www.gi.sanu.ac.rs, www.doiserbia.nb.rs
J. Geogr. Inst. Cvijic. 2022, 72(2), pp. 221–228

Research note

UDC: 911.2:504.4(497.11)
https://doi.org/10.2298/IJGI2202221Z

Received: March 4, 2022
Reviewed: April 19, 2022
Accepted: June 21, 2022

FOREST FIRES IN SERBIA—INFLUENCE OF HUMIDITY CONDITIONS

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Abstract: This study focuses on the possible impact of forest fires on the destruction of forests in Serbia. The variability of forest fires in NUTS 3 regions in Serbia was investigated. By analyzing the data for the period from 2009 to 2018, it can be concluded that there were pronounced oscillations in the number of forest fires and the size of the burned forest areas. It was determined that during the observed period, the maximum number of fires was recorded in 2012, and the minimum in 2014. The largest burned forest areas were 7,460 ha in 2012 and 2,036 ha in 2011, which is correlated with high air temperatures and lack of precipitation. The damage caused in the forest fire, expressed in m^3 for the felled wood mass is the highest in 2012 and the lowest in 2010. The greatest threat to forest fires were in Raška oblast (Užice) and Zlatiborska oblast (Kraljevo), and the lowest were in Severnobanatska oblast (Kikinda), Zapadnobačka oblast (Sombor), and Srednjobanatska oblast (Zrenjanin). The correlation of forest fire occurrence dynamics and humidity conditions were observed on the basis of statistical indicators of the number of forest fires and the values of Standardized Precipitation Index (SPI). The number of forest fires, depending on the influence of humidity conditions is the highest in the dry season.

Keywords: forest fire; burned area; destruction of forests; SPI; Serbia

1. Introduction

Forest fires are common occurrence in Serbia which directly and indirectly trigger the economic and environmental effects and cause significant material damage. According to Sekulić et al. (2012), fires can pose a serious threat to certain ecosystems and species. The size of the area affected by wildfires can affect the sustainable management of forest resources (Aleksić et al., 2009; Banković et al., 2009). In some years, the size of the forest area affected by the fire is larger than the existing forest areas, which calls into question the provision of easy reproduction in the country's forestry.

Fire regimes are strongly related to weather conditions that directly or indirectly affect the ignition and spread of fires (De Angelis et al., 2015). Climatic conditions affect vegetation and thus determine the length of the fire season. Variability of climatic elements indicate when and to what extent there is a risk of forest fires. On a regional scale, atmospheric circulation determines climatic elements that affect fires, and these are winds, precipitation,

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relative humidity, soil moisture, and air temperature (Amraoui et al., 2014; Pereira et al., 2005). The most favorable conditions for forest fires in Serbia are high air temperatures, low relative humidity, wind, and lack of precipitation (Tošić et al., 2020; Tošić et al., 2019). Malinovic-Milicevic et al. (2016) state that trends in the duration of extreme temperatures and small amounts of precipitation are most pronounced in the summer season. Such conditions increase the risk of forest fires. Many studies have found the connection between the number of forest fires and the influence of atmospheric oscillations (Monteiro et al., 2014; Radovanović et al., 2019). The distribution and amount of precipitation increase the humidity of the combustible material which reduces the risk of fire (Ćurić & Živanović, 2013). The water content in combustible material is used as a key variable in the fire risk models (Bradshaw et al., 1984; Van Wagner, 1987). The damage caused by fire depends on the area affected by the fire, the value of the forest, and the type of fire (Aleksić et al., 2009). In crown fires, the damage caused is complete and it is necessary to cut down trees on burned area as soon as possible (Vasić, 1992).

The aim of this research is to indicate the relationship between humidity/dryness conditions and the frequency of forest fires using the Standardized Precipitation Index (SPI). The objectives are to point out the importance of climatic conditions related to the risk of forest fires. Data on the number of fires by regions in Serbia are presented, and based on that, parts of the country where a higher number of fires occur during the year. Also, the size of burned area and the negative effects of forest fires on the destruction of forest resources in Serbia are shown.

2. Materials and methods

For the purposes of this paper, the data of forest cover in the areas of NUTS 2 (region) and NUTS 3 (oblast) in Serbia for the period from 2009 to 2018 were used (Statistical Office of the Republic of Serbia [SORS], 2010a–2019a). As there are no data for the territory of the Province of Kosovo and Metohija (the territory under United Nations Security Council Resolution, No. 1244; United Nations, 1999), they are not included in the data for Serbia (total).

Fire damage was expressed in ha of burned area and in m^3 for felled wood. The cut wood mass means the damaged wood mass measured on the stump in the deepening state. The burned area (ha) and the damaged wood mass (m^3) are divided into areas damaged by surface fires and areas damaged by crown fires. The endangerment of forests by fire was assessed based on statistical data of the registered number of forest fires in NUTS 3 regions in Serbia for the period from 2009 to 2018 (Ministry of Interior of the Republic of Serbia, Emergency Management Sector, n.d.)

Indicator for climate patterns that is used to describe excess or deficit of precipitation over time is the SPI (McKee et al., 1993). This index characterizes humidity/drought conditions. To calculate this index, data on the amount of precipitation during a certain period of time are used, represented by the value of a random variable that has a normal probability distribution. The values of the SPI index are determined for different time periods and are suitable for estimating humidity and analyzing fluctuations and changes in precipitation. The SPI index is used worldwide as a tool in drought monitoring, the analysis of fire danger rating and fire management (Adib et al., 2020; Hafni et al., 2022). For this research, data on the SPI index were taken from the Republic Hydrometeorological Service of Serbia (RHSS, 2021), for the period 2009–2018.

3. Study area

The territory of Serbia is located in the central part of the Balkan Peninsula covering an area of 88,499 km^2 (SORS, 2020). About 2,252,400 ha or 29.1% of the total area of the territory of Serbia is under forests, 1,194,000 ha or 53.0% of which are state-owned and 1,058,400 ha or 47.0% are private-owned (Banković et al., 2009). Forest cover in the area of districts in Serbia are shown in Table 1.

The average annual precipitation in Serbia ranges from 500 to 600 mm in the northern and northeastern parts of Serbia to over 1000 mm in the high mountainous areas of southwestern Serbia. The maximum precipitation is in June (for majority stations in Serbia) and minimum in February (Milovanović et al., 2017). It was found that there is a statistically significant increase in average annual temperatures in the summer and winter months for the period 1961–2010 at stations in Serbia (Milovanović et al., 2018).

4. Results and discussion

4.1. Forest fires in Serbia for the period 2009–2018

Data from the SORS on forest cover in the areas of NUTS 3 regions indicate a pronounced inequality in the forest area of certain areas in Serbia. There is a markedly low forest cover in the Region Vojvodine, the least in Severnobanatska oblast (1.1%). The highest forest cover is in Pčinjska oblast (52.3%; Table 1). The dynamics of forest fires in Serbia in the period from 2009 to 2018 is shown in Table 1. For the period 2009–2018, the occurrence of forest fires is most pronounced in the city areas of Užice, Novi Pazar, and Prijepolje (Table 1). The smallest number of fires is in the Region Vojvodine (Kikinda, Zrenjanin, and Sombor) where the forest cover is the lowest. On the territory of Serbia, out of the total number of fires in the analyzed period, 26.9% occurred in 2012. According to Tošić et al. (2019), the year 2012 was with the longest heat wave and the worst drought. In 2011, 2012, and 2017, conditions were severely dry, which caused a large number of forest fires and large burned forest areas, which is in line with the data of this research. The lowest number of forest fires was in 2014 and 2016. During 2014, 185 forest fires were registered compared to 2012 when 1,354 fires were recorded on the territory of Serbia. The values of the SPI index show that in most meteorological stations in Serbia in 2014 there were extremely humid conditions, and in 2016 they were extremely humid (in Pčinjska oblast and Nišavska oblast), very humid (Region Šumadije i Zapadne Srbije), or moderately humid (other areas), which indicates increased humidity and reduced number of fires in those years.

Table 1. Forest cover in NUTS 3 regions (at the end of 2017) and the number of forest fires in their headquarters in Serbia (2009–2018)

Oblast	FC (%)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	∑
Region Vojvodine												
Južnobačka (Novi Sad)	6.6	6	2	6	13	0	1	1	0	2	4	35
Južnobanatska (Pančevo)	5.5	5	1	9	38	1	0	1	2	2	6	65

Table 1. Forest cover in NUTS 3 regions (at the end of 2017) and the number of forest fires in their headquarters in Serbia (2009–2018) (*Continued*)

Oblast	FC (%)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	∑
Region Vojvodine												
Severnobačka (Subotica)	2.1	4	5	4	12	1	1	2	2	3	0	34
Severnobanatska (Kikinda)	1.1	0	0	1	0	1	3	2	0	2	1	10
Srednjobanatska (Zrenjanin)	2.0	2	0	1	11	6	0	1	0	0	1	22
Zapadnobačka (Sombor)	5.4	5	3	0	1	1	0	1	1	2	0	14
Sremska (S. Mitrovica)	16.0	6	1	1	24	7	1	3	0	6	2	51
Beogradski region												
Beogradska	19.2	12	12	34	51	9	23	10	4	35	16	206
Region Južne i Istočne Srbije												
Borska (Bor)	44.4	23	8	25	52	5	1	24	14	25	1	178
Braničevska (Požarevac)	29.6	3	2	7	8	4	4	8	0	2	8	46
Jablanička (Leskovac)	51.4	14	12	23	46	6	1	4	3	0	0	109
Nišavska (Niš)	38.4	4	9	10	24	4	8	7	5	19	5	95
Pčinjska (Vranje)	52.3	4	11	44	80	19	9	16	9	32	32	256
Pirotska (Pirot)	37.5	38	9	48	38	14	10	12	1	20	5	195
Podunavska (Smederevo)	8.3	6	2	7	37	7	0	4	1	8	1	73
Toplička (Prokuplje)	46.0	46	10	65	111	40	28	22	20	36	23	401
Zaječarska (Zaječar)	39.2	9	5	18	17	3	0	6	6	19	1	84
Region Šumadije i Zapadne Srbije												
Kolubarska (Valjevo)	24.9	8	11	18	68	19	3	11	2	28	15	183
Mačvanska (Šabac)	23.8	23	1	20	44	12	1	22	8	21	7	159
Moravička (Čačak)	39.9	38	15	59	86	30	11	26	13	47	13	338
Pomoravska (Jagodina)	41.0	6	8	10	13	1	2	8	1	11	8	68
Rasinska (Kruševac)	35.1	16	10	32	74	25	5	25	13	43	16	259
Zlatiborska (Užice)	42.2	40	18	69	148	36	20	53	31	136	30	581
Zlatiborska (Prijepolje)		43	27	58	87	34	18	42	28	89	29	455

Table 1. Forest cover in NUTS 3 regions (at the end of 2017) and the number of forest fires in their headquarters in Serbia (2009–2018) (*Continued*)

Oblast	FC (%)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	∑
Region Šumadije i Zapadne Srbije												
Raška (Novi Pazar)	51.2	19	38	66	109	37	23	47	40	92	32	503
Raška (Kraljevo)		19	10	43	54	28	7	16	3	35	15	230
Šumadijska (Kragujevac)	29.6	9	24	56	108	14	5	15	8	45	20	304
∑		408	254	734	1,354	364	185	389	215	760	291	4,954
%		8.3	5.2	15.0	26.9	7.4	3.4	7.9	4.4	15.5	5.9	100

Note. FC = forest cover; ∑ = total. Data on FC were calculated on the bases of the data from "Municipalities and Regions of the Republic of Serbia" [Annual statistics from 2009 to 2018], by the Statistical Office of the Republic of Serbia, 2010b–2019b (https://www.stat.gov.rs/sr-cyrl/publikacije/?d=13&r). In the public domain; *Number of fires, burned area in state forest of Serbia for the period 2009–2018* [Unpublished data], by Ministry of Interior of the Republic of Serbia, Emergency Management Sector, n.d.

4.2. General characteristics of humidity conditions and SPI index

Although normally present, drought causes many negative consequences around the world in the territories with very different climates. Drought is present in the entire territory of Serbia, but with different intensity. Drought conditions negatively affect the vegetation, which causes the dryness of the fuel material and a higher probability of fire (Spasov, 2003). Researches confirm that humidity/drought conditions have a great impact on the occurrence and number of forest fires (Adib et al., 2020; Hafni et al., 2022; Tošić et al., 2019). Table 2 shows the humidity conditions calculated based on the value of the SPI index in meteorological stations of the regions of Serbia.

Table 2. Moisture conditions estimated on the basis of SPI index by regions in Serbia (2009–2018)

Region	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Vojvodine	US	EV	JS	ES	N	EV	US	UV	US	N
Beogradski	S	UV	US	US	US	EV	S	N	US	N
Južne i Istočne Srbije	N	UV	ES	S	ES	EV	US	JV	US	N
Šumadije i Zapadne Srbije	N	UV	US	IS	ES	EV	US	JV	S	JV

Note. Estimation based on methodology used by the RHSS. IS = exceptional drought (SPI ≤ –2.326); ES = extreme drought (–2.326 < SPI ≤ –1.645); JS = severe drought (–1.645 < SPI ≤–1.282); US = moderate drought (–1.282 < SPI ≤ –0.935); S = minor drought (–0.935 < SPI ≤ –0.524); N = near normal (–0.524 < SPI < +0.524); UV = moderately increased moisture (+0.935 ≤ SPI < +1.282); JV = considerably increased moisture (+1.282 ≤ SPI < +1.645); EV = extremely wet (+1.645 ≤ SPI < +2.326).

Forest fires are very susceptible to occurrence when the SPI index is negative. Based on the result of the SPI index in Serbia, the lowest drought value indices were in 2012 and 2011, indicating extreme and severe drought (Table 2). In 2012 a large number of forest fires was recorded as well as the largest burned areas (7,460 ha) and damaged wood mass (63,118 m^3; Table 3). On the other hand, during 2014, the conditions were extremely humid on the territory of the entire country, except for the north of Banat, where the conditions were moderately humid, which coincides with the small number of forest fires and burned areas (only 284 ha) in all regions. Thus, the correlation between humidity, the number of forest fires, burned forest areas, and the forest cover is obvious, which was confirmed by this research.

4.3. Damage caused by forest fires

Statistical data indicate that in the investigated period, 14,482 ha (or 1.55%) of forest were burned in fires on the territory of Serbia. The most common occurrences are surface fire, which affected 59.3% of the burned area. The occurrence of crown fires, which affect the crowns of forest trees, is not common and covers 40.7% of the burned area. The largest total burned area in forests were during 2012 and 2011 which is in line with the large number of fires in those years. Also, the lowest number of forest fires and burned area was recorded in 2014, when conditions were extremely humid throughout Serbia (Table 3).

Table 3. Damages caused by fire in Serbia, period 2009–2018

Years	Burned area (ha)			Damaged wood volume (m^3)		
	Overall	Surface fire	Crown fire	Overall	Surface fire	Crown fire
2009	1,210	1,010	200	1,932	249	1,683
2010	503	488	15	57	57	0
2011	2,036	1,570	466	24,570	4,360	20,210
2012	7,460	2,820	4,640	63,118	5,689	57,429
2013	561	400	161	7,343	2,170	5,173
2014	284	138	146	10,256	9,761	495
2015	827	723	104	5,059	3,889	1,170
2016	296	291	5	37,114	37,114	0
2017	1,002	850	152	11,415	4,518	6,897
2018	303	298	5	707	428	279
Total	14,482	8,588	5,894	161,571	68,235	93,336

Note. Data are from "Bulletin – Forestry in the Republic of Serbia" [Annual statistics from 2009 to 2018], by the Statistical Office of the Republic of Serbia, 2010a–2019a (https://www.stat.gov.rs/sr-Latn/publikacije/?a=13&s=1304&d=5&r=). In the public domain.

Using the insight into the data related to the burned area per one forest fire, it can be seen that the largest burned area per one fire was recorded in 2012, when 18.1 ha of state forests per one fire burned (Ministry of Interior of the Republic of Serbia, Emergency Management Sector, n.d.). The smallest burned area per fire was recorded in 2014, when 4.33 ha were affected. Between 2009 and 2018, a total of 4,954 fires were recorded while the burned area amounted to 14,482 ha. Damaged wood mass during the research period was 161,571 m^3, where the most of the area was destroyed in crown fires. Forest fires are among the greatest ecological threats in Europe, especially in the Mediterranean countries, and represent one of the important factors that cause the destruction of forests (Chaparro et al., 2016; Pereira et al., 2005; San-Miguel-Ayanz et al., 2013). Also, forest fires represent a considerable risk of natural disasters in Serbia (Dragicevic et al., 2011) and are a significant environmental and economic problem in Serbian forestry (Aleksić et al., 2009).

5. Conclusion

Forest fires in Serbia are one of the important factors in the destruction of the environment. During the period 2009–2018, the number of forest fires, the size of the burned forest area, and the damaged wood mass vary significantly from year to year. Years with severe drought have greater harmful consequences than forest fires. Extremely humid periods reduce the risk of fire. Surface fires cause more damage compared to fires that affect the crowns of forest trees.

The analysis of data on the number of forest fires indicates that the highest risk of forest fires is in Zlatiborska oblast (Region Šumadije i Zapadne Srbije) due to the high rate of afforestation. Also, humidity index values indicate that the highest degree of danger from forest fires is in the period with reduced humidity level. Identifying areas where forests are at high risk of fire is useful information in order to make appropriate decisions. Taking appropriate measures in forest management can significantly reduce the destruction of the environment from the effects of forest fires.

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