Changes and trends of climate elements and indices in the region of Mediterranean Croatia

Promjene i trendovi klimatskih elemenata i indeksa na području sredozemne Hrvatske

Damir UGARKOVIĆ[1*] and Nikolina KELAVA UGARKOVIĆ[2]

[1]Faculty of Forestry University in Zagreb, Department of Forest Ecology and Silviculture, Svetošimunska 25, Zagreb, Croatia, *correspondence: damir.ugarkovic@gs.htnet.hr

[2]Faculty of Agriculture University of Zagreb, Department of Animal Science and Technology, Svetošimunska 25, Zagreb, Croatia

Abstract

Climate is complex ecological factor described by different climate elements and phenomena that effect development of vegetation and its natural distribution. Climate elements the most important for vegetation are air temperatures, amount of precipitations, air humidity and wind. The aim of this research was to determine trends and changes of climate elements in the region of Mediterranean Croatia. Meteorological stations with the longest monitoring period in the region of the Mediterranean Croatia were chosen in order to determine trends of the climate elements. Decreasing or increasing trends of individual climate elements and indices were analysed using linear trend of regression analysis. Climate elements and indices of the referent line were compared with period between 1991 and 2010. At all meteorological stations was found negative trend of annual amount of precipitations and Lang´s rain factor. Exception was meteorological station Rijeka with increase of annual amount of precipitations and Lang´s rain factor. Trends of air temperatures at all meteorological stations were positive. Values of Lang´s rain factor in the researched region are decreasing resulting higher aridity of the region. Trends of potential evapotranspiration are significant and positive at all meteorological stations. Changes of air temperatures are more noticeable than those of precipitations, while changes of potential evapotranspiration are more noticeable than those of Lang´s rain factor. Forest vegetation and crop plants of Mediterranean Croatia are adapted to certain climate conditions predominating in this region. This conditions change through time effecting growth and development of all organisms.

Keywords: climate elements, climate indices, Mediterranean Croatia

Sažetak

Klima je kompleksan ekološki čimbenik koji opisujemo pomoću različitih klimatskih elemenata i pojava koji utječu na razvoj vegetacije i njeno prirodno rasprostranjene. Za vegetaciju su najvažnije temperature zraka, količine oborina, vlaga zraka i vjetar. Cilj istraživanja je bio utvrditi trendove i promjene klimatskih elemenata i indeksa na području sredozemne Hrvatske. Za istraživanje trendova klimatskih elemenata na području sredozemne Hrvatske odabrane su meteorološke postaje sa najduljim razdobljem motrenja. Trendovi smanjenja ili povećanja pojedinih klimatskih elemenata i indeksa analizirani su pomoću linearnog trenda regresijskom analizom. Uspoređene su vrijednosti klimatskih elementa i indeksa referentnog niza sa razdobljem 1991.-2010. Na svim meteorološkim postajama je utvrđen negativan trend vrijednosti godišnjih količina oborina i Langovog kišnog faktora, osim na meteorološkoj postaji Rijeka, gdje je utvrđeno povećanje godišnjih količina oborina i vrijednosti Langovog kišnog faktora. Trendovi temperatura zraka na svim meteorološkim postajama su pozitivni. Vrijednosti Langovog kišnog faktora se na području istraživanja smanjuju, što ide u prilog povećanju aridnosti područja. Trendovi potencijalne evapotranspiracije su statistički značajni i pozitivi na svim istraživanim meteorološkim postajama. Promjene temperature zraka su jače izražene nego što je to slučaj sa oborinama dok su promjene potencijalne evapotranspiracije jače izražene nego vrijednosti Langovog kišnog faktora. Šumska vegetacija i poljoprivredne kulture sredozemne Hrvatske su prilagođene na određene klimatske uvjete koji prevladavaju u tom području. Ti se uvjeti mijenjaju kroz vrijeme, a to se odražava na rast i razvoj svih organizama.

Ključne riječi: klimatski elementi, klimatski indeksi, sredozemna Hrvatska

Prošireni sažetak

Klima je kompleksan ekološki čimbenik koji opisujemo pomoću različitih klimatskih elemenata i pojava koji utječu na razvoj vegetacije i njeno prirodno rasprostranjene. Za vegetaciju su najvažnije temperature zraka, količine oborina, vlaga zraka i vjetar. Šumska vegetacija i poljoprivredne kulture sredozemne Hrvatske prilagođene su na određene klimatske uvjete koji prevladavaju u tom području. Međutim ti se klimatski uvjeti mijenjaju kroz vrijeme, a to se odražava na rast i razvoj svih vrsta organizama. Klima je u stalnoj mijeni. Posljednjih godina klimatske promjene su dokumentirane diljem svijeta.

Uz problem promjena klime od klimatskih elemenata najviše su vezane temperatura zraka i količina oborine. Cilj istraživanja je bio utvrditi trendove i promjene klimatskih elemenata i indeksa na području sredozemne Hrvatske. Za istraživanje trendova klimatskih elemenata na području sredozemne Hrvatske odabrane su meteorološke postaje sa najduljim razdobljem motrenja. Trendovi smanjenja ili povećanja pojedinih klimatskih elemenata i indeksa analizirani su pomoću linearnog trenda regresijskom analizom. Uspoređene su vrijednosti klimatskih elementa i indeksa referentnog niza sa razdobljem 1991.-2010.

Na području istraživanja vrijednosti količina oborine se smanjuju s izuzetkom meteorološke postaje Rijeka. Trendovi smanjenja količina oborina su statistički značajni na području meteoroloških postaja Crikvenice i Hvara. Vrijednosti srednjih godišnjih temperatura zraka se povećavaju, a statistički su značajni na svim meteorološkim postajama s izuzetkom meteorološke postaje Rijeka. Analogno promjenama količina oborine, ponašaju se i promjene Langovog kišnog faktora. Na svim istraživanim meteorološkim postajama prisutno je statistički značajno povećanje vrijednosti potencijalne evapotranspiracije (tablica 2).

Prema rezultatima u tablici 3. ne postoje statistički značajne razlike u vrijednostima količina oborina između referentnog niza sa razdobljem 1991. - 2010. Srednje godišnje temperature zraka razdoblja 1991. – 2010. su se povećale u odnosu na referentni niz. Ovo povećanje bilo je od + 0.5 °C do + 1.0 °C (tablica 4). Za istraživane meteorološke postaje vrijednosti Langovog kišnog faktora su se smanjile.

Ovo smanjenje je bilo statistički značajno jedino na području Rovinja (tablica 5). U razdoblju 1991. – 2010. bilo je prisutno statistički značajno povećanje vrijednosti potencijalne evapotranspiracije u odnosu na referentni niz. Ovo povećanje bilo je od 12 do 22 mm (tablica 6).

Klimatske promjene mogu pozitivno i negativno utjecati na šumske ekosustave i poljoprivrednu proizvodnju. To ovisi o vrsti i ekologiji šumskog drveća te o vrsti usjeva i regiji. Na svim meteorološkim postajama je utvrđen negativan trend vrijednosti godišnjih količina oborina i Langovog kišnog faktora, osim na meteorološkoj postaji Rijeka, gdje je utvrđeno povećanje godišnjih količina oborina i vrijednosti Langovog kišnog faktora. Trendovi temperatura zraka na svim meteorološkim postajama su pozitivni. Vrijednosti Langovog kišnog faktora se na području istraživanja smanjuju, što ide u prilog povećanju aridnosti područja. Trendovi potencijalne evapotranspiracije su statistički značajni i pozitivi na svim istraživanim meteorološkim postajama. Promjene temperature zraka su jače izražene nego što je to slučaj sa oborinama dok su promjene potencijalne evapotranspiracije jače izražene nego vrijednosti Langovog kišnog faktora.

Šumska vegetacija i poljoprivredne kulture sredozemne Hrvatske su prilagođene na određene klimatske uvjete koji prevladavaju u tom području. Ti se uvjeti mijenjaju kroz vrijeme, a to se odražava na rast i razvoj svih organizama.

Introduction

Climate is one of the most important limiting factors in forest and agriculture production: risk of frost during vegetation period and risk of draught are the main problems in forest and agriculture production (Moonen, at al., 2002). Climate is complex indirect ecological factor. Climate is described by different climate elements, phenomena and indices that effect vegetation development and its natural distribution. The most important ecological factors effecting development, composition and distribution of certain vegetation forms are climate and soil. Plant world depends on weather-climate conditions. From climate elements the most important are air temperatures, amount of precipitations, air humidity and wind.

Forest vegetation and crop plants of Mediterranean Croatia are adapted to certain climate conditions that predominate in this region. However, these climate conditions are changing through time effecting growth and development of all species of organisms. Climate is in constant change. During last years, climate changes are documented all around the world. Hasselman (1997) found that during last decade, average air temperature has increased for 0.5 ºC. Weber, et al. (1997) reported changes in temperature regime during 20th century for mount region of the Middle Europe. Decrease of amount of precipitation was reported in Russia Federation (Gruza, et al., 1999), Turkey (Türkes, 1998), Africa (Mason, 1996) and China (Zhai, et al., 1999). At 19 meteorological stations in north and middle Europe, Heino, et al. (1999) did not found changes in precipitation extremes. Minimal temperatures have increased everywhere, and maximal and average temperatures have increased in north and middle Europe, all over Russia Federation, Canada (Bootsma, 1994). These results confirm claims of Smit, et al. (1988) that average altitude regions like Middle West of USA, south Europe and Asia become warmer and drier, while lower altitude regions are becoming warmer and moister.

The longer the period is, the changes are larger, while during shorter period one gets the impression of stability of average climate elements. In climatology there are several terms describing climate instability. They describe changes from the smallest to the largest one. Climate change is the most general term including all possible types of climate instability regardless to their static nature or physical conditions (Šegota and Filipčić, 1996). In order to have simpler overview in this study the climate instability will be considered under the most general term *climate change*. Climate elements affected the most by climate change are air temperatures and amount of precipitations. To calculate climate indices are used most often two climate elements. They are air temperatures and amount of precipitations. Therefore, changes of air temperatures and amount of precipitations are influenced by changes of majority of climate indices.

Forest ecosystems and crop plants are influenced by numerous local meteorological and climatological conditions. Numerous ecological processes (photosynthesis, evapotranspiration, respiration, decomposition of substances, etc.) are closely correlated to meteorological conditions. Meteorological stress factors (like draught, high and low temperatures, coldness etc.) are considered to be possible causes of damaging forest tree and crop plants. To study these processes and detect possible causes, exact data about climate are necessary (Xia, et al., 2001). For this reason it is important to understand climate and climate conditions.

Ecological problem of Mediterranean karst vegetation is water deficiency during summer months. Summer period without precipitations or with very little rain is accompanied with high temperatures of air and soil, frequent wind of lower intensity causing increased evapotranspiration and ecological draught (Prpić, 1986).

According to the Fifth National Communication of the Republic of Croatia to the United Nation Framework Convention on Climate Change (MHS, 2009) positive trend of air temperatures was reported in entire territory of Croatia. This positive trend was especially noticeable during last 50, and particularly during last 25 years. Trends of average annual air temperatures during 50 i.e. 25 years are significant at all meteorological stations. The highest contribution to the positive trend of air temperatures in the Mediterranean is given by summer trends (+0.13 ºC during 10 years in Crikvencia and +0.07 ºC during 10 years in Hvar). Trend of annual amount of precipitations shows decrease during 20th century in entire territory of Croatia being same to the draught periods present in the Mediterranean. Trend is more noticeable in the Mediterranean costal region than in Mediterranean inside (Crikvenica -1.8 % during 10 years and Hvar -1.2 % during 10 year).

Giorgi (2002) found negative trend of winter precipitations in the large region of the Mediterranean during 20th century. However, significant decrease was characteristic in west, middle and east parts of Mediterranean. Brunetti, et al. (2001 ab) found negative trend for number of wet days and annual precipitations in Italy.

Giorgi (2002) analysed variability of the air temperature and trends in the large area of Mediterranean during 20th century. He found significant trend of warming of 0.75 ºC per country, mainly due to warming in early and late decades of the 20th century. Somewhat higher variability was found during summer and winter. Using same data, Jacobeit, et al. (2003) reported extreme summer warming from 1969 to 1998. Clear east-west differentiation in Mediterranean trends of the summer air temperature can be noticed. Cooling, although not significant, was found for the Balkan region and parts of the eastern bay. In the other regions significant trend of warming of 3 ºC / 50 years was found.

The aims of this study were to analyse trends of the climate elements and indices and compare climate elements and indices of the referent line (1961 – 1990) with period between 1991 and 2010.

Materials and methods

Research of trends of climate element and indices in the region of the Mediterranean Croatia was done at the meteorological stations with the longest monitoring period (figure 1). On some stations monitoring started during 19th century (table 1).

Figure 1. Locations of the researched meteorological stations

Slika 1. položaj istraživanih meteoroloških postaja

Table 1. Meteorological stations in the researched region, monitoring period and analysed climate element and trends

Tablica 1. Meteorološke postaje na području istraživanja, razdoblje motrenja te klimatski elementi I indeksi

Meteorological station	Observation period	Climate elements/indexes
Rovinj	1949 – 2010	
Rijeka	1948 – 2010	*Precipitation amount (mm)*
Crikvenica	1892 – 2010	*Average annual air temperature (°C)*
Sinj	1950 – 2010	*Lang´s rain factor*
Hvar	1858 – 2010	*Potential evaporation (mm)*
Lastovo	1948 - 2010	

Analysed climate elements were average annual air temperatures (ºC) and annual amount of precipitations (mm). Analysed climate indices were Lang´s rain factor and potential evapotranspiration (mm). Lang´s rain factor was calculated as ration between annual amount of precipitations and average annual air temperatures. Potential evapotranspiration (PET) in mm was calculated according to Blaney and Criddlea method (Tomić, 1988).

In order to determine differences caused by temperature and precipitation changes, trends of the end of the 19th, during the 20th and at beginning of the 21st century (till 2012) were analysed. Decrease or increase of the climate elements and indices was analysed using linear trend of regression analysis. Student *t*-test of independent samples was used to compare average climate elements and indices of referent or control line (1961-1990) with period between 1991 and 2010. According to the conclusions of the 13th meeting of the Commission for climatology of World Meteorological Organisation, referent or normal line between 1961 and 1990 is used for general comparisons, while next normal line is between 1991 and 2020 meaning till 2021 (Šegota and Filipčić 1996).

All data were analysed using KlimaSoft 2.0 and Statistica 7.1 programmes.

Results of the research

In Table 2 are shown trends of climate elements and indices, and trends significance. In the researched region amount of precipitations is decreasing with exception of Rijeka meteorological station with increase of amount of precipitations. Decreasing trends of amount of precipitation were significant at the area of Crikvenica and Hvar meteorological stations. Average annual air temperatures are increasing, and are significant at all meteorological stations with exception of meteorological station Rijeka. Lang´s rain factor changes analogous to changes of amount of precipitations. At all researched meteorological stations, significant increase of potential evapotranspiration was found (Table 2).

Table 2. Yearly trends of climate elements and indices, and trends significance

Tablica 2. Godišnji trendovi klimatskih elemenata I indeksa te njihova signifikantnost

Meteorological station	Precipitations (mm)		Air temperatures (°C)		Lang´s factor		PET (mm)	
	slope	p-level	slope	p-level	slope	p-level	slope	p-level
Rovinj	- 1.64	ns	+ 0.01	*	- 0.17	ns	+ 0.28	*
Rijeka	+ 1.31	ns	+ 0.01	ns	+ 0.04	ns	+ 0.22	*
Crikvenica	- 1.63	*	+ 0.01	**	- 0.16	*	+ 0.17	**
Sinj	- 1.45	ns	+ 0.01	*	- 0.18	ns	+ 0.25	*
Hvar	- 0.58	*	+ 0.01	**	- 0.04	*	+ 0.10	**
Lastovo	- 0.66	ns	+ 0.01	**	- 0.07	ns	+ 0.34	**

Observation period mentioned in Table 1, PET= potential evapotranspiration; ns=not significant; *p<0.05; **p<0.01

Table 3. Average amount of precipitations (mm) of referent line compared with period 1991-2010

Tablica 3. Usporedba srednjih vrijednosti količine oborine (mm) referentnog niza sa razdobljem 1991-2010

Meteorological station	Referent line 1961-1990 (mm)	Period 1991-2010 (mm)	Significance level
Rovinj	870 ± 147.80	798 ± 149.57	ns
Rijeka	1561 ± 228.88	1561 ± 263.09	ns
Crikvenica	1244 ± 243.63	1213 ± 181.58	ns
Sinj	1206 ± 202.25	1149 ± 163.53	ns
Hvar	730 ± 152.19	735 ± 175.55	ns
Lastovo	691 ± 162.88	634 ± 168.23	ns

mean±sd; ns= not significant

According to the results of the Student´s *t*-test of independent samples (Table 3), there is no significant difference in amount of precipitations between referent line with period between 1991 and 2010. The highest decrease was in the area of Rovinj (-72 mm), and the highest increase in the area of Hvar (+5 mm).

Table 4. Average annual air temperatures (ºC) of the referent line compared with period 1991-2010

Tablica 4. Usporeda srednjih vrijednosti godišnjih temperatura zraka (°C) referentnog niza sa razdobljem 1991-2010

Meteorological station	Referent line 1961-1990 (°C)	Period 1991-2010 (^{o}C)	Significance level
Rovinj	13.1 ± 0.44	14.1 ± 0.50	**
Rijeka	13.6 ± 0.41	14.4 ± 0.62	**
Crikvenica	14.1 ± 0.41	15.0 ± 0.80	**
Sinj	12.5 ± 0.37	13.0 ± 0.48	**
Hvar	16.3 ± 0.34	16.8 ± 0.50	**
Lastovo	15.4 ± 0.33	16.0 ± 0.47	**

mean±sd; **p<0.01

Average annual air temperatures in the period between 1991 and 2010 were increasing compared to referent line. Increase was from +0.5 ºC to +1.0 ºC (Table 4).

Table 5. Average Lang´s rain factors of referent line compared with period 1991-2010

Tablica 5. Usporedba srednjih vrijednosti Langovog kišnog faktora referentnog niza sa razdobljem 1991-2010

Meteorological station	Referent line 1961-1990	Period 1991-2010	Significance level
Rovinj	66 ± 11.73	57 ± 11.16	*
Rijeka	115 ± 18.44	109 ± 20.74	ns
Crikvenica	88 ± 18.09	82 ± 13.91	ns
Sinj	97 ± 17.88	88 ± 14.48	ns
Hvar	45 ± 9.83	44 ± 11.20	ns
Lastovo	45 ± 10.81	40 ± 10.74	ns

mean±sd; ns= not significant; *p<0.05

Meteorological stations included in monitoring and research showed decrease of Lang´s rain factor. Decrease was significantly ($p<0.05$) only in the area of Rovinj (Table 5).

Table 6. Average potential evapotranspiration (mm) of referent line compared with period 1991-2010

Tablica 6. Usporedba srednjih vrijednosti potencijalne evapotranspiracije (mm) referentnog niza sa razdobljem 1991-2010

Meteorological station	Referent line 1961-1990 (mm)	Period 1991-2010 (mm)	Significance level
Rovinj	733 ± 9.95	755 ± 11.57	**
Rijeka	744 ± 9.86	764 ± 14.83	**
Crikvenica	754 ± 9.42	775 ± 18.95	**
Sinj	719 ± 8.85	733 ± 11.39	**
Hvar	802 ± 8.10	814 ± 11.75	**
Lastovo	781 ± 8.08	797 ± 11.55	**

mean±sd; **p<0.01

In the period between1991 and 2010 was found significant ($p<0.01$) increase of potential evapotranspiration compared to referent line. Increase was from +12 mm in the Hvar area to +22 mm in the Rovinj area (Table 6).

Discussion

Beside air temperature, depending on cloudiness and air insolation, precipitations have the highest effect on vegetation development being the major source of moisture in soil. Deficiency of precipitations with high air temperatures, weakness resistant force of plants due to lose of large amount of water by increased evapotranspiration. According to Vajda (1965), due to precipitation deficiency, soil becomes drier, so that tree cannot compensate transpirated water from soil. Thus, longer draught periods cause soil drying and deterioration of physiological processes in trees and plants. In the region of Mediterranean Croatia results of this study showed decrease of precipitations, with exception of meteorological station Rijeka. Small changes in amount of precipitations indicate relatively high increase of precipitations extremes (Waggoner, 1989; Groisman, et al., 1999). Same effect was found in case of temperature changes (Folland, et al., 1999).

According to Sardans and Penuelas (2004) in the near future longer and often draught periods in the Mediterranean can be expected. For the Mediterranean region decrease of amount of precipitations as result of climate changes is expected till the end of 21st century (Limousin, et al., 2008). This will effect on negative water balance in soil during summer months. Results of the present study showed that changes of air temperature in the Mediterranean Croatia have significantly effected on changes of potential evapotranspiration. Same results were reported by Westman and Malanson (1992) researching mediterranean type of vegetation in California that in majority of ecological factors is comparable with mediterranean vegetation of costal Croatia. According to Oršanić, et al. (2011) soil moisture is significantly effected by air temperatures, dew point and amount of precipitations. Regional climate model used as scenario for climate changes in Croatia was developed by Dickinson, et al. (1989) and Giorgi (1990). According to regional climate model for Croatia decrease of total precipitations in three seasons (spring, summer and autumn) is predicted, especially in costal, south and mount Croatia (MHS, 2009). Same climate model predicts significant decrease of total precipitations only in south areas of east Adria region. Results of these climate scenarios of future climate correspond to this study. Decreasing trends of amount of precipitations were negative at almost all meteorological stations, and significant for area of Crikvenica and Hvar.

Present study showed significant increase of air temperatures and potential evapotranspiration. Moderate increase of global temperatures will result changes in frequencies (occurrence) of extreme weather events like draught, sudden precipitations and storms (Balling and Idso, 1990).

Climate changes will have direct or indirect effect on vegetation. Indirect effect is manifested through climate change and not only of temperature but many other climate parameters. Air temperature is crucial climate factor. Found differences between air temperatures of analysed periods are important for determining how these differences will effect on climate change in researched region.

Giannakopoulos, et al. (2005) researched effect of climate change in the Mediterranean as a result of global temperature increase for 2 ºC. Results of this research refer to period 2031-2060. Results of the research showed that global increase of temperature for 2ºC will probably result in warming from 1 ºC to 3 ºC in Mediterranean region. According to results presented in Table 4, air temperature for Croatian Mediterranean region for period 1991-2010 compared to referent line have increased from 0.5 ºC to 1.0 ºC with further increasing tendency.

In scenario of climate changes according to regional climate model in Croatia, average values of 30 years long period of the future climate (2041-2070) were compared with average values of 30 years long period of referent climate line (1961-1991). According to this scenario, climate changes in all seasons will significantly increase air temperatures. According to the results of the present study, changes of the average annual air temperatures for analysed meteorological stations during period between 1991 and 2010 have increased significantly compared to referent line (Table 4). Amount of precipitations in Croatia according to regional climate model will decrease during three season (spring, summer and autumn), especially in costal, south and mount Croatia. Changes of total amount of precipitations, especially during winter and spring, is concentrated in relatively narrow costal region of Croatia, while in the larger part of Mediterranean Croatia there are no changes of amount of precipitations or they are small. According to the results presented in Table 3 changes of precipitations in period between 1991 and 2010 were not significant comparing to referent line.

Natural adaptation of vegetation to climate changes happens in only small percent of effected vegetation. Vegetation model made by IMAGE2 showed that effective adaptation is possible only with very slow climate change, less than 0.1 ºC/10 years and absolute climate change less than 1ºC totally (Leemans, 1999). Research of paleo and recent climate in Croatia showed that secular or perennial climate changes had no significant effect, neither by warming nor by cooling, on composition of climatozonal vegetation (Trinajstić 1998). These changes have only influenced moving of vegetation zones in direction from lower altitudes towards (warming) and vice versa (cooling). Based on these knowing it can be expected that future climate changes or changes resulted from direct or indirect human effect will cause shifting climatozonal vegetation forms in direction that climate is changing (Matić, et al., 1998, Trinajstić, 1998).

Determined and according to certain scenarios assumed climate changes in Croatia can lead to changes in spatial distribution of forest vegetation, change of composition, structure and productivity of forest ecosystems, change of ecological stability, forest health status, and changes in yield, health status and composition of crop plants.

Climate changes can have positive or negative effect on forest ecosystems depending on ecological valence and ecological niche of forest species (Anić, et al., 2009). Climate changes, characterised by average increase of air temperatures and decrease of precipitations, effect on decline and deterioration, especially of main tree species with narrow ecological valence (Ugarković, et al., 2010). Result of these changes is appearance and increasing share of forest tree species with wide ecological valence that had not dominant role neither in proportion nor in structure of forest stands. This causes to certain extent decrease of forest economical value, but their non-wood forest functions or chances for survival are not significantly decreased. Effect of two the most important climate elements (air temperature and precipitations) can be crucial factor for tree decline. Beside sudden decrease of amount of precipitation causing physiological weakening of trees, simultaneously increase of air temperatures occurs having favourable effect on development and spreading of harmful insects (Kirigin, 1975). Oszlányi (1997) as stress factors resulting damaging of forest ecosystems, destruction of tree assimilation system and later decline of entire ecosystem, states among other and draught, climate change, sudden and unexpected temperature changes. High annual air temperatures significantly effect the occurrence of fires. It is expected that forest fires will stimulate spreading of invasive species found to stimulate more often and more intensively forest fires (Vučetić, 2000).

Agriculture production is highly effected by climate and changes of greenhouse gas concentrations, changes of radiation and temperature can have high impact on potential and real yield. Beside in colder regions where temperature is momentarily below optimal level, growing air temperatures can have negative effect on crops. Increase of CO_2 concentration in atmosphere can increase production of different crops (Franzaring, et al., 2008). Importance of climate changes on agriculture depends greatly on crop species (Moonen, et al., 2002). Draught and increased air temperatures are two main problems considering weather conditions and agriculture production in Croatia. Period between 1991 and 2000 was the warmest decade in 20th century in Croatia. Due to high temperatures and risks from summer draught, agriculture was especially vulnerable in middle part of Adriatic coast and islands (MENPPC, 2006).

Draught periods in Croatia are more frequent. After 1981 are 40 % more frequent than in period between 1970 and 1981 (Mađar, et al., 1997). Effect of climate changes depends on species and region: autumn and winter crops can benefit from climate changes. Spring and summer crops can also benefit from climate changes, but through time yield decreases, first in the south, and later in the north. In order to ensure stabile yield, in south Europe irrigation is necessary. In north Europe irrigation is necessary during summer. Adaptation like changes in farm planning and development of new breeding strategies should consider also regional differences (Supit, et al., 2012). Climate changes will effect and livestock production effecting pasture yield and water accessibility for livestock keeping.

Some of the ways of adaptation to climate changes in agriculture production are introducing of varieties resistant to the draught, investment in irrigation systems and crop insurance.

Climate changes are not just scientific hypothesis anymore. They are becoming predominating paradigm of whole world (Zemankovics, et al., 2012).

Conclusions

Change of climate elements and indices in the region of Mediterranean Croatia was found to have negative trend of annual amount of precipitations and Lang´s rain factor at all meteorological stations, except at meteorological station Rijeka. Trends were significant for meteorological station Crikvenica and Hvar. Trends of air temperatures and potential evapotranspiration were positive and significant. At meteorological station Rijeka trend of air temperatures was not significant. Changes of air temperatures were more expressed than in the case of precipitations. Changes of potential evapotranspiration were more expressed than values of Lang´s rain factor. Lang´s rain factor is decreasing resulting increase of aridity in researched region. Increase of air temperature reflects in general significant increase of potential evapotranspiration.

References

Anić, I., Vukelić, J., Mikac, S., Bakšić, D., Ugarković, D., (2009) Utjecaj globalnih klimatskih promjena na ekološku nišu obične jele (*Abies alba* Mill.) u Hrvatskoj. Šumarski list, 3−4, 135−144.

Balling, Jr., R.C., Idso, S.B., (1990) Effects of greenhouse warming on maximum summer temperatures. Agricultural and Forest Meteorology, 53, 143−147.

Bootsma, A., (1994) Long-term (100 years) climate trends for agriculture at selected locations in Canada. Climatic Change, 26, 65−88.

Brunetti, M., Colacino, M., Maugeri, M., Nanni, T., (2001a) Trends in the daily intensity of precipitation in Italy from 1951-1996. International Journal of Climatology, 21, 299−316.

Brunetti, M., Maugeri, M., Nanni, T., (2001b) Changes in total precipitation, rainy days and extreme events in north-eastern Italy. International Journal of Climatology, 21, 861−871.

Dickinson, R.E., Errico, R.M., Giorgi, F., Bates, G.T., (1989) A regional climate model for the western United States. Climatic Change, 15, 383−422.

Folland, C.K., Miller, C., Bader, D., Crowe, M., Jones, P., Plummer, N., Richman, M., Parker, D.E., Rogers, J., Scholefield, P., (1999) In: Proceedings of the Workshop on the indices and indicators for climate extremes, Asheville, NC, USA, 3–6 June 1997, Breakout Group C. Temperature indices. Climatic Change, 43, 31−43.

Franzaring, J., Högy, P., Fangmeier, A., (2008) Effects of free-air CO_2 enrichment on the growth of summer oilseed rape (Brassica napus cv. Campino). Agriculture, Ecosystem and Environment, 128, 127−134.

Giannakopoulos C., Bindi, M., Moriondo, M., LeSager, P., Tin, T., (2005) Climate change impacts in the Mediterranean resulting from a 2°C global temperature rise. WWF, Gland, Switzerland, p. 54.

Giorgi, F., (1990) Simulation of regional climate using a limited area model nested in a general circulation model. Journal of Climate, 3, 941−963.

Giorgi F., (2002) Variability and trends of sub-continental scale surface climate in the twentieth century. Part I: Observations. Climate Dynamics, DOI 10.1007/s00382-001-0204-x.

Groisman, P.Y., Karl, T.R., Easterling, D.R., Knight, R.W., Jamason, P.F., Hennessy, K.J., Suppiah, R., Page, C.M., Wibig, J., Fortuniak, K., Razuvaev, V.N., Douglas, A., Førland, E., Zhai, P., (1999) Changes in the probability of heavy precipitation: important indicators of climatic change. Climatic Change, 42, 243−283.

Gruza, G., Rankova, E., Razuvaev, V., Bulygina, O., (1999) Indicators of climate change for the Russian Federation. Climatic Change, 42, 219−242.

Hasselmann, K., (1997) Climate – change research after Kyoto. Nature, 390, 225−226.

Heino, R., Brázdil, R., Førland, E., Tuomenvirta, H., Alexandersson, H., Beniston, M., Pfister, C., Rebetez, M., Rosenhagen, G., Rösner, S., Wibig, J., (1999) Progress in the study of climatic extremes in northern and central Europe. Climatic Change, 42, 151−181.

Jacobeit, J., Wanner, H., Luterbacher, J., Beck, C., Philipp, A., Sturm, K., (2003) Atmospheric circulation variability in the North-Atlantic-European area since the midseventeenth century. Climate Dynamics, 20, 341−352.

Kirigin, B., (1975) Kolebanja klimatskih elemenata i sušenje jele na području SR Hrvatske. Radovi, 23, 16−27.

Leemans, R., (1999) Applying global change scenarios to assess changes in biodiversity. Research for man and environment report, 481508 012, 2−65.

Limousin, J.M., Rambal, S., Ourcival, J-M., Joffre, R., (2008) Modeling rainfall interception in a mediterranean Quercus ilex ecosystem: Lesson from a throughfall exclusion experiment. Journal of Hydrology, 357 (1-2), 57−66.

Mađar, S., Marušić, J., Šoštarić, J, Tomić, F., (1997) Some Climatic Changes and its Impact on Agriculture in East Croatia. International Conference on Sustainable Agriculture for Food, Energy and Industry, Braunschweig, Germany.

Mason, S.J., (1996) Climatic change over the Lowveld of South Africa. Climatic Change, 32, 35−54.

Matić, S., Oršanić, M., Anić, I., (1998) Utjecaj klimatskih promjena na strukturu i razvoj šumskih ekosustava. U: M. Maceljski (ur.), Prilagodba poljoprivrede i šumarstva klimi i njenim promjenama, Hrvatska akademija znanosti i umjetnosti, Zagreb, p. 239−250.

Meteorological and Hydrological Service (MHS), (2009) Peto nacionalno izvješće Republike Hrvatske prema Okvirnoj konvenciji Ujedinjenih naroda o promjeni klime (UNFCCC). Državni hidrometeorološki zavod Republike Hrvatske, Zagreb.

Ministry of Environmental and Nature Protection, Physical Planning and Construction (MENPPPC), (2006) Drugo, treće i četvrto nacionalno izvješće Republike Hrvatske prema okvirnoj konvenciji Ujedinjenih naroda o promjeni klime (UNFCCC), Zagreb, p. 96.

Moonen, A.C., Ercoli, L., Mariotti, M., Masoni, A., (2002) Climate change in Italy indicated by agrometeorological indices over 122 years. Agricultural and Forest Meteorology, 111, 13-27.

Oszlanyi, J., (1997) Forest health and environmental pollution in Slovakia. Environmental Pollution, 98(3), 389−392.

Oršanić, M., Drvodelić, D., Ugarković, D., (2011) Ekološko-biološke značajke hrasta crnike (*Quercus ilex* L.) na otoku Rabu. Croatian Journal of Forest Engineering, 32 (1), 31−42.

Prpić, B., (1986) Odnos hrasta crnike i nekih njegovih pratilica prema vodi i svjetlu. Glasnik za šumske pokuse, posebno izdanje, 2, 69−77.

Sardans, J., Penuelas, J., (2004) Drought decreases soil enzyme activity in a Mediterranean Quercus ilex L. Forest. Soil Biology and Biochemistry, 37, 455−461.

Smith, B., Ludlow, L., Brklacich, M., (1988) Implications of a global climatic warming for a agriculture: a review and appraisal. Journal of Environmental Quality, 17, 519−527.

Supit, I., Diepen van C.A., Wit van A.J.W., Wolf, J., Kabat, P., Baruth, B., Ludwig, F., (2012) Assessing climate change effects on European crop yields using the Crop Growth Monitoring system and weather generator. Agricultural and Forest Meteorology, 164, 96−111.

Šegota, T., Filipčić, A., (1996) Klimatologija za geografe. Školska knjiga Zagreb, p. 471.

Trinajstić, I., (1998) Utjecaj općih klimatskih promjena na prostorni raspored klimazonalnih oblika šumske vegetacije u Hrvatskoj. U: M. Maceljski (ur.), Prilagodba poljoprivrede i šumarstva klimi i njenim promjenama, Hrvatska akademija znanosti i umjetnosti, Zagreb, 259−268.

Tomić, F., (1988) Navodnjavanje. Savez poljoprivrednih inženjera i tehničara Hrvatske, Fakultet Poljoprivrednih Znanosti, Sveučilišta u Zagrebu, Zagreb, p. 154.

Türkeş, M., (1998) Influence of geopotential heights, cyclone frequency and southern oscillation on rainfall variations in Turkey. International Journal of Climatology, 18, 649−680.

Ugarković, D., Tikvić, I., Seletković, Z., Oršanić, M., Seletković, I., Potočić, N., (2010) Dieback of silver fir (Abies alba Mill.) in Gorski kotar in correlation with precipitation and temperature. Glasnik za šumske pokuse, 43, 19−36.

Vajda, Z., (1965) Uloga klime u sušenju šuma. Glasnik za šumske pokuse, 28, 1−12.

Vučetić, M., (2000) Vremenske prilike i šumski požari na hrvatskom priobalju tijekom 2000. Šumarski list, 7−8, 367−378.

Waggoner, P.E., (1989) Anticipating the frequency distribution of precipitation if climate change alters its mean. Agriculture and Forest Meteorology, 47, 321−337.

Weber, R. O., P. Talkner, I. Auer, R. Bohm, M. Gajić-Čapka, K. Zaninović, R. Brazdil, Faško, P., (1997) 20th century changes of temperature in the mountain regions of Central Europe. Climate Change, 36, 327−344.

Westman, W.E., Malanson, G.P., (1992) Effects of climate change on Mediterrean-type ecosystems in California and Baja California. In Peters, R.L., Lovejoy, T.E. eds: Global warming and biological diversity. Yale University Press, London, 258−276.

Xia, Y., P. Fabian, M. Winterhalter, Zhao, M., (2001) Forest climatology: estimation and use of daily climatological data for Bavaria, Germany. Agricultural and Forest Meteorology, 106, 87−103.

Zhai, P., Sun, A., Ren, F., Liu, X., Gao, B., Zhang, Q., (1999) Changes of climate extremes in China. Climatic Change, 42, 203−218.

Zemankovics, H.M., (2012) Mitigation and Adaptation to Climate Change in Hungary. Journal of Central European Agriculture, 13 (1), 58−72. DOI: 10.5513/JCEA01/13.1.1015.