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Contemporary Climate Variability and Forest Fires in Deliblatska pescara

Abstract: Considering the actual scenario of contemporary global climate changes and their possible influence on forest fires, the connections between temperature changes and precipitations on fires have been examined in Deliblatska pescara. The basic characteristics of fires have been analyzed in the area which is considered the most endangered in Serbia. The decreasing trend of annual number of fires was ascertained for period the 1948-2002. However, the trend of annual temperature and precipitation changes is not in accordance with the trend of annual number of fires. Some seasonal aspects related with the change of climate elements cannot also explain the decreasing number of fires. A rising trend of annual fire spread surface have been ascertained, which is in accordance with air temperature rise at the end of the 20th century. However, five extreme values were far above the upper standard deviation, which was explained by non climate factors (increase of surface under pine trees, mistakes during fire extinguishing and similar).

Key words: Deliblatska pescara, forest fires, climate changes

Introduction

Forest fires are one of the largest problems of forest protection in Serbia. Their annual number and total fire spread surface significantly varies, but it has also been noticed that all lumber camps usually face this problem.

According Dimitrov (1984) only sandy terrains fall into the category of the most endangered areas in Serbia (Deliblatska and Suboticko-Horgoska). From the survey of fire spread surfaces and total damages, it results that Deliblatska pescara, which is situated between Belgrade and Vrsac - next to the border with Romania, represents the most endangered area of fires in our country.
The term 'Deliblatska pescara', which is used in the paper, relates to Camp unit of 'Deliblatski pesak' (sand of Deliblato) of 27 598 39 ha. In the period of 1948

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to 2002, 245 forest fires were recorded on this area, while the total fire spread surface was 11 315 ha. Approximately, half of that surface were on fire (5 710 ha). Bush fires made 88.6% of the total number of fires, while the higher ones were recorded in 11.4% of cases.

Human factor was the most important origin for 67.3% of fires, while for 32.7% of them the cause is left unknown. For the area of the Balkans (Tab. 1) according Nikolov (2006), "it may be concluded that averagely 58.8% of the total number of forest fires originate from human factor, 3.3% is natural while 37.9% of fires is of unknown origin." The highest percent of the forest fires caused by people was recorded in Croatia (75.3%) while the lowest was in Bulgaria (30.4%). On the other side, Bulgaria has the highest percent of fires of unknown cause (67.9%).

Table 1 Number of fires in the Balkan countries in period 1988-2004. (Nikolov, 2006)

Year	Albania	Bulgaria	Croatia	Greece	R. of Macedonia	Slovenia	Serbia and Montenegro -Serbia-	Turkey	Total	Average
1988	121	101	/	1 898	126	/	25	1 372	3 643	455
1989	132	578	/	1 284	95	/	48	1 633	3 770	471
1900	269	208	/	1 322	241	/	98	1 750	3 888	486
1991	147	73	/	941	38	30	55	1 481	2 765	346
1992	659	602	/	2 042	235	40	44	2 117	5 739	717
1993	560	1 196	/	2 406	390	108	157	2 545	7 362	920
1994	585	667	/	1 763	195	66	70	3 239	6 585	823
1995	110	114	/	1 438	24	25	15	7 676	9 402	1 175
1996	490	246	/	1 508	90	50	45	1 645	4 074	509
1997	735	200	/	2 271	174	59	28	1 339	4 806	601
1998	601	578	/	1 842	151	151	78	1 932	5 333	667
1999	628	320	/	1 480	452	53	11	2 075	5 019	627
2000	915	1 710	7 797	2 581	1 187	98	281	2 353	16 922	2 115
2001	327	825	4 024	2 658	165	65	42	2 631	10 737	1 338
2002	140	402	4 692	1 400	59	60	112	1 471	8 336	1 042
2003	771	452	6 924	1 452	96	224	57	2 177	12 153	1 519
2004	143	294	2 855	/	73	/	5	1 762	5 132	642
Total per country	7 333	8 566	26 292	28 286	3 791	1 029	1 171	39 198	**115 666**	850
Average per country	*431*	*504*	*1 547*	*1 664*	*223*	*61*	*69*	*2 306*		

Two critical periods may be distinguished for the origin of fires in Deliblatska pescara. During February, March and April there was 57.6% of fires, while 22% take place on July, August and September. According Ducic, Radovanovic (2005) climate of this region bears A-1-a sign, which means that negative temperature extremes decrease even below -32 °C, while maximum air temperatures exceed 42 °C. Annual precipitation is about 600 mm. However, on the basis of data for meteorological screen Susara in the very sands, it may be concluded that this area is a bit colder than its surroundings, as by values of temperature elements so by length of lasting during the year (Kolic, 1969). Our researches have shown that this could probably be explained by somewhat

higher altitude (138 m) and by higher albedo of the sands itself, as air warming occurs less. Also, the high percent of sand in soil, which has small heat capacity, enables higher radiation. In relation to the surroundings, greater forestation and the terrain itself influence on a decrease of summer and maximum temperatures. On the other side, forest clearings, due to its specific nature enable the formation of expressive frost pockets (Ducic, Milovanovic, 2004). Besides that, annual precipitation is insignificantly increased in relation to the surroundings (Kolic, 1969). On the basis of above mentioned, it still may be supposed that hydrothermal characteristics of soil are more significant than regionally-climatic factors as the origin of fires.

All soils of Deliblatska pescara are sandy soils, so that they are characterized by high water permeability. The surface of sand is being intensively warmed up, which makes bush fuel load drying.

Pine trees greatly enlarge the endangerment of Deliblatska pesara from fires. The total area under black pine cultures (Pinus nigra Arn.) and white pine (Pinus silvestris L) is 3 684 according data from 1998. Juniper tree (Juniperus communis L.) also contributes to an increased danger from fires.

The region of Deliblatska pescara is characterized by a complete absence of water currents and hydro accumulations which is one of the main limiting factors for water supplying under forest fire extinguishing.

People, as potential instigators of fires, are present in this area during most part of the year such as passersby, excursionists, farm workers, loggers, hunters and other individuals.

Forest roads are of special significance during fire extinguishing. Asphalt roads of Deliblatska pescara region are Bela Crkva-Kovin, Deliblato-Susara and Banatski Karlovac-Susara. Total length of soft (sandy) roads is 420 km. These sand surface roads are not suitable for movement of fire engines as they often became overgrown with surrounding vegetation.

The following measures of fire prevention have been applied in Deliblatska pescara so far: fire fighting cuts (also including biological fire fighting belts), measures of care (spaces and trimming lower branches), propaganda, patrol and information, strengthen supervision, etc.

Recent researches

The latest report of IPCC (2007)[1], as well as the previous one, predicts a serious of harmful consequences of global climate changes that might appear as a consequence of anthropogenic greenhouse effect. Among others, the increase of danger from forest fires is also predicted in the region of south Europe where our country belongs. Predominant decrease of precipitation was recorded in the period 1950-2005 in Serbia. The highest decrease was in Negotinska Krajina (about 120 mm on the annual level), while in Voivodina the precipitation insignificantly decreased mainly in the area of Zrenjanin-Kikinda. The increase of precipitation occurred mainly in mountainous parts of western Serbia and in the south of Metohia.

It is also mentioned that in the period following a further trend of air temperature growth is being expected in our country as well as a decrease of precipitation followed by reduction in the number of days with snow and snow blankets, reduction of runoff, soil moisture and availability of water resources. According to these projections even with a partial application of measures for reducing gas emissions with greenhouse effect, it might be expected that the average annual air temperature increases for 3-4 °C to the end of the century, while annual precipitation decrease would be about 1% per decade. The most expressive decrease of precipitation is expected to happen in the warmest part of the year.

The latest Fourth Report of the Work group 1, IPCC, concludes that the higher part of the mean global temperature increase in the second half of the 20th century most probably occurred due to an observed increase of gas concentration with greenhouse effect under the influence of anthropogenic emissions.

Considering the problem of wildfire frequency in the western part of the USA, Running (2006) concludes that they happened as the consequence of an increase of fire season duration. It came to the increase due to earlier snow melting, as well as due to summer temperature increase. Proceeding from IPCC projections, it is estimated that during the 21st century, depending on the applied scenario of temperature increase, the frequency of fires would increase from 74 to 118%.

The paper of Kadovic et al. (2005) is of particular interest concerning this theme. They investigated temperature and precipitation changes on the basis of the meteorological screen of Banatski Karlovac. Giving regional review, they have

[1]http://www.hidmet.sr.gov.yu/podaci/ipcc/4_IZVESTAJ_RADNE_GRUPE_1_OSNOVNI_SISTEMI%20(SRP).pdf

concluded that in the period 1951-1980, a negative trend of annual air temperature was observed in the whole territory of Yugoslav Federal Republic. In the period 1961-1990 the regions of positive trend were observed in the north and northwest. However, even in that period the area of Deliblatska pescara did not presented a statistically significant temperature trend. Nevertheless, if we consider the period of the second half of the 20th century, this area records the increasing temperature trend between 0.5 and 0.75 °C. This is, above all, the consequence of a temperature increase in the last decade of the 20th century. The mentioned authors have stated that temperature increase was about 1 °C per decade in period 1994-2003. They have concluded that "we are in a period of melting which is especially expressed in the last two decades, while other notions have pointed us that such tendency we should also expect in decades that follow."

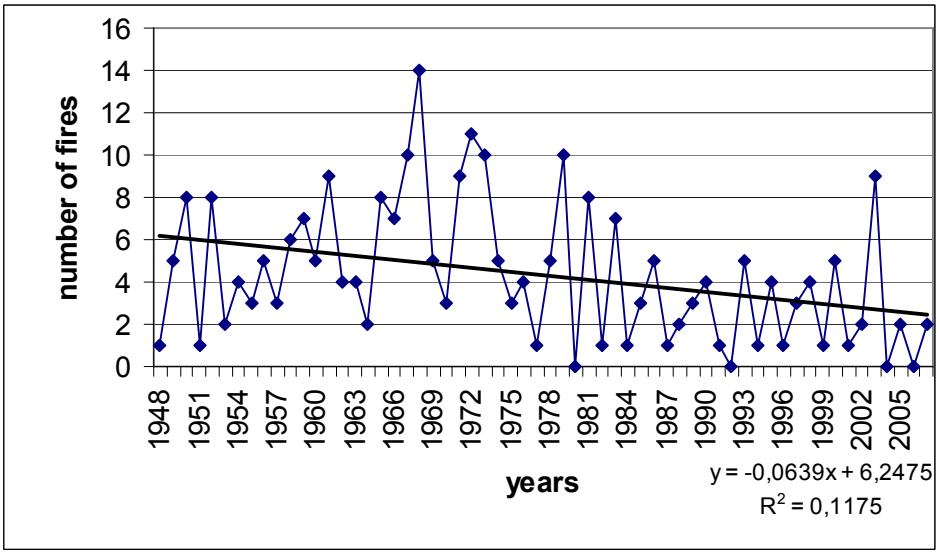
In the period 1961-2003, precipitations have a mild negative trend of 5% over the normal value in Banatski Karlovac. However, trends for shorter periods have positive signs mostly due to high values of precipitation in 1999. In the last decade of the 20th century the annual precipitation decreased from 636 mm (period 1961-2000) to 612 mm (3.8%), but during the vegetation period it resulted in an increase of precipitation of 10 mm (2.6%).

In the period 1961-2000., potential annual evapotranspiration was 720 mm, and it increased on 726 mm (0.8%) in the last decade of the 20th century, while it also increased for 0.8% in vegetation period. The relationship between precipitations and potential evapotranspiration showed a decrease of 4.5% on the annual level (it became drier), but it resulted in a decrease of 1.7% in the vegetation period (it became more humid).

Research results

The first step in researching the connection between change of climate elements and fires in Deliblatska pescara has been directed towards establishing the trends of their changes.

A significant negative linear trend of total number of fires during the year was observed during the period 1948-2002 (Graph1). Therefore, the annual number of fires was decreasing by a rate of 0.64 per decade, for 3.5 days cumulatively, namely for approximately 50% in the mentioned period of 55 years.



Graph1 Dynamics of annual number of fires in Deliblatska pescara with trend line

If we observe changes as moving decimal values, we may notice that the greatest number of fires has been recorded in decade 1965-1974 (8.2 annually), while the smallest one was in the period 1987-1996 (2.2 annually). In the last 10 years (1993-2002) the number of fires has been of 2.7 per decade, which is 40% below the average of the whole series.

If we observe the years having the number of fires above upper standard deviation of the whole series (over 8), then there are 11 of them, where most fires were recorded in 1968 (14). Extremely fire years were concentrated in the period 1961-1973. (7). 1981 was the last extreme year of the observed series (8 fires). After 1981, a relatively weakly active fire period came with 9 extremely inactive years (below lower standard deviation) of one fire annually or without fires at all. Therefore, in the last 21 years (1982-2002) the extremely fire inactive years make for 43% of the total number.

What was happening with temperature and precipitation trends in the mentioned period? We have taken into processing the data for the meteorological screen Vrsac, as the closest with a long series of observations. In order to have a clearer picture we have observed annual and seasonal changes of both elements.

In the period 1948-2002 an increase of annual air temperature of 0.061 °C per decade has been noticed, which is in accordance with the trend of global changes in the same period. The highest increase of 0.214 °C per decade has been noticed in spring. This it is the only statistically significant change of air temperature. Summer temperature trend is insignificant (+ 0.05 °C per decade). Fall temperatures record negative trend of 0.153 °C per decade. If we observe just the sign of changes with expected sin phase synchronization (higher temperatures-more fires and vice versa), then it is obvious that only changes of fall temperatures are in accordance with the expectation. In other words, the trend of changes of the annual and seasonal air temperatures in Vrsac (except autumn) is not in accordance with the trend of changes of the number of fires in the period 1948-2002.

Changes of precipitation trend in Vrsac in the observed period have shown that the annual precipitation was reducing per rate of 1.48 mm per decade. That is not also in accordance with the expected anti phase synchronization this time (less precipitations-more fires and vice versa). The greatest decrease has been recorded in winter months (7.13 mm per decade). Summer changes of precipitation show an increase of 2.34 mm per decade, while fall ones increase per rate of 3.63 mm per decade, what would be in accordance with expected anti phase synchronization of connection between fires and precipitation.

Estimate of the correlation coefficients for moving decimal values of temperature and precipitation with fires has shown the highest value for winter precipitations and number of fires (0.52) and summer temperatures and number of fires (-0.36). These are the only statistically important correlations having a level of confidence of 0.05%. However, the correlation sign is not, again, in accordance with the expectation that more precipitations mean fewer fires and higher temperatures mean more fires.

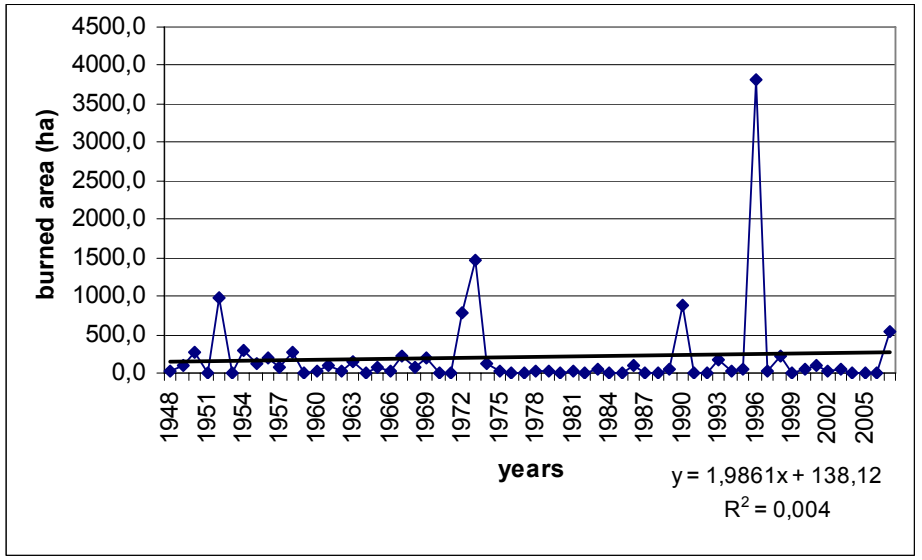
Discussion

Consequently, in the period 1948-2002, the annual number of fires was reducing per rate of 0.64 per decade, for 3.5 days cumulatively, namely for approximately 50% during 55 years. In the same period mean annual air temperature in Vrsac had a rising trend, while the annual precipitation was reducing.

Changes of climate elements are not in accordance with the expected sign of connection with the number of fires.

Nevertheless, some trends of changes of seasonal values of temperature and precipitations are in accordance with expectations. The trend of temperature and precipitation changes for fall months is in accordance with the trend of number of fires. However, the analysis of seasonal arrangement of fires has shown that their greatest number occurred in spring months (56%) while 9% of all fires occurred in autumn. From this, it is clear that above the fact the sign agrees, the climate conditions in autumn months are not decisive for the number of fires. The sign of summer precipitation trend is corresponding to the expected connection with the number of fires. However, 22% of fires occurred in summer period, which is not even a relative majority, and the coefficient correlation sign is not in accordance with the expected.

Having in mind what was previously mentioned contradictories, we wanted to establish whether the trend of climate elements is, eventually, in accordance with the trend of annual fire spread surfaces (Graph 2).



Graph 2 Dynamics of fire spread surfaces in Deliblatska pescara with trend line

We have ascertained the rising trend of annual fire spread surfaces, which is in accordance with the expected connection with trends of annual temperatures and precipitations. However, the extreme values of fire spread surfaces have been noticed with far larger exceptions than the upper standard deviation (1952, 1972, 1973, 1990 and 1996) which is difficult to explain only by climate variability.

Eight fires were recorded in 1952 with total fire spread surface of 974 ha (whereof about 20% of forests). Although danger from fires was great during that year, there was not real ecological disaster. The main reason lies in the fact that during that time in the whole region of Deliblatska pescara a little more than 500 ha was of pine cultures which are very endangered by fires.

Eleven fires were recorded in 1972 while the total fire spread surface was 790.71 ha. Most phenomena were recorded at the end of winter and at the beginning of spring when the conditions for appearing and spreading of fires were suitable. In that year according data of the main meteorological screen Vrsac, not a day of snow blanket was recorded during winter, while during autumn that preceded, there were only six such days. Snow blanket is important because it creates suitable conditions and gives necessary moisture for disassembling of dry grass cover from the previous year. Therefore, the absence of snow blanket as the consequence has the presence of great quantity of dry grass which presents excellent fuel load.

Similar circumstances were also in the following 1973 when 10 fires were recorded with total fire spread surface of 1 475.78 ha. Fire from March 27-28th represented the real ecological disaster since the total fire spread surface was 1 006.69 ha, whereof 748.38 ha of forests. In that time this fire was the largest one in recent history of Deliblatska pescara when younger pine cultures were mostly destroyed.

It is important to mention that with intensive afforesting by pine trees, the conditions for catastrophic fires were made. According data from 1967, under the pine trees were 3 793 ha in Deliblatska pescara, which is the increase of over 7 times in relation to 1953 (526 ha). Afforesting by pine trees continued even after the great fire so that in 1977. 4 283ha were recorded and even 5 915 ha under pine trees were recorded in 1987. Such situation enabled new catastrophic fires in the area of Deliblatska pescara.

In the fire from August 30th to September 5th 1990, a surface of 881.6 ha was spread over whereof about 80% under forest. Pine cultures made even 90% of fire spread forest surface.

Fire from August 10th-16th, 1996 was by all indexes the greatest one in recent history of Deliblatska pescara 3 815.4 ha were fire spread, whereof 2 235 ha under forest. Conifers (exclusively pine trees) burned on the surface of 1 557.63 ha (close to 70% of fire spread forest surface).

Catastrophic summer fires from 1990 and 1996 were the consequence of not only the surface increase under pine trees but also of increased older pine cultures participation, which made the conditions for making high fires, which since then has not been significant characteristic of this area.

We may see from the following data (period 1948-2002) how catastrophic fires from 1973, 1990 and 1996 are separated from all others in the area of Deliblatska pescara.[2]

Total fire spread surface in three largest fires (5 703.69 ha) makes 50.43% of the total fire spread surface in all the fires from the mentioned period.

Total fire spread forest surface in three largest fires (3 688.55 ha) makes for 64.61% of the total fire spread forest surface.

Fire spread surface in the fire from August 10th-16th, 1996 (3 815.4 ha) makes for 33.74% of the total fire spread surface.

Total fire spread forest surface in the fire from August 10th-16th, 1996 (2 235 ha) makes for 39.14% of the total fire spread forest surfaces.

The sum of fire spread surfaces of two catastrophic summer fires in 1990 and 1996 (4 697 ha) makes for 41.53% of the total fire spread surface.

Forests of 2 940.17 ha were spread in these two fires, which makes for 51.49% of the total fire spread forest surface.

Approximately three-fourths of fire spread forests were under pine trees in fires from 1990 to 1996.

Nevertheless, it should be emphasized that fire extinguishing activities have greatly influenced fire damage degree as well as fire spread surface. Mistakes may enlarge damages in this phase, what may be seen in the example of the fire from 1996 when fire spread over the asphalt road Deliblato-Susara and when fire extinguishing out of planes, which is the most effective in such cases, was late more than 3 days. Applying modern methods for struggling against destructive power of fires, in countries that suffer far larger consequences than it is the case with our country, even in spite of considerable efforts mostly did not give satisfying results. In Portugal, for example, it was concluded that certain

[2] Authentic material of "Voivodinasume", Novi Sad; Lumber Camp "Banat", Pancevo

activities "only confirmed that the strategy which has been followed till then did not solve the problem" (Gomes, 2006). Recent researches (Radovanovic et al, 2007, Gomes, Radovanovic, 2008, Radovanovic, Gomes, 2008) have pointed to hypothetic possibility of causative-effective connections of the processes on the Sun and forest fires, especially in cases for which the causes were not established. When such cases are observed in Europe, it results that there are 40% of them (Tab. 2).

Table 2. Origin of fires on forest soils from 1950.to1991 was the following[3]:

Unknown	40.0%
Lightning	29.7%
Carelessness	11.5%
Accident	9.6%
Repeated fires	3.0%
Others	5.3%

From the above mentioned, it results that monocultures of pine trees, changes in their age structure as well as mistakes under fire extinguishing have influenced on the extreme values of annual fire spread surfaces. Therefore, climate variability obviously has not decisively influenced the extreme values of fire spread surfaces in the last decades of the 20th century. Nevertheless, there is a coincidence between sudden temperature increase in period 1993-2002 (0.14% per year) and the largest forest fire in Deliblatska pescara ever recorded (1996). However, significant deviations from average temperature and precipitation values were not recorded in 1996. It is interesting to notice that this fire, although catastrophic one, was the only recorded in that year on sands of Deliblatska pescara.

Having in mind sudden temperature growth in the period 1993-2002, we wanted to check whether there were any similar temperature rises in the past. We started with HadCRUT3 data. It is data net of lower instrumental measures presented as temperature deviations from the mean value. The data are available[4] as annual values for period from 1880 in grids of 5x5°.

Comparing periods of the same length (1951-2002) for Vrsac and HadCRUT3 for responding grid, the correlation coefficient was 0.93, which also satisfies Student's test on the level of 0.05 and 0.01%. Therefore, HadCRUT3 data may

[3] http://www.feudeforet.org/english/forets_europe.htm#haut
[4] http://www.co2science.org/scripts/CO2ScienceB2C/data/temperatures/hadley.jsp

be considered as reliable. On basis of those data we may see that there had been similar rises in the past. Thus in period 1940-1949 temperature rise by trend line was 0.24 °C per year, which means that if the trend continued up today the temperature increase would be over 14 °C by the trend line. However, almost in the following decade (1950-1959) temperature decrease of 10 °C per century was present. Of course, the trend for such a short period is not statistically significant, which points to be cautious in applying projection models of future climate element changes.

Riano et al, (2007) have observed spatial and time aspect of fire spread surfaces dynamics on the global level. Precise satellite data have been used with a resolution of one 'pixel' (8x8 km) for period 1981-2000. The authors have concluded that significant rising trend of fire spread surfaces was present in some parts of the world. Some parts of Euro Asia and western part of North America record the increase of 24.2 pixels per year. However, the increase of fire spread surfaces was followed by equivalent decrease in the tropical part of southeastern Asia and Central America. Viewed globally, according the authors "there was not significant rising or decreasing trend of fire spread surfaces in the mentioned period on the Planet as a whole." The authors have also concluded that latitude is not the decisive factor and that fire spread surfaces of different trend sign may also be seen on the same latitudes.

Bergeron, Archambault (1993) analyzed changes in increment of rings and fire frequencies in northwestern Quebec for period back to 1688. In the last 100 years they registered significant decrease of fire frequency even above the fact that in the same period it came to temperature increase. They concluded that "contradictory results between projected and noticed effects of melting on fire frequency endanger our current ability to generalize the effect of CO_2 concentration growth on fire frequency."

Conclusion

Deliblatska pescara represents the most fire endangered area in our country. 245 fires were recorded in period 1948-2002, while the total fire spread surface was 11 315 ha (whereof 57 100 ha of forests). All soils of Deliblatska pescara are the soils on sand, characterized by high water permeability. The surface of sand is being intensively warmed up which makes brush fuel load drying. Monocultures of pine trees greatly enlarge fire endangerment of Deliblatska pescara (3 684 ha according to data from 1998).

The latest report of Intergovernmental Panel for Climate Changes (IPCC, 2007) has predicted a series of harmful consequences of global climate changes, which could appear as the consequence of anthropogenic greenhouse effect. According to these projections, endangerment from forest fires will strengthen in the region of south Europe, where further trend of air temperature growth is being expected, as well as precipitation decrease.

In the period 1948-2002 significant negative linear trend of the total number of fires during the year has been recorded in Deliblatska pescara. If we observe the changes as moving decimal values, we may notice that the greatest number of fires was recorded in decade 1965-1974 (8.2 per year), while the smallest one in period 1987-1996 (2.2 per year). In the last 10 years (1993-2002) the number of fires was 2.7 per decade, which is 40% below the average of the whole series. A relatively weakly active period of fires with nine extremely inactive years has started in 1981.

Therefore, in the period 1982-2002 extremely inactive fire years make for 43% of the total number. In the period 1948-2002 the annual number of fires were reducing by rate of 0.64 per decade, for 3.5 days cumulatively, namely for approximately 50% during 55 years. In the same period the mean annual air temperature in Vrsac had a rising trend, while the annual precipitation was decreasing. Changes of climate elements are not in accordance with the expected sign of connection with the number of fires. On the extreme values of annual fire spread surfaces mainly influenced monocultures of pine trees, changes in their age structure, as well as mistakes in fire extinguishing.

Thus, climate variability obviously did not crucially influence the extreme values of fire spread surfaces in the last decades of the 20th century. Nevertheless, there is a coincidence between sudden temperature growth in period 1993-2002 (0.14 °C per year) and largest forest fire ever recorded in Deliblatska pescara (1996). However, significant deviations from the average temperature and precipitation values were not recorded in that year.

References

Bergeron Y, Archambault S. (1993): Decreasing frequency of forest fires in the southern boreal zone of Québec and its relation to global warming since the end of the 'Little Ice Age'. *The Holocene*, Vol. 3, No. 3, 255-259.

Dimitrov T, Jurčec V. (1984): Utjecaj vremenskih prilika na pojavu šumskih požara na području priobalnog krša tijekom 1983. godine (Influence of weather

conditions of forest fires in the karst coastal area during 1983). *Šumarski list* CVIII (1984) 9-10, 427-445.

Дуцић В, Миловановић Б. (2004): Термичке специфичности Делиблатске (Банатске) пешчаре(Thermal characteristics of Deliblatska (Banat) pescara). *Зборник радова Географског факултета*, Свеска LI, 1-12.

Дуцић В, Радованоић М. (2005): Клима Србије (Climate of Serbia). Завод за уџбенике и наставна средства, Београд.

Gomes F. P. J. (2006): Forest fires in Portugal: How it happened and why it happened. *International Journal of Environmental Studies,* Vol. 63, No. 02, p. 109–119.

Gomes F. P. J, Radovanovic M. (2008): Solar activity as a possible cause of large forest fires — A case study: Analysis of the Portuguese forest fires. *Science of the total environment* 394, p. 197–205, doi:10.1016/j.scitotenv.2008.01.040.

Кадовић Р, Кнежевић М, Летић Љ, Поповић Т. (2004): Промена климе и могући утицај на шумске екосистеме Делиблатске пешчаре (Climate change and possible influence on forest ecosystems of Deliblatska pescara). СРП „Делиблатска пешчара“ – *Зборник радова* VII, 69-80.

Колић Б. (1969): Климатске прилике Делиблатског песка (Climate conditions of sands of Deliblato). Делиблатски песак, *Зборник радова* I, 5-34.

Nikolov N. (2006): Global Forest Resources Assessment 2005 – Report on fires in the Balkan Region. Forestry Department, Food and Agriculture Organization of the United Nations, Fire Management Working Papers, Working Paper FM/11/E, Rome (www.fao.org/forestry/site/fire-alerts/en).

Радовановић М, Gomes F. P. J. (2008): Сунчева активност и шумски пожари (Solar activity and forest fires). Географски институт Јован Цвијић, САНУ, Посебна издања, књ. 71, Београд.

Радовановић М, Дуцић В, Луковић Ј. (2007): Шумски пожари у Србији – анализа случаја 13.-19. марта 2007. године (Forest fires in Serbia-case analysis from March 13th-19th, 2007). Зборник радова са научног скупа „Србија и Република Српска у регионалним и глобалним процесима”. Географски факултет Универзитета у Београду, Природно-математички факултет Универзитета у Бањалуци, Београд-Бањалука, стр. 275-280.

Riano D, Moreno Ruiz J. A, Isidoro D, Ustin S. L. (2007): Global spatial patterns and temporal trends of burned area between 1981 and 2000 using NOAA-NASA Pathfinder. *Global Change Biology* 13: 40-50.

Running S. W. (2006): Climate Change: Is Global Warming Causing More, Larger Fires? *Science Express*, Vol. 313, no. 5789, pp. 927-928.