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VARIATION OF CLIMATE IN THE REGION OF GORSKI KOTAR

KOLEBANJE KLIME NA PODRUČJU GORSKOG KOTARA

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Abstract

Climate is a complex ecological factor described by different climate elements and events that affect vegetation development and its natural distribution. For forest vegetation, the most important factors are air temperatures, amount of precipitations, air humidity, snow and wind. The aim of this research was to determine changes of climate elements in Gorski kotar region. The increasing or decreasing trends of individual climate elements were analysed using the linear trend method. Values of climate elements from the referent line were compared to the period from 1991 to 2007. For the research of climate element trends in the region of Gorski kotar the meteorological stations with the longest period of observations were chosen. Trends of air temperatures at all meteorological stations were positive. Negative trend of annual precipitation was recorded at all meteorological stations. Trend of days with snow and maximal snow height showed the smallest changes. Forest vegetation in the region of Gorski kotar is adapted to certain climate conditions that are predominant in this region. These conditions change through time, and this reflects on growth and development of all organisms. Assumed climate variations can lead to changes in spatial distribution of forest vegetation, change in composition, structure and productivity of forest ecosystems, change in ecological stability, health status of forest as well as non-wood forest functions.

Key words: climate variation, climate elements, Gorski kotar

Sažetak

Klima je kompleksan ekološki čimbenik koji opisujemo pomoću različitih klimatskih elemenata i pojava koji utječu na razvoj vegetacije i njeno prirodno rasprostiranje. Za šumsku vegetaciju najvažnije su temperature zraka, količine oborina, vlaga zraka, snijeg i vjetar. Cilj istraživanja je bio utvrditi promjene klimatskih elemenata na području Gorskog kotara. Trendovi smanjenja ili povećanja pojedinih klimatskih elemenata analizirani su pomoću linearnog trenda. Uspoređene su vrijednosti klimatskih elemenata referentnog niza sa razdobljem 1991-2007. Za istraživanje trendova klimatskih elemenata na području Gorskog kotara odabrane su meteorološke postaje sa najduljim razdobljem motrenja. Trendovi temperatura zraka na svim meteorološkim postajama su pozitivni Na svim meteorološkim postajama je utvrđen negativan trend vrijednosti godišnjih količina oborina. Trendovi broja dana sa snijegom i maksimalnih visina snijega su pokazali najmanje promjene. Šumska vegetacija na području Gorskog kotara je prilagođena 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. Pretpostavljena klimatska kolebanja mogu dovesti do promjena u prostornoj razdiobi šumske vegetacije, promjeni u sastavu, strukturi i proizvodnosti šumskih ekosustava, promjeni ekološke stabilnosti, zdravstvenog stanja šuma te općekorisnih funkcija šuma.

Ključne riječi: *kolebanje klime, klimatski elementi, Gorski kotar*

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INTRODUCTION
UVOD

The term climate change refers to the change that takes place in one direction while the climate variation refers to the rhythmic oscillation with larger or smaller deviations around a single mean value. In determining climate change, time becomes a key factor. Namely, a change in one direction during a certain period can be observed as part of climate variation if observed for a longer period of time. Climate change can be determined by using change of one climate element. Change of one element is associated with changes of other elements and appearances. Changes of air temperatures are associated with change of precipitation (Kirigin, 1975). According to Penzar et al. (1975) changes can occur at the same time for most of climate elements (air temperature, air humidity, air pressure, precipitation) or just some of them.

Significant climate changes that appear or will appear in the future as a result of increased CO_2 levels, will have serious biological and ecological consequences on forest ecosystems. The threat of negative climate events must not be underestimated, especially for species very sensitive to climate stressors like silver fir (Becker et al., 1989). Among stress factors effecting damage of forest ecosystems, destruction of tree assimilation system and subsequent dieback of entire ecosystem Oszlányi (1997), drought, climate change and sudden and unexpected temperature changes were reported.

Since the problem of tree dieback is mainly associated with air temperatures and amount of precipitations (Vajda, 1965, Prpić, 2001, Ugarković, 2011), the effect of these two climate elements can be the crucial factor causing tree dieback.

Climate changes are an important element in the process of tree dieback as they determine water balance, especially in situations of disturbed water supply and water transport in forest trees (Tesche, 1989; Saxe, 1993). According to Uscupulić et al. (2007) climate is the main factor causing tree dieback. Long perennial droughts have weakened the condition of plants and their system of defence against biotic harmful agents (mistletoe, *Armillaria* fungi and insects). At the same time, these conditions have caused Bark beetle reproduction over the critical threshold for species number.

Trends are the greatest in the northern boreal geographical latitudes, 1-2°C from 1970. The greatest warming happens during spring and winter, when the minimal daily air temperatures raise more rapidly than the maximal ones (Easterling et al., 1997; Boisvenue & Running, 2006; Bonsal et al., 2001).

Global precipitations trends are less consistent, but have been generally showing an increase of 3 to 5% in the last decade (Groisman et al., 2004; Boisvenue & Running, 2006). This increase of precipitation amount does not necessarily mean that greater water amount is available to the forest. High air temperatures cause greater water losses by evapotranspiration, and an increase of annual precipitations amount in the form of rain increases surface flow (water loss), greater than accumulation of water in form of snow cover (Knowles et al., 2006).

Height of snow cover decreased significantly during the last 30 to 50 years in the west part of the USA, as well as and in Canada, and spring flow appears one to four weeks earlier (Stewart et al., 2005). Also, there is evidence that moist climate becomes even moister, and dry climate even drier, resulting in greater extremes in hydrological cycle.

Hasselman (1997) found that during the last century mean air temperature increased by 0.5°C. Weber et al. (1997) reported changes of temperature regime during the 20^{th} century for the mountain region of Middle Europe. Research included differences between maximal and minimal air temperatures during a hundred year long linear trends. Mountain meteorological stations at higher altitudes showed small changes in differences between maximal and minimal air temperatures.

Seletković, Tikvić and Ivkov (1993) analysed meteorological data over the last hundred years from the meteorological station Zagreb-Grič and found changes in temperature and precipitation regime in Croatia. Matić et al. (1998) defined climate changes that caused dieback of certain tree species, especially of silver fir. At the same time, stands with different ratio of tree species in the mixture ratio were formed, somewhere with other tree species.

In order to understand importance and role of climate changes on growth and increment of forest trees, Hasenauer et al. (1999) used ecosystem model "Forest-BGC" to predict net primer production of forest trees. Authors researched growth and increment of forest trees in regard to climate change in Austria for period from 1961 to 1990 and found no changes in precipitation amount i.e. precipitation regime. Authors reported significant increase of the mean annual air temperature of 0.7°C, the mean annual minimal temperature of 0.8°C, winter temperature of 2.3°C as well as an increase of vegetation temperatures and prolongation of vegetation period by 11 days. All these climate changes resulted in an increase of radial increment of silver fir trees in Austria. Owing to air temperature increase during the last twenty years, heights of annual snow cover in Northern Hemisphere decreased by 10% (Groisman et al., 1994). For this reason in Alpine countries like Austria, with maximal amount of precipitation during vegetation period (Auer, 1993), prolongation of vegetation period as a result of higher air temperatures in combination with changes of habitat conditions can result in increased forest production.

Forest ecosystems are affected by numerous local meteorological and climatic conditions. Various ecological processes (photosynthesis, evapotranspiration, respiration, decomposition of substances, etc.) are closely connected with meteorological conditions. Recent damages of forests in Europe are more and more emphasised (Mueller-Edzards et al., 1997). Meteorological stress factors (like drought, high and low temperatures, cold, etc) are considered to be the possible causes of these forest damages. To study these processes and determinate possible causes, correct climate data are necessary (Xia et al., 2001).

Emphasised sensitivity of fir and beech-fir forests, as well as tree dieback and dieback of entire stands have contributed to the choice of Gorski kotar region as location for climate researches. The aims of this research were to determine variation and calculate trends of climate elements (air temperature, precipitation amount, number of warm and cold days, number of snow days, and height of snow).

RESEARCH AREA
PODRUČJE ISTRAŽIVANJA

The research was done in the mountain region of Croatia, in the area of beech-fir and fir forests in Gorski kotar. According to Köppens classification, Gorski kotar can be classified into Cfsbx type of climate. This type is characterised by moderate warm rain climate, without the drought period. The mean annual air temperature in the researched region was 7.2°C, and the mean amount of precipitation was about 2000 mm (Seletković, 2001). The basic substrate is composed of limestone, dolomites and sandstones of varying age. The dominant soil types are humus, brown and illimerized soils, rendzinas, dystric brown soils and brunipodzol. The relief of researched region is very irregular and loose. It is broken with heads, ditches, rocks, coves and cliffs i.e. karsts geomorphologic forms.

MATERIALS AND METHODS
MATERIJALI I METODE

For meteorological stations (table 1) in the researched region, linear trends of annual air temperatures and amount of precipitations, absolute maximal and minimal air temperatures, number of warm and hot days, number of days with precipitation ≥ 0.1 mm, number of days with snow ≥ 1 cm, maximal snow height were calculated. The data analysed using the linear-regression method.

By using the Student's *t* test of independent samples, the mean values of climate elements of the referent line (1961-1990) were compared with the period 1991-2007.

According to conclusions of the 13th Meeting Commission for Climatology of the World Metrological Organization, the referent period 1961-1990 is used for general comparisons, up to the end of

Table 1 List of meteorological stations, type of station and monitoring period
Tablica 1 Popis meteoroloških postaja, tip postaje i obrađeno razdoblje motrenja

Meteorological station *Meteorološka postaja*	Type of station *Tip postaje*	Monitoring period *Razdoblje motrenja*
Vrelo Ličanke	Climatological *Klimatološka*	1960 - 2007
Lokve Brana		1960 - 2007
Parg		1950 - 2007
Mrzla Vodica	Rain gauge *Kišomjerna*	1946 - 2007
Ravna Gora		1946 - 2007

the next referent (normal period) 1991-2020, meaning untill 2021 (Prikaz br.18, 2008; Šegota & Filipčić, 1996). All data were analysed using KlimaSoft 2.1 and Statistic 7.1. software.

RESEARCH RESULTS
REZULTATI ISTRAŽIVANJA

According to the results presented in Table 2 linear trends of annual air temperatures in the researched region are positive. The mean annual air temperatures and the absolute maximal temperatures are increasing significantly. The trends of the absolute minimal air temperatures are negative and are not significantly different (Table 3).

Table 2 Linear trends of annual and vegetation air temperatures
Tablica 2 Linearni trendovi i signifikantnost trendova godišnjih i vegetacijskih temperatura zraka

Meteorological station *Meteorološka postaja*	Mean annual temperature (°C) *Srednje godišnje temperature (°C)*				
	Linear trend *Linearni trend*	Beta	B	t	p-level (95%)
Vrelo Ličanke	Y=0,0508x + 6,4551	0,6468	0,0508	4,7984	0,0000*
Lokve Brana	Y= 0,0161x + 6,8087	0,3506	0,0161	2,5396	0,0145*
Parg	Y= 0,017x + 6,7459	0,3782	0,0170	3,0578	0,0034*

*p<0,05

Table 3 Linear trends of mean annual and absolute annual maximal and minimal air temperatures
Tablica 3 Linearni trendovi i signifikantnost trendova srednjih godišnjih i apsolutnih godišnjih maksimalnih i minimalnih temperatura zraka

Meteorological station *Meteorološka postaja*	Absolute maximal temperatures (°C) *Apsolutne maksimalne temperature (°C)*				
	Linear trend *Linearni trend*	Beta	B	t	p-level
Vrelo Ličanke	Y= 0,1008x + 28,378	0,5019	0,101	3,2832	0,0024*
Lokve Brana	Y= 0,0489 + 28,101	0,4137	0,0489	3,0827	0,0034*
	Absolute minimal temperatures (°C) *Apsolutne minimalne temperature (°C)*				
Vrelo Ličanke	Y= -0,0182x -17,235	-0,0499	-0,0181	-0,2829	0,7790
Lokve Brana	Y= -0,0157x – 17,268	-0,0639	-0,0156	-0,4347	0,6657

*p<0,05

Significant increase in the number of warm and hot days was found in the researched area (Table 4).

Decreasing trends of annual precipitations were found at all meteorological stations. Decreasing trend of annual precipitations was significant at meteorological stations Vrelo Ličanke and Lokve (Table 5).

Table 4 Linear trends of number of warm and hot days
Tablica 4 Linearni trendovi i signifikantnost trenda broja toplih i vrućih dana

Meteorological station *Meteorološka postaja*	Number of warm days (T ≥ 25°C) *Broj toplih dana (T ≥ 25° C)*				
	Linear trend Linearni trend	Beta	B	t	p-level
Vrelo Ličanke	Y= 0,8093x + 13,749	0,5824	0,81	4,0531	0,0003*
Lokve Brana	Y= 0,384x + 8,4043	0,4896	0,384	3,8090	0,0004*
Parg	Y= 0,2539x + 12,63	0,4351	0,254	3,6163	0,0006*
	Number of hot days (T ≥ 30° C) *Broj vrućih dana (T ≥ 30° C)*				
Vrelo Ličanke	Y= 0,1751x – 0,8877	0,5200	0,175	3,4444	0,0016*
Lokve Brana	Y= 0,0569x – 0,4991	0,4712	0,057	3,6236	0,0007*
Parg	Y= 0,0407x – 0,1307	0,3744	0,0407	3,0218	0,0037*

*p<0,05

Table 5 Linear trends of annual and vegetation precipitations
Tablica 5 Linearni trendovi i signifikantnost trendova godišnjih i vegetacijskih količina oborina

Meteorological station *Meteorološka postaja*	Annual precipitations (mm) *Godišnje količine oborina (mm)*				
	Linear trends *Linearni trend*	Beta	B	t	p-level
Vrelo Ličanke	Y= -13,543x + 2801,4	-0,3712	-13,54	-2,2620	0,0306*
Lokve Brana	Y= -15,265x + 2724,4	-0,4943	-15,26	-3,8574	0,0003*
Parg	Y= -2,6431x + 1920,7	-0,2125	-2,643	-1,6281	0,1091
Mrzla Vodica	Y= -2,7766x + 2794,3	-0,1061	-2,800	-0,8199	0,4155
Ravna Gora	Y= -1,0819x + 1965	-0,0654	-1,052	-0,5035	0,6164

*p<0,05

The trend of the number of days with precipitation was also negative i.e. decreasing. The trend of the number of days with snow was negative in the area of Lokve, while in the area of Vrelo Ličanke and Parg an increase in the number of days with snow was found. In the area of Vrelo Ličanke and Parg the decreasing trend in maximal snow height was also characteristic. This decreasing trend of maximal snow heights was found at all stations, except in the area of Lokve (Table 6).

Significant increase in the mean annual air temperatures for period 1991-2007 in regard to the referent line was from 0.5° C to 1.0° C (Table 7).

Similar to the significant increase in the mean annual air temperatures, the significant increase in the number of warm days ((T ≥ 25° C) in the period 1991-2007 was from 10 to 14 days (Table 8).

According to the results presented in Table 9, significant increase in the number of hot days (T ≥ 30° C) in the period 1991-2007 was from 1 to 3 days.

In the researched area, annual precipitations during 1991-2007 in regard to the referent line have decreased from 48.3 mm in the area of meteorological station Parg to the significant 289.4 mm in

Table 6 Linear trends of number of days with precipitation, number of days with snow and maximal snow height
Tablica 6 Linearni trendovi i signifikantnost trendova broja dana sa oborinom, broja dana sa snijegom i maksimalnih visina snijega

Meteorological station *Meteorološka postaja*	Number of days with precipitation ≥ 0,1 mm *Broj dana sa oborinom ≥ 0,1 mm*				
	Linear trend *Linearni trend*	Beta	B	t	p-level
Vrelo Ličanke	Y= -0,3439x + 160,05	-0,2221	-0,3439	-1,2887	0,2067
Lokve Brana	Y= -1,025x + 192,28	-0,6261	-1,025	-5,4469	0,0000*
Parg	Y= -0,1758x + 178,13	-0,1676	-0,1758	-1,2722	0,2085
	Number of days with snow ≥ 1 cm *Broj dana sa snijegom ≥ 1 cm*				
Vrelo Ličanke	Y= 0,0814x + 81,193	0,0268	0,0814	0,1519	0,8801
Lokve Brana	Y= -0,3445x + 101,13	-0,1797	-0,3445	-1,2396	0,2213
Parg	Y= 0,0213x + 97,218	0,0144	0,0212	0,1085	0,9139
	Maximal snow height (cm) *Maksimalne visine snijega (cm)*				
Vrelo Ličanke	Y= -0,2941x + 73,235	-0,0870	-0,2941	-0,4945	0,6243
Lokve Brana	Y= 0,1617x + 33,393	0,1687	0,162	1,1613	0,2514
Parg	Y= -0,1672x + 75,192	-0,0897	-0,1672	-0,6742	0,5029

*p<0,05

Table 7 Result of *t* test for mean annual air temperature values (°C) from referent line with period 1991-2007
Tablica 7 Rezultat Studentovog t-testa nezavisnih uzoraka usporedbe srednjih vrijednosti godišnjih temperatura zraka (°C) referentnog niza sa razdobljem 1991-2007

Meteorological station *Meteorološka postaja*	Referent line *Referentni niz* 1961-1990 (°C)	Period 1991-2007(°C) *Razdoblje 1991-2007 (°C)*	Level of significance *Razina značajnosti*
Vrelo Ličanke	6,8 ±0,55	7,8 ± 0,67	*
Lokve	7,0 ± 0,54	7,5 ± 0,71	*
Parg	6,9 ± 0,57	7,8 ± 0,84	*

*p<0,05; (LSMEAN±SD)

Table 8 Result of *t* test comparison of mean number of warm days (T ≥ 25° C) of referent line with period 1991-2007
Tablica 8 Rezultat Studentovog t-testa nezavisnih uzoraka usporedbe srednjih vrijednosti broja toplih dana (T ≥ 25° C) referentnog niza sa razdobljem 1991-2007

Meteorological station *Meteorološka postaja*	Referent line 1961-1990 *Referentni niz 1961-1990*	Period 1991-2007 *Razdoblje 1991-2007*	Level of significance *Razina značajnosti*
Vrelo Ličanke	20,9 ± 10,49	34,8 ± 13,47	*
Lokve	14,3 ± 7,40	24,8 ± 12,94	*
Parg	18,0 ± 6,98	27,7 ± 11,12	*

*p<0,05; (LSMEAN±SD)

the area of meteorological station Lokve. In the area of meteorological station Ravna Gora an increase of 9.3 mm was found (Table 10).

The number of days with precipitation in the area of meteorological stations Vrelo Ličanke and Lokve has deceased by 6 days and by the significant 18 days. In the area of meteorological station Parg, an increase in number of days with precipitation of 5 days was recorded (table 11).

Table 9 Result of *t* test comparison of mean number of hot days (T ≥ 30° C) of referent line with 1991-2007
Tablica 9 Rezultat Studentovog t-testa nezavisnih uzoraka usporedbe srednjih vrijednosti broja vrućih dana (T ≥ 30° C) referentnog niza sa razdobljem 1991-2007

Meteorological station *Meteorološka postaja*	Referent line 1961-1990 *Referentni niz 1961-1990*	Period 1991-2007 *Razdoblje 1991-2007*	Level of significance *Razina značajnosti*
Vrelo Ličanke	0,6 ± 1,05	3,7 ± 4,13	*
Lokve	0,3 ± 0,71	1,9 ± 2,38	*
Parg	0,7 ± 1,29	2,17 ± 2,48	*

*p<0,05; (LSMEAN±SD)

Table 10 Result of *t* test comparison of mean precipitation amount (mm) of referent line with period 1991-2007
Tablica 10 Rezultat Studentovog t-testa nezavisnih uzoraka usporedbe srednjih vrijednosti količine oborina (mm) referentnog niza sa razdobljem 1991-2007

Meteorological station *Meteorološka postaja*	Referent line *Referentni niz* 1961-1990 (mm)	Period *Razdoblje* 1991-2007 (mm)	Level of significance *Razina značajnosti*
Vrelo Ličanke	2630,9 ± 428,36	2497,7 ± 281,40	ns
Lokve	2433,6 ± 440,89	2144,2 ± 273,50	*
Parg	1849,3 ± 176,51	1801,0 ± 194,45	ns
Mrzla Vodica	2759,0 ± 444,7	2634,2 ± 366,4	ns
Ravna Gora	1919,6 ± 269,51	1928,9 ± 259,06	ns

ns=nesignifikantno; ns=not significant; *p<0,05; (LSMEAN±SD)

Table 11 Result of *t* test comparison of mean values of days with precipitations (≥ 0.1 mm) of referent line with period 1991-2007
Tablica 11 Rezultat Studentovog t-testa nezavisnih uzoraka usporedbe srednjih vrijednosti broja dana sa oborinom (≥ 0,1 mm) referentnog niza sa razdobljem 1991-2007

Meteorological station *Meteorološka postaja*	Referent line *Referentni niz* 1961-1990	Period *Razdoblje* 1991-2007	Level of significance *Razina značajnosti*
Vrelo Ličanke	156,7 ± 16,47	151,3 ± 14,26	ns
Lokve	172,4 ± 21,59	154,1 ± 14,73	*
Parg	167,9 ± 15,20	173,0 ± 17,34	ns

ns=nesignifikantno; ns=not significant; *p<0,05; (LSMEAN±SD)

Table 12 Result of *t* test comparison of mean values of days with snow (≥ 1 cm) of referent line with period 1991-2007
Tablica 12 Rezultat Studentovog t-testa nezavisnih uzoraka usporedbe srednjih vrijednosti broja dana sa snijegom (≥ 1 cm) referentnog niza sa razdobljem 1991-2007

Meteorological station *Meteorološka postaja*	Referent line *Referentni niz* 1961-1990	Period *Razdoblje* 1991-2007	Level of significance *Razina značajnosti*
Vrelo Ličanke	81,7 ± 36,97	83,4 ± 22,64	ns
Lokve	97,5 ± 27,60	86,2 ± 23,57	ns
Parg	103,6 ± 25,59	95,8 ± 21,06	ns

ns=nesignifikantno; ns=not significant; (LSMEAN±SD)

A decrease in the number of days with snow in period 1991-2007 was recorded in the areas of all meteorological stations. This decrease was from 1 to 12 days and was not significant (Table 12).

DISCUSSION
RASPRAVA

Along with air temperature that depends on cloudiness and air insolation, precipitations as a main source of soil moisture have the greatest effect on development of vegetation. Dry periods as stress factors are one of the main reasons of dieback, damage and poor health status of silver fir forest ecosystems (UN-ECE & EC, 2003). Dry years, especially on calcium lacking soils, have a negative impact on Ca status in silver fir trees (Potočić et al., 2005).

Precipitations deficiency, along with high air temperatures weakens the resistance of certain forest tree species as a result of increased evapotranspiration. According to Vajda (1965) because of lack of precipitations, soil becomes drier and drier on a daily basis so that a tree cannot compensate for water lost by transpiration from soil. The increase of air temperatures in the region of Gorski kotar that has been determined will affect the general increase of potential evapotranspiration and the decrease of soil moisture. Therefore, longer dry periods affect the soil dryness and deterioration of physiological processes in trees. The increase of the mean annual air temperatures and the occurrence of climate excesses important for the today's climate change can cause stress states for tree species of narrow ecological valence. This especially refers to the direct ecological factors (heat and water).

With the rapid decrease of precipitation amount causing the physiological weakening of a tree, concurrent increase of the air temperature happens, having a very unfavourable effect on the development and spreading of harmful insects (Androić, 1969).

Changes in physiological status caused by precipitation deficiency are considered to be the cause of Spanish fir dieback and deterioration in the region of Pyrenees (Fromard et al., 1991). These changes are reflected in decreased increment. Greater dieback of trees along with decreased increment, increased numbers of dry years, and other stress factors result in a decrease of wood stock of certain species in comparison to the normal which brings into question the functioning of forest ecosystem of certain species.

Air temperature has key effect on climate character. In that respect, the differences found between temperatures of analysed periods have given us important insight on whether and how these differences affected the change of climate character of the researched area. In the area of meteorological stations in Gorski kotar the mean annual air temperatures during 1991-2007 in regard to the referent line have increased significantly by 0.5°C to 1.0°C. At the same meteorological stations a decrease in the mean annual amount of precipitation of 48.3 mm up to 289.4 mm was found.

A greater increase of the mean annual air temperatures was observed in the area of meteorological stations at the edge of Gorski kotar in comparison to meteorological stations in the inland areas. Also, a greater decrease of the annual amount of precipitations was observed at the edge of Gorski kotar region.

In 1988 in Greece in the areal of Greek fir (*Abies cephalonica* L.) forests, only 60% of annual precipitations and 26% during vegetation period was recorded in comparison to the referent line 1961-1987. The 1988 drought in Greece caused physiological weakening of Greek fir trees, as well as gradation of secondary pests resulting in catastrophic dieback of trees in 1989. In Gorski kotar region, such a drastic decrease of precipitations as in the case of 1988 drought in Greece was not found.

In the area of meteorological stations of Gorski kotar region linear trends of the number of days with snow, and of maximal snow heights showed no significant changes. In the area of all meteorological stations, a negative relation between number of days with snow and maximal snow heights was observed. A positive trend in number of days with snow was followed by a negative trend of maximal snow heights.

The researches of Uscupulić et al. (2007) showed that perennial drought, particularly a very dry year of 2003 was critical for bark beetles infestation. This indicates the need of taking into account climate conditions in managing the forests, especially in planning and performing protective measures. In dry years more attention should be paid to the forest hygiene maintenance. In case of fractured and windthrown trees the bark needs to be removed or trees taken out of the forest immediately. Cutting and export of wood from forest needs to be expedited. Stanovsky (2002) researched the effect of climate factors on health status of forest ecosystems in Czech Republic. During the ten-year long research period (1991-

2000) the trend of dieback trees coincided with the duration of drought period. Using cross-correlation function, a highly significant correlation was found between the duration of drought period (days) and the volume of dieback trees. The cause of this catastrophic dieback of forest ecosystems in Silesian Lowland region was precipitation shortage during the vegetation period and gradation of secondary pests. According to Ugarković et al., (2010, 2011) air temperatures, amount of precipitations, number of dry days and potential evapotranspiration in Gorski kotar are climate factors that significantly affect tree dieback and crow defoliation of silver fir. Global climate changes will cause changes in the environment, and consequently the changes of ecological niches.

Researches done by Anić et al. (2009) showed that climate change will significantly affect tree species with narrow ecological valence. Authors found that double increase of greenhouse gasses concentration caused an increase of the mean annual air temperature of 2.5°C and a decrease of the mean annual precipitations of 152 mm in comparison to the referent line 1950-2000. The research showed that these changes could cause decrease of silver fir ecological niche in Croatia ($p<0.9$) by almost 85% compared to the present state.

The observed significant increase of the mean annual air temperatures in the period of 1991-2007 from 0.5°C to 1°C and the decrease of precipitations from 48.3 mm to 289.4 mm shows significant variation of climate elements important for forest ecosystems of silver fir.

CONCLUSIONS
ZAKLJUČAK

Based on the research conducted, certain variations of climate elements in the region of Gorski kotar were found. The trends of the mean annual and the absolute maximal air temperatures, as well as the number of warm and hot days were positive and significant. The trends of the absolute minimal air temperatures showed no significant changes.

In the area of all meteorological stations, negative trends of annual precipitations were found. The trends were significant in the area of the meteorological satiations Vrelo Ličanke and Lokve. A negative trend of days with precipitations was significant only in the area of metrological station Lokve. The trends of snow precipitations showed no significant changes.

Changes of air temperatures were much more pronounced than in the case with precipitations and snow. In the area of meteorological stations in Gorski kotar, the mean annual air temperatures in the period of 1991-2007 in regard to the referent line have significantly increased by 0.5°C to 1.0°C. In accordance with the increase of the mean annual air temperatures and with the significant positive trend of the absolute maximal air temperatures, the number of warm days during the period of 1991-2007 has increased by 10 to 14 days, and the number of hot days by 1 to 3 days.

For the same meteorological stations a significant decrease of annual precipitations of 48.3 mm to 289.4 mm was found.

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