4	38,4	11,1
May	75,3	36	0,0	0,0	27,6	11,5	36,3	22,0	44,0	66,0	0,0
June	80,8	99	17,9	0,0	0,0	0,0	98,7	4,1	44,0	48,1	0,0
July	65,9	161	4,1	30,4	0,0	0,0	100,4	0,0	13,6	13,6	60,8
Aug	67,5	143	0,0	7,7	0,0	0,0	75,2	0,0	5,9	5,9	67,4
Sep	75,6	70	0,0	0,0	6,0	0,0	69,6	6,0	5,9	11,9	0,0
Oct	68,6	53	0,0	0,0	15,9	0,0	52,7	21,9	5,9	27,8	0,0
Nov	54,8	27	0,0	0,0	27,8	0,0	27,0	22,0	33,6	55,6	0,0
Dec	53,3	19	0,0	0,0	10,4	24,3	18,6	22,0	44,0	66,0	0,0
Year	744	793	44	44	88	90	654				**139,3**

Table 6. The soil water balance for maize in a dry year

Month	P	ETo/ETc	L1	L2	R	Roff	AE	S1	S2	S=S1+S2	Deficit
	Mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
Jan	31,7	40	8,6	0,0	0,0	0,0	40,3	13,4	44,0	57,4	0,0
Feb	52,2	34	0,0	0,0	8,6	10,0	33,6	22,0	44,0	66,0	0,0
Mar	75,8	53	0,0	0,0	0,0	23,1	52,7	22,0	44,0	66,0	0,0
Apr	14,1	102	22,0	22,0	0,0	0,0	58,1	0,0	22,0	22,0	43,9
May	74,0	37	0,0	0,0	36,8	0,0	37,2	22,0	36,8	58,8	0,0
June	24,0	109	22,0	17,6	0,0	0,0	63,6	0,0	19,2	19,2	45,6
July	33,1	195	0,0	19,2	0,0	0,0	52,3	0,0	0,0	0,0	143,0
Aug	69,2	153	0,0	0,0	0,0	0,0	69,2	0,0	0,0	0,0	83,8
Sep	74,2	67	0,0	0,0	7,0	0,0	67,2	7,0	0,0	7,0	0,0
Oct	101,2	43	0,0	0,0	57,8	0,0	43,4	22,0	42,8	64,8	0,0
Nov	56,2	27	0,0	0,0	1,2	28,0	27,0	22,0	44,0	66,0	0,0
Dec	49,3	19	0,0	0,0	0,0	30,7	18,6	22,0	44,0	66,0	0,0
Year	655	879	53	59	111	92	563				**316,3**

Tables 4–7 show that soil water deficit occured during the vegetation period both in the year with an average precipitation amount and in the dry year. The water deficit in the year with an average precipitation amount for maize and soybean was 152.7 mm and 139.3 mm, respectively. In dry years deficit of soil water was higher; for maize and soybean it was 316,3 mm and 299.7 mm, respectively. A slightly higher soil water deficit was estimated for maize both in average and dry years. The estimated difference in soil water deficit could be attributed to the different durations of each phenological phase and development of maize and soybean. It is well–known that soil water deficit affects the growth

and development of field crops, which in turn affect their yields and quality. Water deficit is especially harmful if it occurs in the "plant's critical period of water need". This period may have shorter or longer duration and it can occur in different phenological phases of a particular plant. Similar results were obtained in the former studies in connection with soil water deficit in the continental part of Croatia (Šimunić *et al*., 2007; Kovačević *et al.*, 2013; Šimunić *et al.*, 2020).

Table 7. The soil water balance for soybean in a dry year

Mjesec	P	ETo/ETc	L1	L2	R	Roff	AE	S1	S2	S=S1+S2	Deficit
	Mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
Jan	31,7	40	8,6	0,0	0,0	0,0	40,3	13,4	44,0	57,4	0,0
Feb	52,2	34	0,0	0,0	8,6	10,0	33,6	22,0	44,0	66,0	0,0
Mar	75,8	53	0,0	0,0	0,0	23,1	52,7	22,0	44,0	66,0	0,0
Apr	14,1	102	22,0	22,0	0,0	0,0	58,1	0,0	22,0	22,0	43,9
May	74,0	37	0,0	0,0	36,8	0,0	37,2	22,0	36,8	58,8	0,0
June	24,0	109	22,0	17,6	0,0	0,0	63,6	0,0	19,2	19,2	45,6
July	33,1	186	0,0	19,2	0,0	0,0	52,3	0,0	0,0	0,0	133,7
Aug	69,2	146	0,0	0,0	0,0	0,0	69,2	0,0	0,0	0,0	76,5
Sep	74,2	59	0,0	0,0	15,4	0,0	58,8	15,4	0,0	15,4	0,0
Oct	101,2	43	0,0	0,0	50,6	7,2	43,4	22,0	44,0	66,0	0,0
Nov	56,2	27	0,0	0,0	0,0	29,2	27,0	22,0	44,0	66,0	0,0
Dec	49,3	19	0,0	0,0	0,0	30,7	18,6	22,0	44,0	66,0	0,0
Year	655	855	53	59	111	100	555				**299,7**

Estimation of decline in maize and soybean yields due to water deficit

This section describes the reaction of maize and soybean to water deficit and an estimation of a decline in yields of examined crops. Any deficit of soil water causes “stress” in plants and some decrease in yields.

Table 8. Estimation of decreased yields (%)

Crop	Estimation of a decline in yield (%)	
	Average years	Dry years
Maize	33.9	65.0
Soybean	21.5	40.5

According to Table 8, it is obvious that there was a decline in the yields of both crops. The estimation of the decline in maize yields was higher than for soybean. The reason for the latter could be that maize has a slightly higher soil water deficit than soybean and maize reacts more stressfully to a lack of soil water than soybean. In the northern part of Croatia, Šimunić et al. (2020) estimated the reduction of maize and soybean yields, which varied from 45% to 70% and from 28% to 44%, respectively. Table 9 shows crop yields for a 5–year period in the northeastern region of Croatia.

Table 9. Crop yields in the northeastern region of Croatia

Year	Total precipitation amount (mm)		Yield ($t.ha^{-1}$)	
	Year	May–September (vegetation period)	Maize	Soybean
2012	736.7	262.9	5,175a	2,153a
2014	1,042.4	546.0	8,929b	3,188b
2016	1,076.0	620.5	8,875b	3,202b
2019	841.2	465.9	9,817c	3,584b
2020	801.4	464.7	9,652c	3,454b
The difference between the highest and the lowest yield	$t.ha^{-1}$		4,142	1,431
	%		47.3%	40%

Source about yield: Company Ratarstvo Orahovica

Source: Central Bureau of Statistics of the Republic of Croatia

Source of variation-maize	DF	Sum of squares	Mean squares	F	Pr > F
Between groups	2	14.426	7.213	957.252	**0.001**
Within groups	2	0.015	0.008		
Total	4	14.441			

Source of variation -soybean	DF	Sum of squares	Mean squares	F	Pr > F
Between groups	2	1.265	0.632	147.949	**0.007**
Within groups	2	0.009	0.004		
Total	4	1.273			

Table 9 shows the yield variation of the previously mentioned crops during the examined period. As expected, the lowest yield of both crops was in the year with the lowest precipitation amount (dry year), while the highest yield both for maize and soybean was in the years when annual precipitation amount was on a par with the multi–annual average of annual precipitation amounts. In the years with higher precipitation amounts, the yields of maize and soybean were lower than in the years with average precipitation amount, but the yield of soybean was not statistically justified, while for maize it was statistically justified. High crop yields in hydrologically unfavorable years can be attributed to the effect of drainage, which was confirmed in the research by Šimunić, 1995 and Tomić *et al.*, 2002. The difference between the highest and the lowest yield of maize was 4.142 $t.ha^{-1}$ (47.3%) and for soybean 1.431 $t.ha^{-1}$ (40%). In comparison with the estimated values of decreased yield (Table 8), the actual yield of maize in a dry year was higher, while the actual and estimated yield of soybean was almost the same. Numerous studies indicate that crop yields vary the most as a result of adverse climate conditions despite the applied standard agricultural techniques (Mađar *et al.*, 1998; Šimunić *et al.*, 2007 and 2013; Dragovic *et al.*, 2012; Kovačević *et al.*, 2012; Kovačević and Josipović, 2015; Josipović *et al.*, 2016; Moteva *et al.*, 2016; Hafiane *et al.*, 2020). Therefore, planned and stable yields of agricultural crops in conditions caused by climate change can be achieved by building hydro–technical objects for drainage and irrigation.

CONCLUSIONS

Several conclusions can be reached based on the obtained results:

1.During the examined 20–year period, the mean annual air temperature in the northeastern region of Croatia increased by 1.7oC, while a slight negative trend in annual precipitation amounts is –0.18 mm/20 yrs.

2.The determined soil water deficit in the years with multi–annual mean of precipitation ranged from 139.3 mm (soybean) up to 152.7 mm (maize), while in the dry years water deficit ranged from 299.7 mm (soybean) up to 316.3 mm (maize).

3.The estimation of yield decline (%) in the years with multi–annual mean of precipitation ranged from 21.5% (soybean) up to 33.9% (maize), while in the dry years it ranged from 40.5% (soybean) up to 65.0% (maize).

4.In the 5–year period the lowest yields of both crops were in the year with the lowest annual precipitation amount, while the highest crop yields were when the annual precipitation amount was on a par with the average value. In the year with the highest precipitation amount, crop yields ranged between the value of the yield aged in the drought and the year with the average annual precipitation amount.

5.The problem of yield decline in the northeastern region of Croatia in dry years can be largely solved through irrigation (need to build/expand the irrigation system), as well as through better maintenance of the existing drainage system because the problem can appear during the period with heavy rains.

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