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AGROCLIMATIC CONDITIONS OF THE OSIJEK AREA DURING REFERENT (1961–1990) AND RECENT (1991–2018) CLIMATE PERIODS

Agroklimatski uvjeti na području Osijeka tijekom referentnog (1961. – 1990.) i sadašnjega klimatskog razdoblja (1991. – 2018.)

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Abstract: One highly important segment of agricultural production is the agroecological condition of a given area, including climatic conditions, which have been changing recently. Croatia belongs to a climate zone also known as a climate hot spot, characterised by a pronounced sensitivity to climate change. In order to determine if the climate has changed in the Osijek area, climatic elements and agroclimatic indicators were analysed for a referent period (1961–1990) and a recent period (1991–2018). The analysis shows that the climate has changed in the recent period as compared to the referent period. The identified climate changes manifest in higher mean air temperatures, higher precipitation amount, increased actual evapotranspiration and prolonged vegetation periods in the recent period. Furthermore, hydrothermal condition analysis shows that the ten warmest years and vegetation periods in the studied 58-year period were within the past 26 years. Due to the identified climate change and the assumption that the climate will continue to change in the future, adaptation and mitigation measures will have to be applied in agricultural production. For a more reliable assessment of agroclimatic conditions at certain area, it is recommended to analyse other climatic elements as well, such as the number of consecutive dry or rainy days above the critical precipitation threshold, wind, solar radiation, insolation, etc.

Key words: climate change, agroclimatic indicators, precipitation, air temperature, aridity index, evapotranspiration, air temperature thresholds, Osijek, Croatia

Sažetak: Vrlo važan segment poljoprivredne proizvodnje čine agroekološki uvjeti određenog područja, uključujući klimu koja se u posljednje vrijeme mijenja. Hrvatska pripada klimatskom pojasu poznatom i kao vruća klimatska točka koju obilježava izražena osjetljivost na klimatske promjene. Kako bi se utvrdilo je li došlo do promjene klime na osječkom području, analizirani su klimatski elementi i agroklimatski pokazatelji za referentno razdoblje 1961. – 1990. i sadašnje razdoblje 1991. – 2018. godine. Analizom je utvrđeno kako je došlo do promjene klime u sadašnjem razdoblju u odnosu na referentno razdoblje. Utvrđene klimatske promjene očituju se u višoj prosječnoj temperaturi zraka, većoj količini oborine, povećanoj stvarnoj evapotranspiraciji i produženomu vegetacijskom razdoblju u sadašnjem razdoblju. Također, analiza hidrotermičkih značajki klime pokazala je da su od deset najtoplijih godina i vegetacijskih razdoblja u ukupno istraživanome 58-godišnjem razdoblju, sve godine i razdoblja utvrđeni u posljednjih 26 godina. S obzirom na utvrđenu promjenu klime i pretpostavku da će se klima u budućnosti i dalje mijenjati, bit će potrebno provoditi mjere prilagodbe i ublažavanja klimatskih promjena u poljoprivrednoj proizvodnji. Za pouzdaniju ocjenu agroklimatskih uvjeta određenog područja preporučuje se analizirati i druge klimatske elemente poput broja uzastopnih sušnih odnosno kišnih dana iznad kritičnoga oborinskog praga, strujanje, Sunčevo zračenje, osunčavanje itd.

Ključne riječi: klimatske promjene, agroklimatski pokazatelji, oborina, temperatura zraka, indeks ariditeta, evapotranspiracija, temperaturni pragovi, Osijek, Hrvatska

1. INTRODUCTION

Osijek-Baranja County, with its centre in Osijek, is a predominantly flat area with plentiful water resources, fertile soils and a climate suitable for agricultural production. It is thus one of the most intensive agricultural areas in Croatia. In Osijek-Baranja County, 260,778 ha of agricultural land is cultivated, of which 95.1% consists of arable land and gardens, 1.7% orchards, 1.0% pastures, 1.0% vineyards and 1.2% meadows (OBZ, 2020). According to Köppen climate classification, which is defined by mean annual precipitation and temperature course, Osijek-Baranja County has a Cfwbx climate i.e. a warm temperate rainy climate (Zaninović et al., 2008). According to Köppen climate classification, the area has an average highest monthly temperature below 22°C, it has no extremely dry months during the year, the month with the least precipitation is in the cold part of the year, and it has one precipitation maxima (in early summer) in its annual precipitation course (Penzar and Penzar, 2000).

Climate change will have both positive and negative impacts on agricultural production in various parts of the world. Considering climate change impact predictions, Croatia belongs to a zone with pronounced sensitivity to climate change, for which a further increase in air temperature (by 2–6°C) is predicted; a decrease in precipitation is also predicted, the largest being up to -40% in spring and summer as compared to 1971–2000 (Srnec et al., 2017). Projections for the agricultural sector include: changes in the duration/length of vegetation periods; frequent droughts, which will lead to higher demand for irrigation and lower yields; more frequent floods and stagnation of surface water, which will also lead to lower yields or will destroy them completely; the emergence of new diseases; disorders in reproduction, animal growth and quality of animal products (Croatian Ministry of Environmental Protection and Energy, 2020). Therefore, it will be a major challenge to produce sufficient food through agricultural production adapted to climate change while simultaneously mitigating climate change in the agricultural sector (Smith and Olesen, 2010; Jug et al., 2017).

Determining the impact of climate change on certain areas helps us define the degree of vulnerability and the best adaptation measures to implement. In order to determine the impact of climate change in the Osijek area, climatic elements (air temperature and precipitation) and agroclimatic indicators (rain factor, air temperature thresholds, soil water balance and aridity index) were analysed for two periods: 1961–1990 and 1991–2018.

2. MATERIALS AND METHODS

The impact of climate change in the Osijek area was determined by comparing climatic elements and agroclimatic indicators in a referent period to those in a recent period. The period selected as representative of the climate during the last century is a referent 30-year climatological period from 1961–1990; the period representative of the recent climate is a 28-year period from 1991–2018. Climatic conditions were described and agroclimatic indicators were calculated based on the climatic element data (mean air temperature and precipitation) collected at the main Osijek-Čepin meteorological station (h = 89 m n.m., ϕ = 45°30'9" N, λ = 18°33'41" E) from the Croatian Meteorological and Hydrological Service's network of meteorological stations. The analysis describes the annual course of mean monthly air temperature and total monthly precipitation amount, as well as agroclimatic indicators: rain factor, vegetation periods with air temperatures above 5°C, 10°C, 15°C and 20°C, soil water balance (evapotranspiration) and aridity index.

Hydrothermal characteristics were identified based on the ten years with the highest and lowest mean air temperatures and total precipitation during the vegetation period (April–September) and the calendar year throughout the entire 58-year period from 1961–2018.

Rain factor (RF) was calculated and interpreted according to Lang for annual values (Eq. 1) and according to Gračanin for monthly values (Eq. 2) (Butorac, 1976):

$$RF = \frac{P_y}{T_y} \tag{1}$$

where P_y is annual precipitation (mm) and T_y is mean annual air temperature (°C).

$$RF_m = \frac{P_m}{T_m} \tag{2}$$

where P_m is monthly precipitation amount (mm) and T_m is mean monthly air temperature (°C).

An air temperature threshold of 5°C is considered the cardinal temperature (T_c) for intensive development of winter crops, i.e. winter crops begin their growth and development when temperatures are above this threshold (Mesić, 2009). Spring crops begin to germinate at 10°C, while a temperature of 15°C is important for pollination and flowering. Temperatures above 20°C are suitable for thermophilic cultures. Knowing the beginning and the end of the periods with temperatures above a certain threshold is important in the implementation of certain agrotechnical measures and the selection of cultivars and hybrids.

The duration of vegetation periods with air temperatures above threshold values of 5°C, 10°C, 15°C and 20°C, n (days) was calculated according to Butorac (1976):

for the beginning of the period with temperatures above cardinal values (5°C, 10°C, 15°C, 20°C):

$$n = \frac{(T_b - T_a)}{30} \tag{3}$$

$$x = \frac{(T_c - T_a)}{n} \tag{4}$$

and for the end of the period with temperatures above cardinal values (5°C, 10°C, 15°C, 20°C):

$$n = \frac{(T_b - T_a)}{30} \tag{5}$$

$$x = \frac{(T_b - T_c)}{n} \tag{6}$$

where T_a is the mean monthly air temperature at the beginning/end of the period closest to but below the cardinal value, T_b is the mean monthly air temperature (at the beginning/end of the period) closest to but higher than the cardinal value, T_c is the cardinal temperature (5°C, 10°C, 15°C, or 20°C) and x is the number of days to be added to the middle of the month with a temperature a (for the beginning of the period) or with a temperature b (for the end of the period)

Soil water balance (the calculation of potential evapotranspiration, PET) was calculated according to the Thornthwaite method (Penzar and Penzar, 2000). Actual evapotranspiration (AET), soil water deficit (D) and soil water surplus (S) were determined as

$$\begin{array}{lll} AET = PET & if & (R_0+P)>PET \\ AET = R_0+P & if & (R_0+P)<PET \\ R=(R_0+P)-AET & & \text{max 100 mm} \\ D= AET-(R_0+P) & if & (R_0+P)<AET \\ S= (R_0+P)-AET-R & if & (R_0+P)>(AET+R) \end{array}$$

where P is total monthly precipitation in the current month (mm), R_0 is soil water reserve from the previous month at a depth of up to 40 cm (mm), R is soil water reserve in the current month at a depth of up to 40 cm (mm).

Monthly aridity index (AI) was calculated and interpreted according to UNEP (1992) and Perčec Tadić et al. (2013):

$$AI = \frac{P}{PET} \tag{7}$$

where P is total monthly precipitation (mm) and PET is monthly potential evapotranspiration (mm).

The aridity index (AI) is interpreted as follows

$AI < 0.05$	Hyper-arid	
$0.05 \le AI < 0.20$	Arid	
$0.21 \le AI < 0.50$	Semi-arid	
$0.51 \le AI < 0.65$	Sub-humid	
$0.65 \le AI$	Humid	

3. RESULTS AND DISCUSSION

3.1. Air temperature

In addition to precipitation amount, air temperature is the most important climatic element for agricultural production. During the

1961–1990 referent period in the Osijek area, the annual course of mean monthly air temperature indicates a continental climate with springs warmer than autumns by 0.2°C on average. The mean air temperature of the vegetation period is 17.6°C and is 6.8°C higher than the multi-year average. During the recent 28-year period, the annual course of monthly air temperature also indicates a continental climate, but with springs warmer than autumns by 0.5°C on average. Mean air temperatures in the recent period during all seasons, vegetation periods and annually were higher than in the referent period, with more pronounced changes in summer (JJA period – 1.4°C) and winter (DJF period – 1.1°C) (Tab. 1). The same results were obtained by the Croatian Ministry of Environmental Protection and Energy (2018), who recorded positive trend of air temperature for Republic of Croatia, with the biggest contribution of summer trends to the overall positive trend of air temperature. Determined increase in mean annual air temperature by 0.9°C in the recent period is almost in line with the prediction of future climate changes by the scenario RCP4.5 that predict an almost uniform increase of mean annual values of air temperatures by 1.0 to 1.2°C throughout Croatia for the period 2011–2040.

During the year, mean monthly air temperatures begin to rise from the coldest (January) until the warmest (July) month of the year; it then begins to decrease from mid-summer until January – the coldest month of the year (Fig. 1).

During the period 1961–1990, the mean annual air temperature was 10.8°C (Tab. 1). Mean air temperatures range is 19.3–23.8°C in July and -7.7–3.5°C in January. The temperature is more stable in the warmer part of the year (April–October) than in the colder part of the year (November–March), as indicated by the temperature variability expressed by standard deviation. The smallest standard deviation was identified for the June–August period (1.0–1.2°C); the highest standard deviation was identified for January and February (2.8–2.9°C) (Fig. 1).

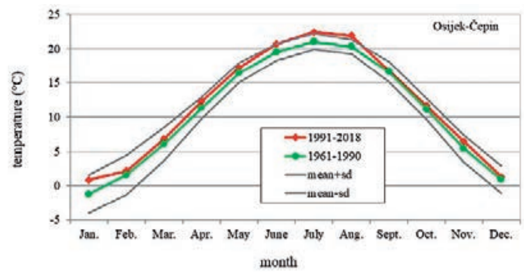

Figure 1. Mean monthly air temperature (mean, °C) for the Osijek-Čepin meteorological station during the periods 1991–2018 (red line) and 1961–1990 (green line) and the mean+sd and mean-sd intervals for the period 1961–1990 (grey lines).

Slika 1. Srednja mjesečna temperatura zraka na meteorološkoj postaji Osijek-Čepin tijekom razdoblja 1961. – 1990. (zelena linija) i 1991. – 2018. (crvena linija) te intervali srednjak + sd i srednjak - sd za razdoblje 1961. – 1990. (sive linije).

Table 1. Mean, maximum and minimum seasonal air temperatures (°C) and standard deviation for the seasons, vegetation periods and annually at the Osijek-Čepin meteorological station during the periods 1961–1990 and 1991–2018.

Tablica 1. Srednje, maksimalne i minimalne sezonske temperature zraka (°C) te standardna devijacija po godišnjim dobima, u vegetacijskom razdoblju i godišnje na meteorološkoj postaji Osijek-Čepin tijekom razdoblja 1961. – 1990. i 1991. – 2018.

	1961–1990						1991–2018					
	MAM	JJA	SON	DJF	VEG	ANN	MAM	JJA	SON	DJF	VEG	ANN
mean	11.3	20.3	11.1	0.4	17.6	10.8	12.1	21.7	11.6	1.5	18.6	11.7
sd	1.1	0.6	1.1	1.9	0.6	0.6	1.0	1.0	1.0	1.6	0.9	0.8
max	13.1	21.8	12.9	3.0	18.7	11.8	13.7	23.8	13.6	5.0	20.1	12.9
min	8.9	19.1	9.2	-4.3	16.1	9.7	10.4	20.1	9.6	-1.5	17.2	10.2

Abbreviations: MAM: March–May; JJA: June–August; SON: September–November; DJF: December–February; VEG: April–September; sd: standard deviation; max: maximum; min: minimum.

Skraćenice: MAM: ožujak – svibanj; JJA: lipanj – kolovoz; SON: rujan – studeni; DJF: prosinac – veljača; VEG: travanj – rujan; sd: standardna devijacija; max: maksimum; min: minimum.

During the recent period (1991–2018), the mean annual air temperature was 11.7°C, which is 0.9°C higher than the mean annual air temperature of the referent period (Tab. 1). The mean air temperatures range is 19.9–24.8°C in the warmest month and -5.1–6.8°C in the coldest month. In the spring and summer months, mean monthly temperatures were higher than the corresponding referent mean monthly temperatures, which caused above-average mean values for the vegetation period and the year (Fig. 1).

3.2. Precipitation

During the referent period in the studied area, mean annual precipitation amounted to 650 mm (Tab. 2); June was the month with the highest amount of precipitation (88 mm). More precipitation (57%) fell on average in the warmer part of the year than in the colder part (Fig. 2). This precipitation is very useful to plants during the growing season.

Mean annual precipitation in the recent period (1991–2018) is 707 mm, which is 57 mm higher than in the referent period. In the recent period, small changes (from 2% to 6%) were recorded in mean annual, spring, summer and winter precipitation regime, while an increase of 37% in the autumn regime was recorded as compared to the referent period. The increase in precipitation was also recorded by the Croatian Ministry of Environmental Protection and Energy (2018), which determined a predominantly insignificant but positive trend for the eastern lowland areas of Croatia (where Osijek is located) during the recent 50-year period from 1961–2010. The positive trend in annual precipitation in the eastern lowland area was primarily caused by a significant increase in autumn precipitation, as was also determined by the current study.

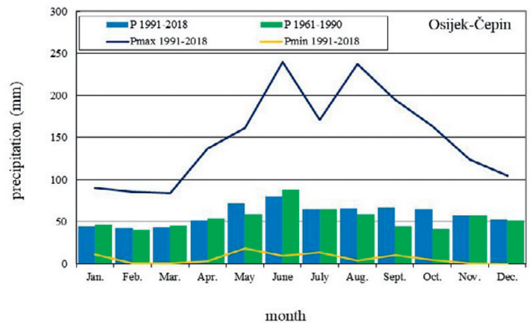

Figure 2. Mean (blue bars), maximum (blue line) and minimum (yellow line) monthly precipitation amounts for the Osijek–Čepin meteorological station during the 1991–2018 period and mean monthly precipitation amounts for the 1961–1990 period (green bars).

Slika 2. Srednja (plavi stupići), maksimalna (plava linija) i minimalna (žuta linija) mjesečna količina oborine za razdoblje 1991. – 2018. i srednja mjesečna količina oborine (zeleni stupići) za razdoblje 1961. – 1990. za meteorološku postaju Osijek-Čepin.

Table 2. Mean, maximum and minimum precipitation amounts (mm), standard deviation and coefficient of variation for the seasons, vegetation periods and annually for the Osijek-Čepin meteorological station during the periods 1961–1990 and 1991–2018.

Tablica 2. Srednje, maksimalne i minimalne količine oborine (mm) standardna devijacija i koeficijent varijacije po godišnjim dobima, u vegetacijskom razdoblju i godišnje, za meteorološku postaju Osijek-Čepin tijekom razdoblja 1961. – 1990. i 1991. – 2018.

	1961-1990						1991-2018					
	MAM	JJA	SON	DJF	VEG	ANN	MAM	JJA	SON	DJF	VEG	ANN
P	157	211	143	139	368	650	167	207	196	142	390	707
sd	52	65	49	55	72	103	55	91	70	60	149	161
c_v	0.33	0.31	0.34	0.39	0.20	0.16	0.33	0.44	0.36	0.43	0.38	0.23
P_{max}	285	459	246	319	613	885	282	519	318	295	699	1038
P_{min}	78	138	63	46	246	467	35	78	45	1	155	317

Abbreviations: MAM: March – May; JJA: June – August; SON: September – November; DJF: December – February; VEG: April – September; P: mean; sd: standard deviation; c_v: coefficient of variation; P_{max}: maximum; P_{min}: minimum.

Skraćenice: MAM: ožujak – svibanj; JJA: lipanj – kolovoz; SON: rujan – studeni; DJF: prosinac – veljača; VEG: travanj – rujan; P: srednjak; sd: standardna devijacija; c_v: koeficijent varijacije; P_{max}: maksimum; P_{min}: minimum

3.3. Hydrothermal climatic characteristics

The identification of hydrothermal climatic characteristics determined that all ten of the warmest years and vegetation periods throughout the entire 58-year studied period were recorded during the recent period, i.e. since 1992 (Tab. 3). Similar results were recorded worldwide, where nine out of the ten warmest years since the beginning of systematic meteorological measurements were recorded in the 21st century (Croatian Ministry of Environmental Protection and Energy, 2018). Furthermore, similar results were also recorded by Majstorović (2015) for the area of Bosnia and Herzegovina, by Bilandžija et al. (2019) for the Đurđevac area and by Bilandžija (2019) for the Zagreb area. The majority (eight out of ten) of the coldest years and vegetation periods in the entire 58-year studied period were recorded during the referent period (Tab. 3).

The analysis of the precipitation regime showed that there is no clear grouping of "dry" and "wet-rainy" years. In the entire 58-year study period, four out of the ten driest years and seven out of the ten driest vegetation periods were recorded in the recent period (Tab. 3). Seven out of the ten wettest/rainiest years and eight out of the ten wettest/rainiest vegetation periods were recorded in the recent period. The increase in the driest and wettest vegetation periods in the recent climate has had a negative impact on agricultural production, as too little or too much precipitation causes damage. Similar results showing no clear grouping of the driest or wettest years have also been determined by other authors for the Neretva and Trebišnjica River Basin, as well as for the Đurđevac and Zagreb areas (Bašić et al., 2016; Bilandžija et al., 2019; Bilandžija, 2019).

Table 3. Hydrothermal climatic factors for the Osijek-Čepin meteorological station during the 1961–2018 period.

Tablica 3. Obilježja hidrotermičkog režima za meteorološku postaju Osijek-Čepin tijekom razdoblja 1961. – 2018.

Highest temperatures (^{0}C)				Lowest temperatures (^{0}C)				Most precipitation (mm)				Least precipitation (mm)			
Calendar year		Vegetation period		Calendar year		Vegetation period		Calendar year		Vegetation period		Calendar year		Vegetation period	
1992	12.3	1994	19.2	1962	10.1	1965	17.0	1964	810.5	1964	461.7	1961	542.8	1979	266.9
1994	12.2	2000	19.6	1963	10.2	1970	17.1	1972	884.7	1972	612.7	1971	519.4	1986	246.4
2000	**12.9**	2003	19.5	1964	10.1	1974	17.0	1981	817.1	1995	489.6	1978	530.6	1988	282.0
2007	12.4	2007	19.1	1965	10.3	1976	16.9	1995	821.5	1996	518.6	1983	466.9	**2000**	**154.5**
2008	12.5	2009	19.6	1969	10.2	1977	16.8	1996	868.8	1999	504.3	1986	536.3	2003	226.5
2009	12.3	2011	19.4	1978	10.0	1978	16.3	1999	873.1	2001	651.0	1990	540.9	2007	229.9
2012	12.3	2012	20.0	**1980**	**9.7**	**1980**	**16.1**	2001	944.5	2004	473.4	**2000**	**317.0**	2009	205.3
2014	12.8	2015	19.5	1985	10.0	1984	16.7	2004	865.4	**2005**	**699.0**	2003	516.5	2011	244.9
2015	12.6	2017	19.1	1996	10.2	1991	17.2	2005	973.7	2010	676.6	2009	544.6	2017	174.3
2018	12.8	**2018**	**20.1**	2005	10.4	1997	17.2	**2010**	**1038.0**	2014	523.3	2011	422.2	2018	195.0

Years/vegetation periods in recent period | Years/vegetation periods in referent period

Table 4. Lang's and Gračanin's rain factor for the Osijek-Čepin meteorological station during the periods 1961–1990 and 1991–2018.

Tablica 4. Langov i Gračaninov kišni faktor za meteorološku postaju Osijek-Čepin tijekom razdoblja 1961. – 1990. i 1991. – 2018.

Period	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	year
1961–1990	-	25.8	7.4	4.7	3.6	4.5	3.1	2.9	2.7	3.7	10.5	57.2	60.4
	-	ph	h	sa	sa	sa	a	a	a	sa	h	ph	sh
1991–2018	53.5	19.7	6.4	4.2	4.1	3.9	2.9	3.0	4.0	5.5	8.8	40.4	60.3
	ph	ph	sh	sa	sa	sa	a	a	sa	sh	h	ph	sh

Abbreviations: ph: perhumid; h: humid; sh: semihumid; sa: semiarid; a: arid climate.

Skraćenice: ph: jako vlažna; h: vlažna; sh: poluvlažna; sa: polusuha; a: suha klima.

3.4. Rain factor

According to Lang's rain factor (Tab. 4), the Osijek area is characterized as a semihumid (sh) climate in both of the studied periods. According to Gračanin's monthly rain factor, nine months in the recent period have the same corresponding monthly values as in the referent period. The exceptions are March, which became drier and September and October, which became wetter in the recent period as compared to the referent period (Tab. 4).

3.5. Air temperature thresholds

The analysis of air temperature thresholds in Osijek showed that all researched vegetation periods with temperature thresholds of 5°C, 10°C, 15°C and 20°C began on average 8 days earlier and ended on average 5 days later in the recent period than in the referent period. Vučetić et al. (2018) and Vučetić and Vučetić (2018) also note that some phenological phases of olive and grapevine varieties in Croatia begin earlier than in the past. Vegetation periods with air temperature values above 5°C are 11 days longer, those above 10°C are 9 days longer, those above 15°C are 8 days longer and those above 20°C are 24 days longer in the recent period as compared to the referent period (Tab. 5). The obtained results are in accordance with projections for the agricultural sector considering the duration of vegetation periods, such that longer vegetation periods will allow the cultivation of some new varieties and hybrids, however this will make it impossible to cultivate some traditionally grown crops (Croatian Ministry of Environmental Protection and Energy, 2020).

3.6. Soil water balance

According to the soil water balance for the period from 1961–1990, annual actual evapotranspiration amounted to 552 mm (Tab. 6). Furthermore, water deficiency was determined for the period from July–October in the amount of 135 mm; water sufficiency was recorded for January–March in the amount of 106 mm (Fig. 3 left). During the recent period, the amount of actual evapotranspiration was 38 mm higher than in the referent period, amounting to 590 mm (Tab. 6). Water sufficiency occurs during the winter months and March in the amount of 116 mm, while water deficiency was determined for July–September in the amount of 72 mm in the recent period from 1991–2018 (Fig. 3 right). The 7% increase in actual evapotranspiration in the recent period is in accordance with future cli-

Table 5. Beginning, end and duration of vegetation periods for temperature thresholds of 5°C, 10°C, 15°C and 20°C for the Osijek-Čepin meteorological station during the periods 1961–1990 and 1991–2018.

Tablica 5. Početak, završetak i trajanje vegetacijskih razdoblja za temperaturne pragove od 5 °C, 10 °C, 15 °C i 20 °C za meteorološku postaju Osijek-Čepin tijekom razdoblja 1961. – 1990. i 1991. – 2018.

Cardinal temperature of 5°C			
Period	Beginning	End	Duration in days
1961–1990	10 March	18 November	254
1991–2018	5 March	24 November	265
Cardinal temperature of 10°C			
Period	Beginning	End	Duration in days
1961–1990	7 April	21 October	198
1991–2018	2 April	25 October	207
Cardinal temperature of 15°C			
Period	Beginning	End	Duration in days
1961–1990	7 May	24 September	141
1991–2018	1 May	26 September	149
Cardinal temperature of 20°C			
Period	Beginning	End	Duration in days
1961–1990	25 June	18 August	55
1991–02018	9 June	26 August	79

Table 6. Evapotranspiration for the Osijek-Čepin meteorological station during the periods 1961–1990 and 1991–2018.

Tablica 6. Evapotranspiracija za meteorološku postaju Osijek-Čepin tijekom razdoblja 1961. – 1990. i 1991. – 2018.

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Sum
Referent period 1961–1990													
PET	0.0	3.3	22.4	53.8	96.4	119.6	133.5	118.1	79.3	43.9	15.2	1.6	687.1
R	100.0	100.0	100.0	100.0	62.1	30.4	0.0	0.0	0.0	0.0	42.1	92.1	626.7
AET	0.0	3.3	22.4	53.8	96.4	119.6	95.2	58.5	44.8	41.3	15.2	1.6	552.1
D	0.0	0.0	0.0	0.0	0.0	0.0	38.3	59.6	34.5	2.6	0.0	0.0	135,0
S	46.9	36.9	22.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	106.2
Recent period 1991–2018													
PET	1.4	4.4	23.1	52.6	90.8	114.4	128.3	115.4	71.1	41.3	16.7	2.2	661.9
R	100.0	100.0	100.0	98.6	79.2	45.4	0.0	0.0	0.0	23.5	63.8	100.0	710.6
AET	1.4	4.4	23.1	52.6	90.8	114.4	110.2	65.9	67.1	41.3	16.7	2.2	590.3
D	0.0	0.0	0.0	0.0	0.0	0.0	18.1	49.5	4.0	0.0	0.0	0.0	72,0
S	43.2	38.1	20.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.3	116.4

Abbreviations: PET (mm) – potential evapotranspiration; R (mm) – soil water reserve up to 40 cm depth; AET (mm) – actual evapotranspiration; D (mm) – water deficit; S (mm) – water surplus.

Skraćenice: PET (mm) – potencijalna evapotranspiracija; R (mm) – količina vlage u tlu do 40 cm dubine; AET (mm) – stvarna evapotranspiracija; D (mm) – manjak vlage; S (mm) – višak vlage.

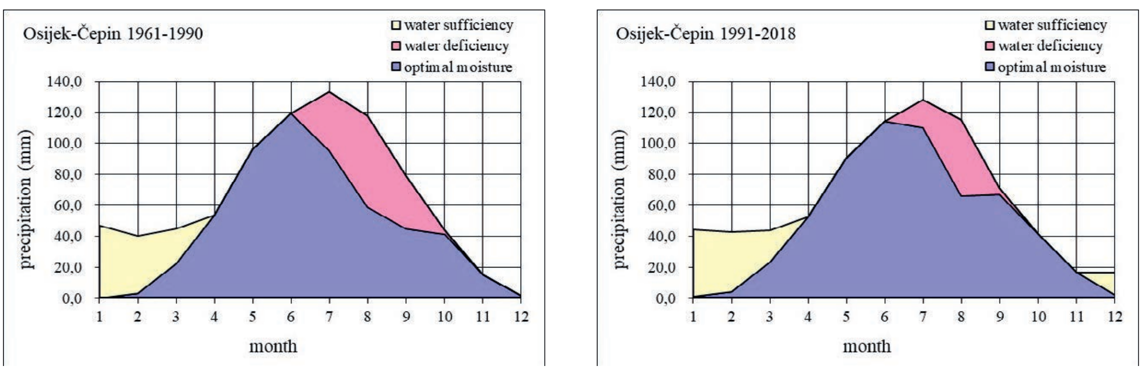

Figure 3. Soil water balance for the Osijek-Čepin meteorological station during the periods 1961–1990 and 1991–2018.

Slika 3. Vodna bilanca u tlu za meteorološku postaju Osijek-Čepin tijekom razdoblja 1961. – 1990. i 1991. – 2018.

Table 7. Aridity index for the Osijek-Čepin meteorological station during the periods 1961–1990 and 1991–2018.

Tablica 7. Indeks ariditeta za meteorološku postaju Osijek-Čepin tijekom razdoblja 1961. – 1990. i 1991. – 2018.

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Referent period 1961–1990												
AI	-	12.049	2.000	1.000	0.607	0.735	0.485	0.495	0.565	0.941	3.764	
	32.671	h	h	h	sh	h	sa	sa	sh	h	h	h
Recent period 1991–2018												
AI	32.880	9.594	1.898	0.973	0.787	0.705	0.505	0.571	0.944	1.570	3.412	23.859
	h	h	h	h	h	h	sh	sh	h	h	h	h

mate projections, which predict an increase in evapotranspiration from 5 to 10% in the period from 2011–2040 in most parts of Croatia (Croatian Ministry of Environmental Protection and Energy, 2020).

3.7. Aridity index

According to the aridity index (Tab. 7), the months with the lowest aridity index values were July and August, which were characterised by a semi-arid (sa) climate in the Osijek area in the referent period. Furthermore, May and September were characterised by a sub-humid climate (sh). The recent climate period saw a change in climate with respect to aridity index values; the driest months (July and August) in the referent period became sub-humid (sh) in the recent period, while May and September became humid (h).

4. CONCLUSION

According to the obtained results, it can be concluded that there was a change in climatic elements and agroclimatic indicators during the recent period 1991–2018 as compared to the referent period 1961–1990. The mean annual air temperature rose by 0.9°C in the recent period. The ten warmest years and vegetation periods in the entire 58-year period were recorded since 1992. Mean annual precipitation amount has increased by 57 mm in the recent period; no clear grouping of the driest/wettest years was determined. Both study periods were characterized by a semi-humid climate according to rain factor. Vegetation periods with air temperature values above 5°C, 10°C, 15°C and 20°C were longer, beginning on average 8 days earlier and ending on average 5 days later in the recent period. Soil water balance shows that actual evapotranspiration increased during the recent period. The aridity index indicates that July and August became more humid in the recent period. This is in accordance with a positive linear trends in precipitation amount in Osijek in July and August during the long-term period 1901–2010 (Ferina at al., 2021). However, it should be emphasized that convective precipitation (heavy rain) prevails in summer months. Due to non-uniform distribution of summer rain, such a storm event can be followed by prolonged dry period. Thus, the climate change is identified and adaptation and mitigation measures will have to be implemented in future agricultural production, such as the cultivation of drought-resistant varieties, irrigation, conservation tillage, interrow crops, etc. Furthermore, to more reliably assess the agroclimatic conditions of certain areas and the corresponding impact of climate change on agricultural production, other climatic elements and agroclimatic indicators must be included in research, such as wind, solar radiation, insolation duration, precipitation intensity, the number of consecutive dry or rainy days above the critical precipitation threshold, etc.

REFERENCES

Bašić, F., N. Herceg, D. Bilandžija and A. Šljivić, 2016: Specific Roles of Soil in Agroecosystems of Neretva and Trebišnjica River Basin. *9th Congress of the Soil Science Society of Bosnia and Herzegovina*, Works of the Faculty of Forestry University of Sarajevo, 71–91.

Bilandžija, D., 2019: Spatio-Temporal Climate and Agroclimate Diversities over the Zagreb City Area. *Geogr. Pannon.*, **23**(4), 385–397.

Bilandžija, D. i sur., 2019: Agroklimatski pokazatelji kao indikator klimatskih promjena na području Đurđevačkih pijesaka. *Zbornik radova sa znanstvenog skupa: Đurđevački pijesci – geneza, stanje i perspektive*, Hrvatska Akademija znanosti i umjetnosti, Zavod za znanstvenoistraživački i umjetnički rad Koprivničko-križevačke županije u Križevcima, Znanstveno vijeće za poljoprivredu i šumarstvo, Znanstveno vijeće za zaštitu prirode, Đurđevac, 29. – 30. lipanj 2017., Zagreb-Križevci, 127 – 148.

Butorac, A., 1976: Opća proizvodnja bilja. Praktikum, Sveučilište u Zagrebu, Agronomski fakultet, Zagreb, Hrvatska.

Ferina, J., V. Vučetić, T. Bašić and M. Aurić, 2021: Spatial distribution and long-term changes in water balance components in Croatia. *Theoretical and Applied climatology,* **144**, 1311–1333. https://dsi:org/10.1007/9000704-021-03593-1.

Jug, D. i sur., 2017: Konzervacijska obrada tla kao mjera ublažavanja klimatskih promjena. Sveučilište J.J. Štrosmajera u Osijeku, Poljoprivredni fakultet, Osijek, 176 str.

Majstorović, Ž., 2015: Promjena režima padavina u Bosni i Hercegovini i uticaj na različite oblasti života i ekonomiju u našoj državi. *Zbornik simpozija Akademije nauka i umjetnosti Bosne i Hercegovine - ANUBiH: Upravljanje rizicima od poplava i ublažavanje njihovih štetnih posljedica*, Sarajevo, 79 – 88.

Mesić, M., 2009: Agroekološko vrednovanje prostora s programima razvitka biljne i stočarske proizvodnje na području Hercegbosanske županije. Sveučilište u Zagrebu, Agronomski fakultet, Zagreb, Hrvatska, 382 str.

Ministarstvo zaštite okoliša i energetike (Croatian Ministry of Environmental Protection and Energy), 2018: Sedmo nacionalno i treće dvogodišnje Izvješće Republike Hrvatske prema Okvirnoj Konvenciji ujedinjenih naroda o promjeni klime (UNFCCC). Zagreb, Hrvatska, 300 str.

Ministarstvo zaštite okoliša i energetike (Croatian Ministry of Environmental Protection and Energy), 2020: Strategija prilagodbe klimatskim promjenama u Republici Hrvatskoj za razdoblje do 2040. godine s pogledom na 2070. godinu. Zagreb, Hrvatska. NN 46/2020.

OBZ 2020: Osiječko-baranjska županija http://www.obz-invest.hr/en/index.php?option=com_content&view=article&id=146&Itemid=74. access 23.9.2020.

Penzar, I. i B. Penzar, 2000: Agrometeorologija. Školska knjiga, Zagreb, Hrvatska, 222 str.

Perčec Tadić, M., M. Gajić-Čapka, K. Zaninović and K. Cindrić, 2013: Drought Vulnerability in Croatia. *Agriculture conspectus scientificus*, **79**(1), 31–38.

Smith, P. and J.E. Olesen, 2010: Synergies between mitigation of, and adaptation to, climate change in agriculture. *Journal of Agricultural Science*, **148**(5), 543–552.

Srnec, L., T. Stilinović, I. Güttler and Č. Branković, 2017: Temperature and precipitation change over the Mediterranean region. *Joint Congress of the 6th International Conference on Meteorology and Climatology of the Mediterranean (MetMed) & Challenges in Meteorology 5 (MI5)*, Zagreb, Hrvatska.

UNEP - United Nations Environment Programme, 1992: World Atlas of Desertification. Edward Arnold, London, 69 pp.

Vučetić, M. and V. Vučetić, 2018: Trends of the phenological phases and growing degree days for olive trees in Croatia. *Proceedings of Abstracts PHENOLOGY 2018 One planet, two hemispheres, many regions*. Melbourne, Australija, 44–44.

Vučetić, V. et al., 2018: Grapevine phenology and agroclimatic indices in Croatia under climate change. *Proceedings of Abstracts PHENOLOGY 2018 One planet, two hemispheres, many regions*. Melbourne, Australija, 44–44.

Zaninović, K. i sur., 2008: Klimatski atlas Hrvatske 1961. – 1990., 1971. – 2000. Državni hidrometeorološki zavod, Zagreb, 200 str. http://klima.hr/razno_e.php?id=news&param=atlas_e.

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