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A DAMAGE ANALYSIS OF WILDFIRES IN THE REPUBLIC OF SERBIA FOR THE 2010-2014 PERIOD

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ABSTRACT: *The topic of this paper is the analysis of wildfires that occurred in both private and state forests in the territory of the Republic of Serbia during the 2010-2014 period. A total of 428 fires has been registered, with a burned area of 10,844 ha, and 105,344 m³ of woody mass damaged. In terms of damage and consequences, wildfires are a global issue and demand the involvement of all institutions and social actors, as well as significant funding for their suppression and rehabilitation of burned areas. Wildfires are one of the most common natural disasters in the Republic of Serbia and present the main economic problem of our forestry, because they destroy vast forest areas, and at the same time are a major environmental issue. The goal of this paper is to draw attention to the frequency and consequences of wildfires and to highlight the importance of forests as a natural resource. Education of the population, especially the younger generations, is one way of reducing the risk of wildfires, because we must not forget that in over 95% of cases wildfires are caused by human activities.*

Keywords: *wildfires, Serbia, burned area, natural disaster*

INTRODUCTION

The forest represents a multilayered, extremely dynamic ecosystem of great importance that has a complex impact on the functioning of the entire planet. The impact of forest ecosystems on the functioning of the biosphere is so great that without forests there would be no life on Earth, at least not in a form that we are familiar with. The complexity of forests is reflected primarily in stratification and diverse interconnectedness of all members of the environmental community. The role of forests in the exchange of gases in the atmosphere is well known. Trees absorb huge amounts of carbon dioxide during the process of photosynthesis, while a large amount of oxygen is returned back to the atmosphere. It has been determined that the role of forests in purifying pollut-

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ed atmosphere is even more important than the function of oxygen production. In this way, forests prevent or at least slow down the greenhouse effect and global warming, and therefore the changing of climatic conditions. Without forest ecosystems, the process of deforestation and gradual formation of deserts would begin very quickly, as has already happened in many parts of the world (www.msb.gov.ba).

Forests cover an area of 4 billion hectares, which makes up 30% of the total surface of the Earth. In Europe, 193 million ha is covered by forests, or 34% (without Russia) (Aleksić et al., 2009). The total forest area in Serbia amounts to 2,252,000 ha, of which 1,194,000 ha, or 53% are state forests, and 1,058,387 ha, or 47% are privately owned forests. Serbia is considered a medium-wooded country. Of the total area of its territory, 29.2% (7.1% in Vojvodina and 37.6% in central Serbia) is under forest cover. Forest coverage is close to the global average, which is 30%, but it is significantly lower than European average, which reaches 46%. In relation to the population forested area amounts to 0,3 ha per capita (www.srbijasume.rs).

Wildfires are the most extreme form of devastation or complete destruction of forests. In terms of damage and consequences, as well as areas that are destroyed every year, wildfires are a global issue and demand the involvement of all institutions and social actors in an effort to prevent and extinguish them. More than 50,000 wildfires occur each year worldwide (Aleksić, Jančić, 2011). They destroy an average of more than 40 million ha of forests, which results in a large number of casualties, reduces the number of wild animals etc. (Lukić et al., 2017).

Wildfires are a natural disaster. Based on the definition and classification of natural disasters done by two organizations: the Centre for Research on the Epidemiology of Disasters (CRED) and Munich Reinsurance Company (Munich RE), wildfires are classified into a group of climatological natural disasters. It should be noted that in the Republic of Serbia wildfires are among the most common natural disasters (Lukić et al., 2013).

The causes of these natural disasters are usually attributed to the irresponsible behavior of man. More specifically, about 5% of fires are attributed to natural causes, and 95% of fires are caused by human activities such as negligence, agricultural work and pyromania (Radovanović, Pereira Gomes, 2008).

Education of the population, especially the younger generations, is one way of reducing the risk of wildfires. The aim of this paper is to show the frequency of wildfires for the 2010-2014 period.

WILDFIRES

Wildfire is a result of physical and chemical processes, when a fuel material, a source of heat and air come together in the necessary combination to provide fire conditions, the so-called "fire triangle". Factors that have decisive influence on the behavior and development of wildfires are: combustible materials, climate and topography (terrain configuration, exposition, altitude and slope of the terrain) (Keller, Blodgett, 2008).

There are several types of fires that can occur in forests: ground, surface (low), crown (high) fires and fires referring to the lonely tree (Markov et al., 2010).

Ground fires occur rarely and during these events, peat and humus beneath the forest litter are burning (smoldering). They are difficult to detect and extinguish, and cause damage primarily to the roots of trees. Surface fires are the most common type of wildfire, which in most cases occur as the beginning of all other types of fire. They are the most damaging in young stands, while in the older lead to the damage of the bark and trees in the bud. Crown fires affect the whole tree and backed by the wind quickly spread and destroy large areas of forest, mainly coniferous (Aleksić, Jančić, 2011). Forests are differently affected by the wildfires. Coniferous stands are much more susceptible to ignition and burning due to the presence of resin and essential oils, and they easily burn even when they are green. Next groups susceptible to ignition are mixed stands and hardwoods. In terms of species, the most endangered are the white and black pine, larch, spruce, while the oak is the most sensitive of the hardwoods, sessile oak in particular. Susceptibility is significantly higher in younger stands (Živojinović, 1957).

Damage caused by wildfires can be economic and environmental. Economic damage includes costs, which are necessary for firefighting, damage caused by the fire itself, and the cost of rehabilitation and reconstruction of destroyed forests. Environmental damage manifests itself many years after the fire, and it is incalculable. Common practice is to assess its value five or ten times more than direct damage. The consequences are: the impact on biodiversity, the disappearance of rare, endangered and vulnerable plant and animal species, landscape change, changes in chemical and physical properties of the soil, climate and microclimate change, the occurrence of landslides and increased erosion, carbon dioxide emission caused by burning wood etc. (Aleksić et al., 2009).

MATERIALS AND METHODS

For the purposes of this study, the data of the Statistical Office of the Republic of Serbia for the period from 2010 to 2014 were used. The report on the damage incurred in the forests of the Republic of Serbia is submitted annually in forest surveys conducted by the Statistical Office of the Republic of Serbia. It is submitted by state forest companies ("Srbijašume" and "Vojvodinašume"), as well as public enterprises of national parks and communities within other companies and agricultural cooperatives engaged in the field of forestry. Data on damage incurred in forests are collected by type of forest and by cause, and are expressed in m3 for the average wood mass and in ha for the area affected.

In addition to state-owned forests, the report includes data on private forests (burned area and damaged wood mass). Burned area and damaged wood mass are divided into areas that had been damaged by surface fires and areas damaged by crown fires.

RESULTS AND DISCUSSION

Analysis of burned areas in the forests of Serbia for the 2010-2014 period

Table 1 gives a general overview of the number of wildfires and the damage that they have caused for the observed period from 2010 to 2014. A total of 428 fires has been registered, with a burned area of 10,844 ha, and 105,344 m3 of damaged wood mass.

The largest number of fires was registered in 2012, and the affected area covered 7,460 ha. In 2010, 2013 and 2014 burned area was not larger than 600 ha, while in 2011 it was 2,036 ha.

Table 1. Damage caused by wildfires in the forests of Serbia for the 2010-2014 period

Year	2010	2011	2012	2013	2014	Total
Burned area (ha)	503	2,036	7,460	561	284	10,844
Damaged wood mass (m^3)	57	24,570	63,118	7,343	10,256	105,344
Number of fires	26	65	282	43	12	428

Source: Statistical Office of the Republic of Serbia

Based on data available from the from the Statistical Office of the Republic of Serbia, the number of wildfires in the observed period ranged from 12, how much was recorded in 2014, to 282 fires recorded in 2012. As can be seen from the Chart 1, the number of fires has steadily increased during 2010 and 2011. Largest number of fires has been recorded in 2012, while a sudden drop characterizes the last two years.

Unkašević and Tošić (2014) state that during the summer of 2012 the longest heat waves and the worst drought have been recorded since the beginning of keeping record in Serbia. Heat waves registered on the territory of the Balkan Peninsula, including the Republic of Serbia, were primarily responsible for the largest number of wildfires.

According to the analysis carried out by Lukić et al. (2017), the number of wildfires registered by the Ministry of Internal Affairs, Department for Emergency Situations, is as high as 1,028. This number corresponds to the aforementioned numbers, but the authors point out that it is necessary to take into account other factors except geophysical ones (e.g. anthropogenic) when performing trend analysis of wildfires.

Of the total number of fires recorded in 2012, 96 fires occurred in the region of Šumadija and Western Serbia, and almost the same number, namely 95 fires, were recorded in the region of Southern and Eastern Serbia. In the region of Vojvodina 71 fires have been recorded, and in the Belgrade region 20 fires. Another important year was 2011, when the largest number of wildfires occurred on the territory of Šumadija and Western Serbia.

During 2010, 2011 and 2013 surface fires have affected greater area than crown fires. The most notable difference between crown fires and surface fires was in 2010, when the area affected by surface fires amounted to 488 ha, while crown fires affected an area of 15 ha. On the other hand, 2012 was dominated by crown fires, that have affected almost twice the area of surface fires (surface fires 2,820 ha, crown fires 4,640 ha).

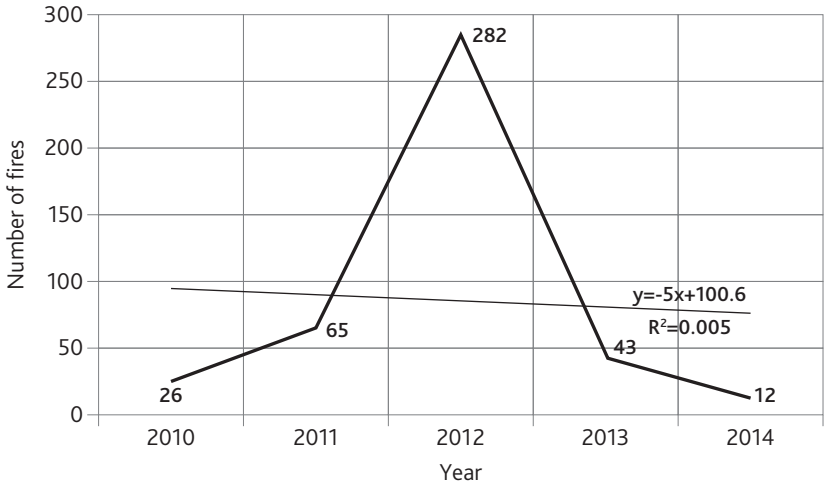

Chart 1. The total number of fires in state and private forests for the 2010-2014 period

Source: Based on data provided by Statistical Office of the Republic of Serbia

Compared to other regions of Serbia, the region of Southern and Eastern Serbia had the largest area damaged by fire during the observed period, especially in 2012, when the area affected was 4,936 ha, followed by 1,271 ha in 2011. In 2013, the region of Southern and Eastern Serbia had almost the same burned area as the region of Šumadija and Western Serbia (276 ha and 247 ha).

Wildfires in Vojvodina affected the largest area in 2012, 227 ha, then in 2013, 38 ha, while the lowest value was recorded in 2010.

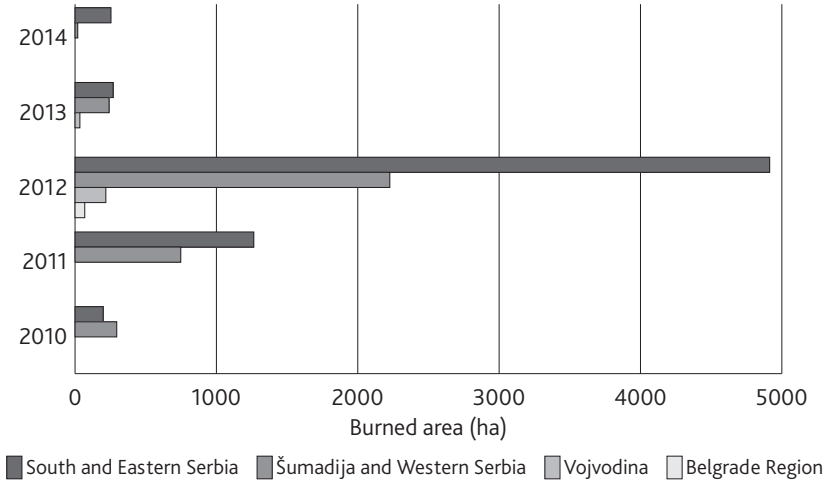

Chart 2. Burned area (in ha) by region for the 2010-2014 period

Source: Based on data provided by Statistical Office of the Republic of Serbia

Data analysis on burned areas in state and private forests, shown in Table 2, shows that of the total area in 2010, 2012 and 2013 state forests were more endangered.

Table 2. Burned areas of state and private forests in Serbia for the 2010-2014 period

Year	2010	2011	2012	2013	2014
Burned areas in state forests (ha)	280	707	5,108	326	52
Burned areas in private forests (ha)	223	1,329	2,352	235	232

Source: Statistical Office of the Republic of Serbia

However, the biggest difference was in 2012, when the state forest area affected by fire was 5,108 ha (3,510 ha in the territory of Southern and Eastern Serbia), and in private forests half that, i.e., 2,352 ha (also the highest in the region of Southern and Eastern Serbia, 1,426 ha). During 2010 and 2013, state forests had more burned areas but it is a small difference compared to the areas of private forests, so it is safe to say that the fires had equally affected them.

When it comes to privately owned forests, during the analyzed period they suffered the most damage in 2012. In comparison with the state forests in 2011 (in Southern and Eastern Serbia 1,057 ha) and 2014 (227 ha, also in the territory of Southern and Eastern Serbia) they were more threatened.

Analysis of damaged wood mass in the forests of Serbia for the 2010-2014 period

Data on damaged wood mass in the forests of Serbia are more or less similar to the previously shown data. The greatest amount of damaged trees was recorded in 2012 - 63,118 m^3, of which surface fires damaged 5,689 m^3, and 57,429 m^3 was damaged by crown fires. The smallest amount was in 2010, 57 m^3.

Table 3. Damaged wood mass (in m^3) in the forests of Serbia for the 2010-2014 period

Year	2010	2011	2012	2013	2014
Total damaged wood mass (m^3)	57	24,570	63,118	7,343	10,256
Wood mass damaged by surface fires (m^3)	57	4,360	5,689	2,170	/
Wood mass damaged by crown fires (m^3)	/	20,210	57,429	5,173	/

Source: Statistical Office of the Republic of Serbia

From Table 3 it can be seen that 2011 and 2013 are characteristic by the amount of damaged wood mass. Another specificity is that surface fires affected three times the area compared to crown fires, but crown fires destroyed much greater quantity of wood mass.

Thus, in 2013 of the total burned area (561 ha), 161 ha was affected by crown fires and at that time 5,173 m^3 was damaged of the total amount, which for that year amounted to 7,343 m^3. Furthermore, in 2011 crown fires affected an area of 466 ha of the total area of 2,036 ha. These fires damaged 20,210 m^3 of wood mass, of the total amount of 24,570 m^3.

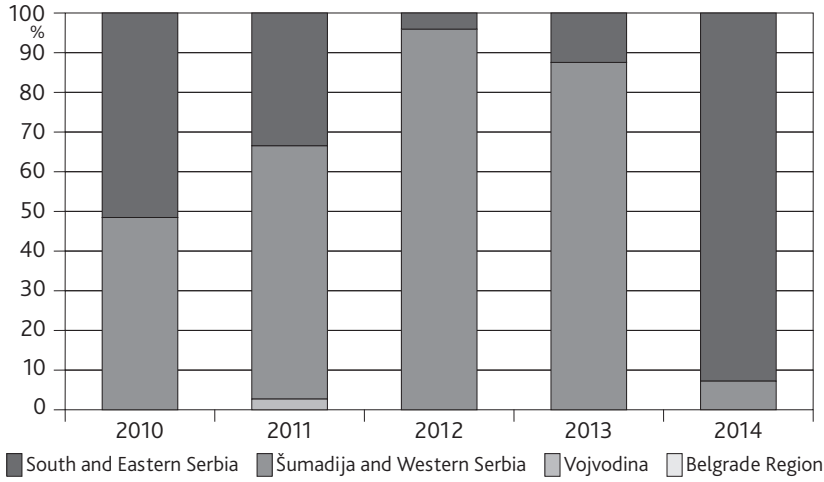

Chart 3. Damaged wood mass by region for the 2010-2014 period

Source: Based on data provided by Statistical Office of the Republic of Serbia

Viewed by region, Šumadija and Western Serbia had the highest amount of damaged wood mass during the observed period, except for 2014, when Southern and Eastern Serbia ranked first in the amount of damaged wood mass.

The analysis of damaged wood mass in wildfires by region led to the conclusion that in 2012, when the highest number of fires in the region of Šumadija and Western Serbia was recorded, the highest amount of wood mass was damaged (60,732 m^3). Significant damage in this region was recorded the year before (16,270 m^3) and the year after (6,553 m^3). During 2014 the forests in the region of Southern and Eastern Serbia were the most affected (9,355 m^3). Belgrade region recorded the greatest damage in 2014, 14 m^3. As for Vojvodina the largest quantities of wood mass were damaged in 2011, 516 m^3, and then in 2012, 95 m^3.

Analysis of damages in state and private forests in Serbia for the 2010-2014 period

Of the total quantity of damaged wood mass in the study period, state forests have twice the amount of damaged wood mass in relation to private forests. Based on a general review by year, state forests have suffered much greater damage in 2011, 2013 and 2014.

In 2012, when the highest number of fires was recorded, and when the largest number of areas was afflicted by fire, and when the greatest damage to the wood mass was recorded, private forests were a bit more affected. Damaged wood mass in private forests amounted to 32,741 m^3, while in the state forests 30,377 m^3 was damaged.

The year 2010 was characterized by a small number of fires (26), less burned areas and minor wood damage compared to the year after that. Burned area of forests owned by the state was greater, but less wood mass was damaged (16 m^3), while in private forests 41 m^3 was damaged. Regionally speaking, when it comes to state-owned forests all

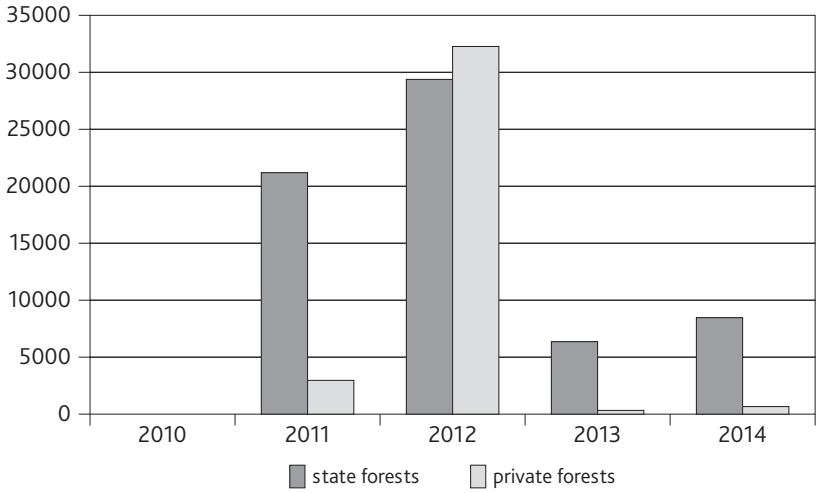

Chart 4. Damaged wood mass (in m³) in state and private forests in Serbia for the 2010-2014 period

Source: Based on data provided by Statistical Office of the Republic of Serbia

16 m³ was damaged in the region of Šumadija and Western Serbia. When it comes to private forests, 33 m³ in the region of Southern and Eastern Serbia, 8 m³ in the region of Šumadija and Western Serbia, while Vojvodina and Belgrade region did not sustain damage during this year.

Specifics for 2011 are that state forests had twice as less burned areas than private forests, but the situation with the damaged wood mass is completely opposite. Namely, the burned area of 707 ha had 21,740 m³ of damaged wood mass, which was the case in forests owned by the state, while the burned area in privately owned forests was twice as big (1,329 ha) but had up to ten times less damaged wood mass (2,830 m³), compared to state forests. In this year, the most affected were the state forests in the region of Šumadija and Western Serbia and private forests in the region of Southern and Eastern Serbia.

It has already been mentioned that state and private forests had almost the same amount of damaged wood mass in 2012, although the state-owned forests had twice the burned area. The largest area was 3,510 ha, in the region of Southern and Eastern Serbia. However, in terms of damaged wood mass, the greatest damage in the course of this year suffered the region of Šumadija and Western Serbia (of the total quantity of 30,377 m³ in this region 29,497 m³ was damaged).

State forests had significantly greater damage in wood mass in 2013. The greatest damage occurred in the region of Šumadija and Western Serbia, then in the region of Southern and Eastern Serbia, while there was no recorded damage on the territory of Vojvodina and Belgrade region. In private forests damage was recorded in the region of Southern and Eastern Serbia, and then in the region of Šumadija and Western Serbia.

The situation in 2014 was very similar to 2013. State forests had the biggest amount of damaged wood mass, even though a much larger area in private forests was affected by fire. During this year, wildfires have occurred in state forests in all regions, and the

damages are as follows: Belgrade region 14 m^3, region of Vojvodina 32 m^3, Šumadija and Western Serbia 855 m^3, and Southern and Eastern Serbia 8,705 m^3. Total damages in private forests amounted to 650 m^3, all in the region of Southern and Eastern Serbia.

CONCLUSION

Wildfires represent chaotic and uncontrolled spreading of fire in the natural environment, caused by natural or human factor. They also represent the most extreme form of devastation or complete destruction of forests. There are different types of wildfires, they do not occur in the same stratum of the forest, and they differ in the way of their formation, appearance, speed of spreading and so forth.

In the forests of the Republic of Serbia for a period of five years a total of 428 fires, 10,844 ha of burned areas and 105,344 m^3 of damaged wood mass has been recorded. The highest number of fires marked the year 2012. The highest number of crown fires was recorded this year, characterized by making the greatest damage (7,460 ha of burned area and 63,118 m^3 of damaged wood mass). During the other years of the analyzed period, surface fires were dominant which caused much less damage (in 2010, 2013 and 2014, burned area was not larger than 600 ha). The forests of the region of Southern and Eastern Serbia were the most affected by fire, especially in the summer period of 2012, primarily because of long heat waves and an unprecedented drought. But as the forests of Šumadija and Western Serbia had a greater number of crown fires, they sustained the greatest damage in the amount of wood mass.

The most important step in protection of forests against fire is prevention in every possible way. Various types of education can raise awareness about the importance of forests and environmental disasters caused by wildfires, because man in most cases is the main cause of this type of fire.

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