Impact of Drought in Serbia on Fire Vulnerability of Forests

Stanimir Živanović

Emergency Management Sector of Serbia
Belgrade, Serbia
E-mail: zivannn@mts.rs

Received: August 02, 2016 **Accepted: February 02, 2017**

Published: June 30, 2017

Abstract: *Droughts in Serbia become more and more frequent, and depending on the intensity and duration, they significantly effect on the state of the vegetation and on the creation of conditions for the occurrence of fire. Long periods of drought are typical which increases the fire risk for flammable materials. The majority of dry periods during the year, in this area, occur during the period from June to September. In recent years, drought is has been recorded in October and even in November.*

This work presents a model that allows the determination of the risk of forest fires affected by drought. The analysis is based on the meteorological data obtained from 26 meteorological stations in Serbia in the period from 1981 to 2010. For evaluation of humidity, Lang's monthly and yearly rain factor and the Standardized precipitation index (SPI) for the growing period has been used.

The aim of this study was to evaluate factors of vulnerability of forests depending on the time of occurrence and duration of the dry season with the assessment of the fire risk degree. There is a correlation between the occurrence of drought and fires in the open air. In Serbia, the danger of forest fires caused by the drought is the greatest in August and July. Particularly affected are the areas where the number of dry days is greater than 20. Some practical data and arguments presented in this paper can be used by the relevant services in assessing vulnerability of forest on fires and implementation of the necessary preventive measures. It is necessary to launch a new scientific researches and to introduce new adaptive forest management in Serbia. The goal of management is to assess the long-term impact of drought and to determine what the community can do now and in the future to respond to these threats.

Keywords: *Drought, Rain factor, Standardized precipitation index, Forest fire.*

Introduction

In recent years, on the territory of Serbia, the drought is getting more and more frequent [5-6], having a large impact on vegetation. Many researchers are dealing with the problem of drought [2, 12-15]. Today, great number of methods for the assessment and prediction of drought are being used. Drought is usually being analyzed through precipitation, its' schedule, air temperature and evaporation. One of the main reasons for the development of drought is the lack of water necessary for normal growth and development of plants during the growing season.

Schedule, type and growth, as well as the state of vegetation depend on the occurrence and duration of drought periods. Needs of plants for moisture and heat are different during the year. Different plant species as well as different organs of the same plant and even plant tissues, have specific requirements for temperature. When certain plant development will phase start and how long will it last, depends on the temperature and duration of sunshine.

For the growth of plants, beside the water and light, available minerals are important. In the lack of water, the growth is being stopped. During the drought, the plant crumble growth is reduced.

The impact of drought is small on plants with deep and spreading root system [10]. How much water will be available for certain plant, depends on the type and physical characteristics of the soil [10]. Sandy soils leak quickly, while heavy clay soils retain water. Sandy soils get faster and more heated, causing the grass vegetation dries quickly and becomes highly flammable even during light drought periods. The best is clay soil with crumble structures, having the best regulated water regime. The occurrence of drought during the growing season causes plant damage and fading. The humidity level is one of the most important factors influencing on the flammability of plants and increased risk of fire [16].

Reduced moisture level in the material creates favorable conditions for the occurrence of wildfires in forests and on the forest land. Dry flammable material contains less moisture and, therefore, catch fire easier and burns faster. Moisture content is being reduced in the early autumn, when vegetative physiological activity stops and plants begin to dry. Moisture increases during the spring and summer, when plants have high natural moisture.

One of the harmful side effects of drought is more frequent occurrence and spreading of wildfires [10]. In Serbia, forest fires with unprecedented and far-reaching effects are common [16]. The intensity of fire devastation and size of the area affected by the fires in largely depends on previous and present values of meteorological elements

Periodic occurrence of forest fires coincide with the drought period. Probability of occurrence and development of fire is minimized in the period of excess rainfall causing greater soil moisture and higher moisture level in the combustible material [4].

The aim of this work is to perform multi-criteria evaluation of fire vulnerability factors of forest fires in correlation with the drought. The big challenge of management governance is to reduce the risk and to implement the strategies for mitigation the harmful effects of drought.

Materials and methods

For the analysis, the data of ground meteorological measurements at stations in the Republic of Serbia have been used [8]. Data from 26 meteorological stations covering almost the whole territory of Serbia, has been compared. For the assessment of drought occurrence in Serbia and for analyze of the drought development process on vegetation, Lang's rain factor (RF) and standardized precipitation index (SPI) were used. Lang rain factor has included monthly and annual values of precipitation and air temperature. According to the size of the RF values of monthly degree of drought are:

- Up to 3.3 – arid (dry weather);
- From 3.3 to 5.0 – semiarid;
- From 5.0 to 6.6 – semi humid, and
- Over 6.6 – humid (wet).

According to the size of the annual index of the Lang's RF, a bioclimatic areas are classified as follows:

RF from
- 0 to 20 desert
- 20 to 40 semi deserts
- 40 do 60 steppes and savannas

} **Arid climate**

- 60 to 100 low forest
- 100 to 160 high forests

} **Humid climate**

Greater than 160 barrens and tundra } **Per humid climate**

SPI is the amount of rainfall recorded over a period of time and presented as a value of the random variable that has a standardized normal probability distribution. This index depends on the probability density function of precipitation and precipitation distribution functions. According to value of SPI, there are the following categories of moisture conditions (see Table 1).

Table 1. Categories of moisture conditions

Mark	Category Moisture Conditions	SPI values
ED	Exceptional Drought	SPI ≤ –2.326
ExD	Extreme Drought	–2.326 < SPI ≤ –1.645
SD	Severe Drought	–1.645 < SPI ≤ –1.282
MD	Moderate Drought	–1.282 < SPI ≤ –0.935
MD	Moderate Drought	–1.282 < SPI ≤ –0.935
A	Arid	–0.935 < SPI ≤ –0.524
NHC	Normal Humidity Conditions	–0.524 < SPI < +0.524
SHH	Slightly Higher Humidity	+0.524 ≤ SPI < +0.935
MIH	Moderate Increased Humidity	+0.935 ≤ SPI < +1.282
VW	Very Wet	+1.282 ≤ SPI < +1.645
ExW	Extreme Wet	+1.645 ≤ SPI < +2.326
ExcW	Exceptionally Wet	SPI ≥ +2.326

Analyses were performed for the period 1981-2010. After processing the data of the Lang's rainy factors, its application is possible in defining the risk of forest fires caused by the drought. Correlation of fire and drought appearance is analyzed on the basis of statistical indicators about the number of fires and SPI values for 2009 and 2010.

General characteristics of drought in Serbia

Territory of Serbia is exposed to frequent occurrences of drought, especially during the warmer half of the year [14]. Popovic et al. [11] report that frequency, intensity and duration of meteorological drought as a result of increased temperatures, reduced summer precipitation and more prolonged dry periods, has been increased in Serbia. Drought is, in line with the UN Convention to combat drought and desertification, defined as a natural phenomenon that occurs when precipitation deviate significantly from the normal values and cause serious changes in the hydrological balance that adversely affect land production systems.

Data drought indices for 26 measuring stations in Serbia and in aggregate for Serbia, by the Lang's method, are given in Table 2.

Monthly and annual indexes of drought are analyzed on the basis of amounts of precipitation and air temperatures [7], indicate that it is a dry regions in terms of humidity. Specifically, based on the value of the RF for the territory of Serbia, calculated value of annual average rain factor is 64.9. Values of the rainy factor measured on 7 out of 26 measuring stations were higher than the national average. One station (Kopaonik) indicates the characteristic of a per humid climate. Most stations are with an index between 50 and 60 < 15 stations or 66% of the total. This indicates that most of the territory of Serbia is with arid climate with Bioclimatic areas with steppes and savannas. According to these indicators of drought, it is evident that the lowest values are in August and July.

Table 2. The value of the rain factor for the period 1981-2010 for meteorological stations in Serbia

Station	**Month**												**Year**
	1	2	3	4	5	6	7	8	9	10	11	12	
Negotin	139.3	23.2	7.2	4.4	2.9	2.8	2.1	2.1	2.6	4.3	10.6	60.4	52.0
Zrenjanin	359	18.8	5.8	3.6	3.2	4.4	2.7	2.1	2.9	3.7	8.0	32.4	50.7
Veliko Gradište	450	28.1	6.7	4.8	3.5	4.1	2.8	2.6	3.4	4.4	8.1	36.2	57.8
Kikinda	-	19.1	5.3	3.7	3.1	3.7	2.5	2.3	3.0	3.5	8.1	42.3	49.2
Sremska Mitrovica	379	18.3	6.3	4.1	3.3	4.2	2.9	2.5	3.0	4.7	9.1	32.6	54.4
Novi Sad	195.5	19.6	6.6	4.2	3.6	4.5	2.9	2.7	3.2	4.5	9.1	32.5	56.8
Sombor	-	21.4	5.9	3.9	3.5	4.0	3.0	2.5	3.3	4.2	9.9	43.1	54.7
Zaječar	-	33.2	6.9	4.7	3.1	2.8	2.5	2.0	2.7	4.4	10.9	77.1	52.9
Palić	-	23.3	5.7	3.8	3.2	3.9	2.6	2.4	3.0	3.5	8.9	58.1	51.0
Beograd	33.5	12.9	6.5	4.3	3.2	4.8	2.7	2.6	3.1	3.9	7.8	21.3	55.3
Kraljevo	150.3	19.7	7.8	5.3	4.3	4.7	3.5	3.0	3.5	4.9	9.4	35.1	64.4
Požega	-	104.8	8.6	5.7	4.9	4.8	3.8	3.1	4.4	5.6	15.5	-	74.9
Kopaonik	-	-	-	44.4	15.1	10.1	7.2	6.3	9.8	13.6	-	-	273.4
Leskovac	-	26.9	7.2	5.3	3.4	3.3	2.0	2.2	3.2	4.6	11.3	39.4	56.3
Smederevska Palanka	60.6	18.7	6.7	4.2	3.2	3.9	2.8	2.7	3.4	4.4	8.1	27.3	55.4
Ćuprija	230.5	28.4	7.4	5.3	3.8	4.1	2.7	2.2	3.2	4.4	9.3	37.7	59.3
Vranje	-	21.3	6.0	4.6	3.5	3.2	2.1	2.0	2.8	4.4	10.1	42.1	52.1
Valjevo	83.2	22.3	8.8	5.2	4.3	5.5	3.2	3.3	3.9	5.4	10.3	31.9	69.1
Zlatibor	-	-	30.6	11.0	7.7	7.2	5.6	4.5	7.5	8.9	28.8	-	132.1
Kruševac	201.5	19.6	7.3	4.8	3.4	3.6	2.5	2.3	3.0	4.3	9.5	34.4	55.1
Kragujevac	42.1	16.1	6.4	4.6	3.5	3.8	2.6	2.7	3.1	4.1	7.7	21.8	53.3
Sjenica	-	-	25.8	8.6	6.2	5.4	4.1	3.8	6.4	8.0	33.7	-	111.9
Loznica	74.1	19.2	9.5	5.3	4.6	5.4	3.9	3.5	4.1	6.2	11.8	31.6	74.8
Dimitrovgrad	-	63.5	8.0	5.4	4.5	3.8	3.0	2.7	3.4	4.8	10.6	58.6	62.5
Niš	64.7	15.3	6.1	4.6	3.4	2.8	2.0	2.1	2.8	3.7	8.6	24.5	48.8
Crni Vrh	-	-	62.8	11.3	6.6	6.3	4.1	3.6	5.6	9.1	38.5	-	115.2
Srbija	-	41.1	8.5	5.3	4.1	4.4	3.0	2.7	3.6	4.0	11.4	69.1	64.9

Assessment of drought during different periods can be displayed using indicators of moisture conditions. SPI is applicable indicator of moisture conditions which can be reached on the basis of data of precipitation [3]. SPI values indicate moisture reserves in the surface layer of soil, which is important for the possibility of the vegetation fire. The drought occurs every time when the SPI is continuously negative and reaches an intensity of −1.0 or less.

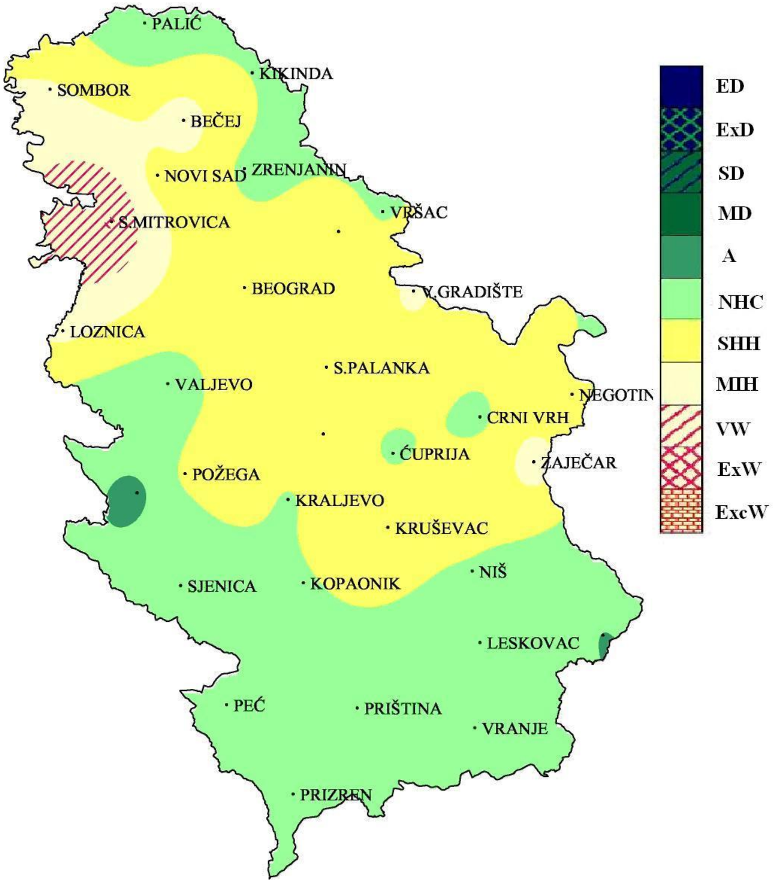

Fig. 1 Characteristics of moisture conditions in the vegetation period for 2009, estimated on the basis of SPI-6 in September

Evaluation of moisture conditions during the vegetation period on the territory of Serbia, based on SPI values, is shown in the Fig. 1 and Fig. 2 [7]. In Fig. 2, we can see that most of the areas of Serbia during the 2010 have been with the normal moisture conditions. Certain areas of Serbia, on the basis of SPI, were very wet, while only the areas of Negotin and Sjenica were dry. SPI changes for 2009 are visible in Fig. 1 when most of the territory of Serbia was defined as dry. In the area of Sremska Mitrovica, strong drought was evidenced.

The dynamics of fires

The appearance of fire in the area of Serbia is different from period to period [1]. Fig. 3 shows the number of fires in the open air during the growing season 2009- 2010 [9]. Analyze of the number of fires on the territory of Serbia shows a significant difference in the number of fires in 2009th, compared with the 2010th. In fact, during the vegetation period in 2010, the number of fires in the open air was reduced for approximately 50.9% compared to 2009. Analyze also shows that the higher number of fires was evidenced in the second half of the vegetation period.

The highest number of fires in the open air in Serbia was registered at the beginning and at the end of the growing season.

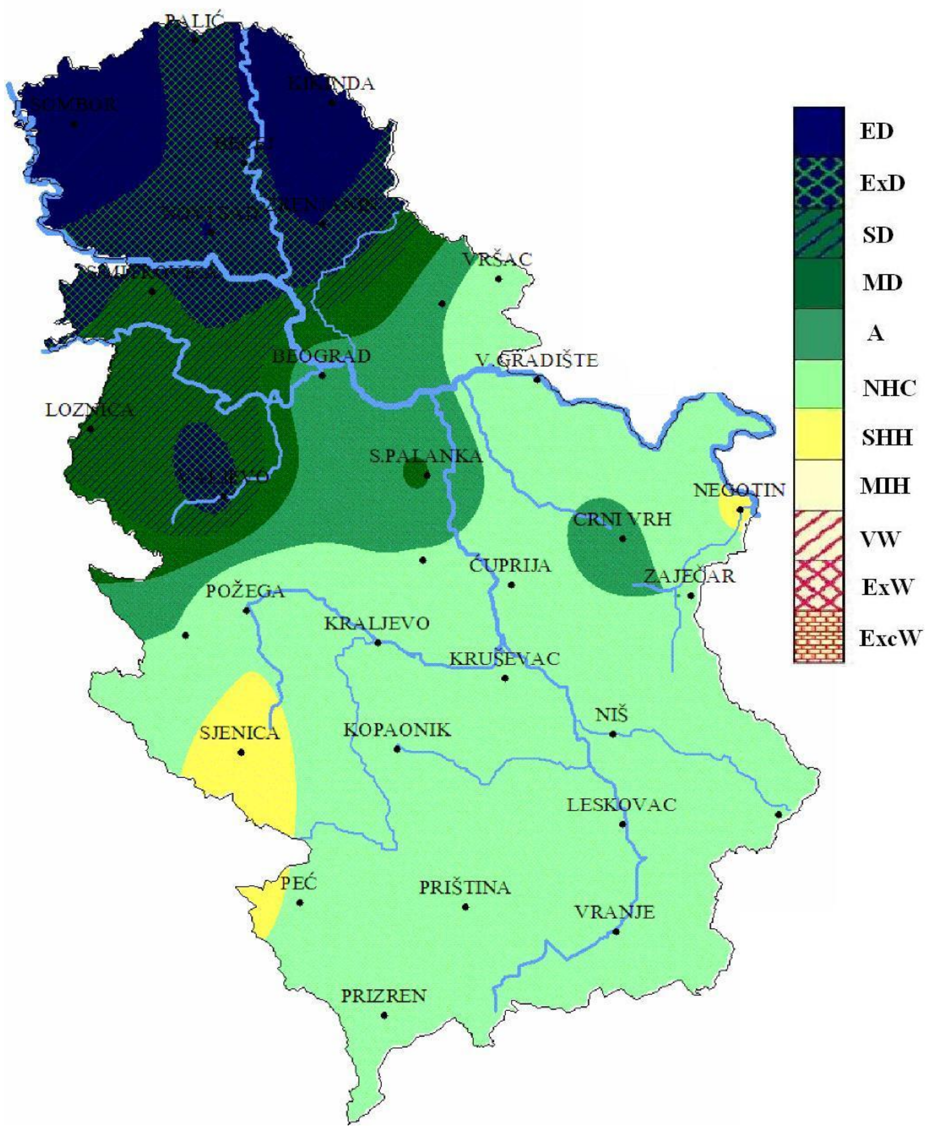

Fig. 2 Characteristics of moisture conditions in the vegetation period for 2010, estimated on the basis of SPI-6 in September

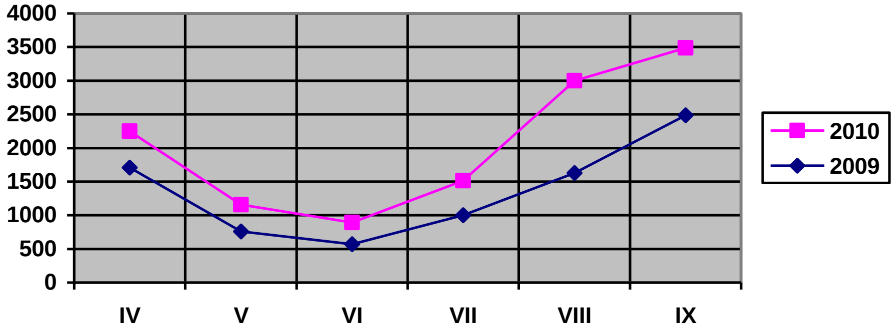

Fig. 3 Number of fires in the open air during the vegetation period

The dynamics of fires occurrence positively correlates with the period when the SPI is with low intensity, Table 3. Table 3 shows significant difference in the number of fires in certain area, depending on the moisture conditions. In fact, the greater the difference of moisture conditions are, the greater is the difference between the numbers of fires increased. The largest number of fires in the area occur if the value of SPI-6 is lower. The minimum percentage deviation in the number of fires is recorded if the humidity conditions (Negotin) are stable or with a small differences in humidity (Kruševac).

Table 3. The occurrence of fire depending on moisture conditions

Territory	**Humidity conditions (SPI-6 for September)**		**Number of fires during the growing season**	
	2009	**2010**	**2009**	**2010**
Sremska Mitrovica	Severe Drought	Very Wet	447	192
Novi Sad	Arid	Exstremely Wet	681	353
Zaječar	Moderate Drought	Normal humidity conditions	237	146
Kruševac	Arid	Normal humidity conditions	181	153
Negotin	Arid	Arid	73	78

Selection criteria and methods for evaluating the impact of drought on the aspect of risk of forest fires

On the basis of performed identification of the aspects of drought, it is necessary to define the criteria for evaluating the significance of their impact on the risk of forest fires.

Evaluation of significance of drought is the process of determining the significance of drought on the probability of fire occurrence and the expected speed of uncontrolled fire growth and spreading. The significance of the drought impact on the risk of forest fires relative term, and as such it cannot be defined in absolute values. Criteria for drought levels (values) of significance are determined. In this case, the method of ranking significance in relation to the calculation of the risk of forest fires, was applied, Tables 4 and 5.

Table 4. Factor significance periods of drought (FSPD)

Period	**The fire incidence estimation**	**Mark**
July and August	expected high rate of fire	3
May, June, September, October,	expected average rate of fire	2
January, February, March, April, November, December	expected low incidence of fire	1

Table 5. Factor significance of the length of the dry season (FSDS)

Number of dry days	**The fire incidence estimation**	**Mark**
more than 20	expected high rate of fire	3
from 10 to 20	expected average incidence of fire	2
up to 10	expected low incidence of fire	1

Assessment of risk of forest fire under the impact of drought presents evaluation of the impacts of drought periods occurrence and length of the dry period. The most vulnerable periods are within months July and August because of high air temperatures and reduced precipitation. The Table 2 shows that the drought indexes, determined by the method of Lang, are at the lowest level in these months at all measuring points in Serbia.

As the second period, may be determined period within September, October, May and June, when the drought index values indicate that these are semiarid months on the basis of long-term average.

From the point of drought, based on Lang-s index, the least affected period is from November to April. For most plants, this is a period of reduced physiological activity.

Length of the dry period, based on the number of dry days, is defined as:

- Short – 10 days;
- Medium – 10 to 20 days, and
- Long – more than 20 days.

The overall risk factor of forest fires in terms of drought is being evaluated considering the influence of the elements of drought appearance and the number of drought days, ranking from the lowest up to the highest influence. The risk of forest fires labeled R from the aspect of drought is calculated as the product of the factor of Significance of Occurrence of Drought Periods and the Significance of the Length of the Dry Period, as follows:

$$R = FSPD \times FSDS \quad (1)$$

Based on this classification, risk of forest fires (R) can be determined from small to medium to high, as follows:

$1 \le R \le 2$ – small;
$3 \le R \le 4$ – medium;
$6 \le R \le 9$ – great.

Solving Eq. (1) leads to the data shown in Table 6. Weight consequences for the wood for the drought stress is the largest in the July-August, if the length of the dry period is more than 20 days, Table 6. According to this model, the risk of forest fires, caused by the drought is on the lowest level during the period from November to April when the length of the dry period is shorter than 10 days.

Table 6. Risk assessment matrix

Period	**Length of the dry period (day)**		
	up to 10	**from 10 to 20**	**over 20**
January, February, March, April, November, December	1	2	3
May, June, September, October	2	4	6
July, August	3	6	9

Conclusion

In Serbia, drought is very important for the creation of conditions for the occurrence of fire, due to its influence on the state of vegetation. The impact of drought is manifested in different vegetation, depending on the occurrence of drought periods and the number of dry days.

The degree of risk of appearance of forest fires is not the same in January, for example, and in July and August, when, due to the high temperature, the risk is greater. The danger of fire is greater if a drought is longer, especially during periods when the air temperature is extremely high. The results show correlation between the dynamics of the fires and the index that indicates the content of moisture in the surface of soil layer and thus the moisture content of dead fuels. Periods of fire are time matched with the drought period.

Analysis of drought occurrence and analysis of its effects on vegetation, provides evaluation of fire vulnerability of forest vegetation. The paper outlines the risk factors of forest fire in terms of drought significantly may be useful to the competent services of fire protection. Expected climate change will effect on increasing the number of drought periods and increasing the number of dry days. The expected changes create the need to develop appropriate strategies for adaptation to climate changes, which will contribute further development of the forest fire protection.

Effective monitoring of the impact of drought on vegetation in this region is crucial for the prediction and management of forest potential. If the effects of drought on vegetation implement the risk assessment of forest fires, such approach can minimize adverse effects.

Genetic and bioengineering researches can have significant role, including researches of new plant varieties which, in some extent, can compensate unfavorable microclimatic conditions, and thus affect the frequency of occurrence and development of fires.

References

1. Aleksić A., M. Krstić, G. Jančić (2009). Forest Fires-ecological and Economic Problem in Serbia, Botanica SERBICA 33-2, Belgrade, 169-176.
2. Allen C. D., A. K. Macalady, H. Chenchouni, D. Bachelet, N. McDowell, M. Vennetier, T. Kitzberger, A. Rigling, D. D. Breshears, E. H. (T.) Hogg, P. Gonzalez, R. Fensham, Z. Zhang, J. Castro, N. Demidova, J.-H. Lim, G. Allard, S. W. Running, A. Semerci, N. Cobb (2010). A Global Overview of Drought and Heat-induced Tree Mortality Reveals Emerging Climate Change Risks for Forests, Forest Ecology and Management, 259(4), 660-684.
3. Collecience A., G. D. Mauro, B. Bonaccorso, G. Rossi (2007). Drought Forecasting Using Standardized Precipitatinin Index, J Water Resources Management, doi: 10.1007ISL 1269-9062-y.
4. Ćurić M., S. Živanović (2013). Dependence between Deficit and Surplus of Precipitation and Forest Fires, Disaster Advances, 6(6), 64-69.
5. Gocic M., S. Trajkovic (2013). Analysis of Precipitation and Drought Data in Serbia over the Period 1980-2010, Journal of Hydrology, 494, 32-42.
6. Gocic M., S. Trajkovic (2014). Spatiotemporal Characteristics of Drought in Serbia, Journal of Hydrology, 510, 110-123.
7. http://www. hidmet.gov.rs / (Access date 15 March 2017)
8. Meteorological Yearbook 1: Climatoligaical Data, for Period 1981-2010 Year, Hidrometeorological Institute of Serbia.
9. Ministry of Interior of the Republic of Serbia, Internal Documents, The Register of Fires from 2009 to 2010.
10. Otorepec S. (1991). Agrometeorology, Scientific Book, Belgrade.
11. Popovic T., V. Djurdjevic, M. Zivkovic, B. Jovic, M. Jovanovic (2009). Climate Change in Serbia and Expected Impacts, EnE09-Environment, siepa.gov.rs.

12. Riley L. K., T. J. Abatzoglou, C. I. Grenfell, E. A. Klene, A. F. Heinsch (2013). The Relationship of Large Fire Occurrence with Drought and Fire Danger Indices in the Western USA, 1984-2008: The Role of Temporal Scale, International Journal of Wildland Fire, 22(7), 894-909.
13. Sekulic G., D. Dimović, Z. Kalmar, K. Jovic, N. Todorovic (2012). Assessing Vulnerability to Climate Change – Serbia, WWF (World Wildlife Fund), Center for the Advancement of Environment, Belgrade.
14. Spassov P. (2003). Droughts in Serbia, Its Monitoring and Prediction Capabilities, Water, 35(1-2), 30-36.
15. Spathelf P., E. van der Maaten, M. van der Maaten-Theunissen, M. Campioli, D. Dobrowolska (2013). Climate Change Impacts in European Forests: The Expert Views of Local Observers, Annals of Forest Science, doi: 10.1007/s13595-013-0280-1.
16. Zivanovic S. (2010). Risk Factors for Forest Fire, Safety Belgrade, 52, 179-190.

Stanimir Živanović, Ph.D.
E-mail: zivannn@mts.rs

Stanimir Živanović was born in 1960. He obtained B.Sc., M.Sc. and Ph.D. from the Faculty of Occupational Safety in Niš, Serbia. He worked in the Ministry of Internal Affairs Emergency Management, Department in Bor as a fire safety specialist, from 1983 to 2013. He is an author and co-author of three monographs, over twenty scientific papers published in international journals and scientific conferences. His research interests involve fire protection and environmental protection.