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Forest fires - ecological and economic problem in Serbia

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ABSTRACT: In the forests managed by the State Enterprise for Forest Management "Srbijašume", in the period 1998-2008, 853 forest fires were registered with the burnt area of 16,357 hectares.

From the aspect of damage and consequences, forest fires are a global problem and demand the engagement of all institutions and social subjects, and also the significant financial means for the prevention and suppression of forest fires and for the reclamation of burnt areas. The consequences of wildfires are evident for many years: degradation of forest ecosystems, protected areas, biological diversity; soil (erosion and landslides), climate, microclimate, water balance, sustainable development, etc.

Forest fires are major economic problems in Serbian forestry, because they destroy vast forest areas, and also an ecological problem, because of their adverse effect on other forest functions. Damages by forest fires are divided into direct and indirect damage. Direct damage includes the damage caused to trees and assortments. Indirect damage is the most important damage and it includes the harm caused by the lack of profit and ecological damage which is beyond price.

The objectives of the organisation of forest protection against wildfires in SE "Srbijašume" are to prevent the occurrence of forest fires and to detect and suppress the wildfire as soon as possible.

Key words: Forest fires, Serbia, ecological consequences, economic consequences

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INTRODUCTION

Forests occupy the area of about 4 milliard hectares, accounting for 30% of the total globe area. Forest area in Europe (without Russia) is 193 million hectares or 34%. In Serbia, forests occupy 2,252,400 ha (state forests 1,194,000 ha or 53.0%, and private forests 1,058,400 ha or 47.0%, according to the National Forest Inventory of the Republic of Serbia, 2009) or 29.1%. The percentage of forest cover in Serbia accounts for 34.0%, including thickets, shrub and brushland.

Forest fires are the most extreme aspect of forest devastation or complete destruction. Regarding the damage and its consequences, and because of the destroyed forest area, forest fires are a global problem and demand the engagement of all institutions and social subjects for their prevention and suppression.

More than 50,000 forest fires occur annually worldwide, and they destroy the forests on more than 400,000 hectares. The causes of forest fires, in more than 95% of cases are people, either by carelessness, accident, or even by deliberate arson (formation of agricultural and pasture lands, built up areas, as one of the methods to get the licence for clear cutting in private forests, etc.).

Education of the widest population, primarily the youngest ones, is one of the ways of reducing the forest fire risk (Veselinović & Milenković 2007.)

Based on the above, the aim of this paper is to point out the problem of forest fires in Serbia, to present the structure of burnt areas in state forests in Serbia - by forest tree species, the causes and dynamics of fire incidence; the method of fire risk rating, and the ecological and economic damages of forest fires.

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MATERIALS AND METHODS

This paper was elaborated based on the following: Project of development of forest fire protection in SE "Srbijašume"; Programme of education in the field of forest fire protection in SE "Srbijašume"; Plan of forest fire protection in SE "Srbijašume", data base on forest fires in SE "Srbijašume", professional references and experiences in the European countries, international conventions, declarations, resolutions and strategies in the field of forest fire protection.

This paper presents the data on the number of forest fires in state forests in Serbia managed by SE "Srbijašume" in the period 1999 - 2008; the structure of burnt areas by forest tree species, causes and dynamics of fire incidence; method of fire risk assessment, ecological and economic damages of forest fires.

The fire danger rating system is based on the Canadian method of calculating the Fire Weather Index - FWI. The method is based on the assessment of forest fuel flammability depending on weather conditions. The daily weather observations affecting fire behaviour are: air temperature, relative humidity, wind speed and precipitation in the previous 24 hours. The Fire Weather Index (FWI) is a numerical indicator of the potential fire intensity in the standard forest fuel, i.e. the approximate potential forest fire risk. The forecast of these weather elements is based on the numerical model for weather forecast WRF-NMM.

The fire danger rating on the territory of the Republic of Serbia, from the spring 2008, has been performed by the Republic Hydrometeorological Service of Serbia (RHMZ, Serbia, 2009 - FWI, Belgrade), which is a contribution to the organised forest fire protection.

The Fire Weather Index - FWI is a combination of Initial Spread Index - ISI, which represents the combined effect of wind speed and moisture content of fine fuel – forest litter, on the potential of fire spreading directly after ignition, and Buildup Index - BUI, which is the indicator of fuel moisture content. FWI is a numerical indicator of the potential fire severity in the standard fuel type and it signifies the degree of produced energy per unit length of fire front. Its value shows the degree of forest fire danger rating in the time interval around noon, which enables the temporal and spatial comparison of this indicator.

RESULTS AND DISUSSION

Causes, dynamics and structure of forest fires in Serbia. The occurrence of forest fires depends on weather conditions, moisture content and amount of fuel (consisting of forest cover: trees, regeneration, shrubs, fallen trees, forest litter, dead branches, stumps, moss, lichens, grass, etc.).

According to Vasić (1983) forest fires can occur throughout the year, but there are three critical periods: early spring (March - April); summer (July - August) and autumn (September - October).

In state forests managed by SE "Srbijašume" (Serbia without Provinces), in the period 1999-2008, forest fires were registered in each month (Tab. 2). The greatest number of forest fires was recorded in July and March, i.e. in the first critical period (March-April) – 31.07 %, in the second period (July - August) – 48.88% and in the third period (September-October) – 2.70%. A great number of fires occurred also in November (4.34%), so the third critical period for forest fires included the period September-November.

The greatest menace to forests, as regards forest fires, is man, who by inadequate behaviour and by some activities (primarily in agriculture) can cause fire (directly when he ignites fire and leaves unextinguished fire, and indirectly when he uses various machines and equipment). The greatest number of forest fires occurs between the morning and 6 p.m., which is the most active period of humans.

The degree of wildfire danger also depends on forest type. Coniferous stands are much more susceptible to ignition and combustion. Due to the presence of flammable resin and essential oils, they burn readily even in the green state. The second in the order of susceptibility are the mixed conifer and broadleaf stands and plantations, and the least susceptible are broadleaf stands. The most endangered tree species are *Pinus nigra* Arn., *Pinus silvestris* L., then *Pinus maritima* Mill., and *Pinus strobus* L., *Larix decidua*

Tab. 1. Indicators of forest fire danger (RHMZ, Serbia, 2009)

Fire danger	Fire agent	Speed of fire spreading	Fire control
Very low	open fire	very slow	self-extinguished
Low	permanent fire	slow	fast and easy
Moderate	match	medium	moderately difficult
High	match	fast	very difficult
Extreme	spark	very fast	extremely difficult

Tab. 2. Number of fires per months in the period 1999-2008. in SE "Srbijašume"

No.	Month	Number of fires	%
1	January	2	0.23
2	February	18	2.11
3	March	152	17.82
4	April	113	13.25
5	May	39	4.57
6	June	49	5.74
7	July	299	35.05
8	August	118	13.83
9	September	11	1.29
10	October	12	1.41
11	November	37	4.34
12	December	2	0.35
SE "Srbijašume"		**853**	**100.00**

Mill., *Picea abies* Karst., and *Abies alba* Mill. as the least susceptible conifer. Among broadleaf species, the most susceptible are oaks, especially *Quercus petraea* (Matt.), Liebl. The susceptibility is significantly higher in younger trees and stands, because the canopy is not closed, so the soil is exposed to the impact of sunlight and temperature for a longer time. This stimulates the more intensive growth of grass and shrub vegetation which, when dry, provides a flammable fuel (Vasić 1983).

In the period 1999-2008, broadleaf forests accounted for 77.82% of the area, conifers – 17.54%, and pastures, meadows and openings – 4.63 % (Tab. 3).

The degree of wildfire danger also depends on the forest specific purpose. Recreation forests, as well as forests in the vicinity of landfills and spoil banks are the most endangered types. The fire risk is also high in the forests along public roads, forests used for animal grazing, collection of forest fruits, game hunting and in forests during silvicultural and logging operations.

Forests on limestone bedrocks are more at risk (thanks to the thermal properties and water permeability, the substrate is more readily warmed, causing the drying of litter and ground vegetation). Sandy soils are warmed faster and more intensively, so grass vegetation dries fast and becomes extremely flammable (the Sands: Deliblatska, Subotička, and Ramsko-Golubačka Peščara).

Orography - relief (altitude, aspect, i.e. exposure, slope) affect the occurrence of forest fires. With the higher altitude, the composition of bedrock and soil changes, the average temperature decreases, the composition and the percentage of fuel are changed, tree species and stand types are changed, and the risk of forest fires decreases.

The lands on south and west slopes are exposed to the sun radiation for a longer time and they support the tree species which are more sensitive to wildfires (pine, etc.). The lands of north aspects support the tree species which are less endangered by wildfires (beech, fir, etc.). Also, the increase of slope increases the risk of forest fires (warm air climbs up the slope and in front of the fireline heats and dries the fuel, so it is faster to ignite and burn).

Climate characteristics in Serbia and the expected effects on forest fires. Climate is a natural resource which has a dominant effect on ecosystems and also on the occurrence of forest fires. The most significant climate factors which can significantly increase the forest fire hazard are: temperature, precipitation, relative humidity, winds, soil moisture, etc.

Climate changes are present worldwide. According to the data in Serbia from 1991, the increasing trend of air temperature has been multiply higher than in the period 1961-1990. Also the summer air temperatures have had an elevated positive trend (Popović *et al*. 2009).

Years with precipitation deficit have been dominant since the eighties of the past century. As for the values of summer precipitation, the periods of negative values of the trend of annual precipitation overlap with the periods of positive values of the trend of annual air temperature.

Year	Structure of burnt forests [ha]				%		
	broadleaves	conifers	other	total	broadleaves	conifers	other
1999	98.00	11.00	0.00	109.00	89.91	10.09	0.00
2000	2,637.57	891.97	40.32	3,569.86	73.88	24.99	1.13
2001	269.90	80.09	6.00	355.99	75.82	22.50	1.69
2002	934.61	225.97	130.27	1,290.85	72.40	17.51	10.09
2003	185.32	113.42	12.40	311.14	59.56	36.45	3.99
2004	8.00	0.25	5.00	13.25	60.38	1.89	37.74
2005	3.69	6.50	0.90	11.09	33.27	58.61	8.12
2006	686.86	31.74	0.20	718.80	95.56	4.42	0.03
2007	7,742.87	1,442.92	524.41	9,710.20	79.74	14.86	5.40
2008.	162.58	65.87	38.50	266.95	60.90	24.68	14.42
Total	**12,729.40**	**2,869.73**	**758.00**	**16,357.13**	**77.82**	**17.54**	**4.63**

Tab. 3. Structure of area burned in the period 1999-2008. in SE "Srbijašume"

Weather characteristics	Date - Weather					
	1.07. 2009. – rainy		02.08. 2009. – dry and very warm		23.08. 2009. – warm and stuffy	
Weather station	FWI	Risk	FWI	Risk	FWI	Risk
Crni Vrh	0	Very low	14	Moderate	10	Moderate
Zlatibor	0	Very low	21	High	8	Moderate
Kraljevo	4	Very low	33	High	26	High
Kopaonik	0	Very low	10	Moderate	5	Low
Niš	8	Moderate	30	High	24	High
Vranje	2	Very low	35	Extreme	34	Extreme
Novi Sad	0	Very low	33	Extreme	27	High

Tab. 4. Fire Weather Index in Serbia (RHMZ, Serbia, 2009)

Based on the generally expected substantially warmer climate (especially during summer months) and the lower quantities of precipitation, the high decrease in precipitation is predicted during summer months and a somewhat lower decrease in the average precipitation during the autumn. However, the precipitation may increase over winter and spring. The increase is also expected in frequency, intensity and duration of heat waves, while the number of frost and ice days will decrease.

The decrease in precipitation and the increase in dry periods directly affect the runoff, i.e. reduce the potential water supply also for the needs of forest fire suppression.

Dry periods and high temperatures favour the increase in the populations of insect pests and plant diseases, and cause forest physiological weakening (Popović *et al.* 2009).

The forest fire danger rating. In the organised forest fire protection, it is very important to evaluate the fire danger, aiming at the adequate prevention and potential repression measures.

Tab. 4 presents the Forest Fire Weather Index in Serbia in summer 2009, for some characteristic weather stations in Serbia, which are located in dominantly forest

Tab. 5. Burnt area in the period 1999-2008. in SE "Srbijašume"

Year	Number of instances	Fire type		Total area burned	Average burnt area per forest fire [ha]
		Surface [ha]	Crown [ha]		
1999	9	107.00	2.00	109.00	12.11
2000	233	2,971.44	598.42	3,569.86	15.32
2001	33	279.04	76.95	355.99	10.79
2002	85	1,154.14	136.71	1,290.85	15.19
2003	57	252.44	58.70	311.14	5.46
2004	6	13.25	0.00	13.25	2.21
2005	8	11.09	0.00	11.09	1.39
2006	33	718.80	0.00	718.80	21.78
2007	358	8,256.75	1,453.45	9,710.20	27.12
2008	31	251.92	15.03	266.95	8.61
Total	**853**	**14,015.18**	**2,341.95**	**16,357.13**	**19.18**
%		**85.68**	**14.32**	**100.00**	

regions. There is a significant correlation between weather conditions and fire danger. The higher Index values correspond to the lower forest fuel moisture content, and the higher wildfire potential.

Structure of burnt area in Serbia. Types of forest fires are: surface fire, crown fire and ground fire. Surface fires are more frequent, they burn litter, ground vegetation, dry grass, shoots, shrubs and waste wood. They are most damaging in juvenile stands, and in older stands they lead to the damage of bark and butt ends. In conifer stands, they can advance to the lower dead branches and the crowns, turning into crown fires. Crown fire is often sustained by a surface fire, it consumes the whole trees and aided by wind it spreads quickly and destroys large areas under forests, primarily, conifer. Ground fire is very rare and it consumes (smoulders) peat and humus below forest litter. It is difficult to detect and causes damage primarily to tree roots (Vasić 1992)

In the analysed period, surface fires accounted for 85.68 % and high fires accounted for 14.32 % of burnt area (Tab. 5).

The average area burned per forest fire, depending on the year, ranged from 1.39 to 27.12 ha, or on the average 19.18 ha. The large average area per forest fire is the consequence of some large-scale fires, e.g. the area burned by one forest fire on Stara Planina was 1,389.85 ha (2007) and 105.92 ha in FE Raška (2002).

According to Aleksić & Jančić (2008) the most endangered regions are east and southeast Serbia. Starting from the fact that the most frequent agent of wildfires is man and that fires mainly originate from private estates and forests, it can be concluded that the public awareness on forest significance is not sufficiently developed, especially in east and southeast parts of Serbia.

Ecological and economic damage of forest fires

Ecological consequences: Forest have a positive effect on climate, soil, mitigation of the impacts of exhaustion and immission gases, on the purification of atmospheric water, they mitigate the adverse effects of winds, contribute to the increase of agricultural production and production of safe food, landscape diversity, development of sport and recreation. Also forests create conditions for the greater use of fuelwood as the replacement for fossil fuels. Forests have a key role in the maintenance of ecological processes and ecological balance.

The consequences of forest fires are evident for a long time after the fire occurrence. Forest fires affect the biological diversity (irreparable losses); causing the extinction of rare, threatened and vulnerable plant and animal species (i.e. the decrease of specific and genetic diversity); changes of landscape and landscape beauty (landscape diversity); soil (changes of physical and chemical properties, as well as the microbiological composition); climate and microclimate,

and water balance (severe disturbance of hydrological regime, causing decrease of water reserves and floods). The recreation potential of forests is also reduced. Severe forest fires cause human psychological disturbances. Forest fires destroy agricultural crops, houses, infrastructure (bridges, power lines, etc.), sometimes even human lives. Forest fires cause the loss of organic matter in the soil, the release of carbon back into the atmosphere and the increase of global warming. Wood combustion also causes the return of carbon dioxide into the atmosphere.

Burnt areas are often subject to landslides and various forms of strong erosion (wind erosion in the area of the Sands: Deliblatska, Subotička and Ramsko-Golubačka Peščara).

Forests attacked by forest fire, i.e. damaged and physiologically weakened trees, soon become the foci of insect pest outbreaks and plant diseases (bark beetles and plant diseases in conifer stands and chained damage).

Fig. 1. Forest fire suppression

Fig. 2. Reclamation of destroyed forests

Economic consequences: Total damage by forest fires includes costs: of fire suppression, of reclamation and regeneration of the destroyed forest.

Costs of fire suppression include: of fire-fighters who participate in fire suppression, the engaged machines and equipment, costs of board and lodging, etc.

Fire damage is classified as direct and indirect damage. Direct damage is damage to standing trees and produced assortments (if they were stocked in the forest). Indirect damage of forest fires is the greatest damage and it includes the lost increment (very often forest fires consume the young coniferous plantations and natural stands) and ecological damage, which is beyond price, but usually it is calculated worldwide as fivefold to tenfold value of the direct damage resulting from forest fires.

Costs of reclamation of destroyed forests include the following: removal of burnt trees from the forest, site preparation for forest regeneration, planting, tending and protection of the established plantation and the construction of forest roads for the needs of reclamation of burnt areas and forest regeneration.

The damage of forest fires includes also the costs of amendments of planning documents, such as forest management plans, programmes of protection and development of the protected areas, drawing up of reclamation programmes for burnt areas, etc.

One of the most damaging consequences is the time (several decades) which is necessary for the forest to regenerate and fulfil its multiple functions.

Of the total area burned (16,357.12 ha) there was no serious damage (there was no need for the removal of the existing stands), primarily in a part of oak forests, in old pine forests, and scrubs and brushland, in the area of 5,511.00 ha, where sanitation cuttings were performed (and are underway) (costs of sanitation cuttings: 5,511.00 ha x 4,493.76 din. = 23,765,111.36 dinars).

Natural regeneration (by seed) is completed or is underway on 2.491,00 ha (costs of regeneration: 2,491.00 ha x 2,726.40 din. = 6,791,462.40 din.)

Artificial regeneration (planting) is performed on 8,355.13 ha (costs of regeneration: 8,355.13 ha x 107,126.78 din. = 895,058,173.38 din.).

The transport of timber products from the burnt area and the subsequent silvicultural operations required the construction of 49.07km of forest roads (construction costs: 49.07 km x 2,400,000 din. = 117,768,000.00 din.) and 122.75 km of tractor skidding roads (costs: 122.75 km x 240,000 din. = 29,460,000.00 dinars).

The burnt or damaged timber volume amounted to 1,393,782.82 m^3, value 2,663,479,932.73 din.

The amount of lost increment, due to the interruption of plant growth, was approximately equal by quantity and value to that of the consumed and damaged wood.

The cost of silvicultural and protection operations (tillage, cutting of shoots), till the plantation age of five years, on the area of 8,355.13 ha, amounted to 505,789,993.04 din.

In the naturally regenerated stands, liberation cutting was performed (or is underway) on 2,491.00 ha (costs of liberation cutting: 2,491.00 ha x 11,647.87 din.= 29,014,844.17 din).

Ecological damage is evaluated as ten times the value of direct damage and it amounted to 26.63 milliard din.

Based on all the above costs, the total damage of forest fires on 16,357.13 ha amounted to 33.56 milliard dinars, i.e. about € 330 million.

Organisation of forest fire protection. Organisation of forest fire protection in SE "Srbijašume" is established based on three goals: prevention of the occurrence of forest fires, fast detection and fast suppression.

In this aim, the following measures are undertaken:

- against potential causes of forest fires: public awareness raising on ecological, economic, social and cultural significance of forests, warnings for the higher hazard of forest fires, prohibition signs and warning signs at the accession roads to forests, along the roads, picnic grounds, tourist facilities, etc. (Jančić & Zelić 2007);
- to prevent forest fires: fire warden service control of the potential agents of forest fires, i.e. farmers who burn their fields after harvest, weeds and other plant material, owners of weekend-houses, collectors of forest fruits, medicinal plants and mushrooms, picnickers, visitors, etc.;
- aiming at the fast detection of forest fires: lookouts, observation of forest at risk and tours of duty in critical periods of forest fires;
- aiming at the fast suppression of forest fires: developed road network especially to the most endangered regions, mobility and good equipment of the fire brigades for quick suppression of forest fires, managed water intake structures and water storages, maintenance and management of water resources in the forests with the obligatory conservation of headwater sites; training of workers in the field of forest fire protection, and
- to prevent the forest fire occurrence and spreading: timely performance of all measures of timber stand improvement, such as cleaning, thinning, pruning of branches and removal of dead branches; maintenance and cleaning of belts along the public roads (motor roads and railways); maintenance and cleaning of belts of power lines; establishment of mixed broadleaf and conifer forests; establishment of biological fire breaks; establishment of forest order; construction and maintenance of fire breaks, etc..

CONCLUSION

Forest fires are a universal problem and are classified as harmful events that can cause great damage in a short time and change the appearance of the entire forest region.

The occurrence of forest fires depends on weather conditions, moisture content and amount of fuel (consisting of forest cover: trees, seedlings, shrubs, fallen trees, forest litter, branches, stumps, mosses, lichens, grasses, etc.).

In the period 1999-2008 forest fires (853 in total) burned on 16,357.13 ha and the damage amounted to 33.56 billion dinars (ecological damage is estimated to 26.63 billion dinars and 6,93 billion dinars costs of fire suppression, direct damage, damage of lost increment, costs of forest reclamation and regeneration of burnt area, costs of tending and protection of the established plantations). The average area burned per forest fire was 19.18 ha. Surface fires consumed 85.68% and crown fires consumed 14.32% of burnt area. In the structure of burnt area, broadleaf stands account for 77.82%, coniferous 17.54 and other 4.63%. The most endangered regions are east and southeast Serbia.

In forest fire protection, the most important step is the prevention by all possible means. Various education topics can raise the public awareness on forest significance and ecological disasters caused by forest fires, because man is most often the cause of forest fires.

The strategy of forest fire protection in SE "Srbijašume" is based on the realisation of the following goals: prevention of forest fires, rapid detection and rapid suppression.

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REZIME

Šumski požari – ekološki i ekonomski problem u Srbiji

Predrag Aleksić, Milun Krstić, Gordana Jančić

Šumski požari su najekstremniji vid devastacije ili potpunog uništenja šuma. Predstavljaju svetski problem i spadaju u štetne pojave koje za kratko vreme mogu da pričine velike štete i da izmene izgled jednog šumskog područja.

U periodu 1999.-2008. godine šumskim požarima (853) opožareno je 16.357,13 ha i pričenjena je šteta u iznosu 33,56 milijardi dinara (ekološke štete 26,63 milijarde dinara i 6,93 milijarde dinara troškovi gašenja požara, direktne štete, štete od izgubljenog prirasta, troškovi sanacije i obnavljanja požarišrta, troškovi nege i zaštite novopodiguntih zasada). Prosečno opožarena površina po šumskom požaru je 19,18 ha. Prizmeni požari zahvatili su 85,68% a visoki 14,32% opožarene površine. U strukturi opožarene površine lišćarske satojine čine 77,82%, četinarske 17,54 i ostalo 4,63%. Najugroženija područja su istočna i jugoistočna Srbija.

Pojava požara u šumi zavisi od vremenskih prilika, stanja vlažnosti i količine gorivog biljnog materijala (koga čini biljni pokrivač u šumi: drveće, podmladak, šikara, šibljaci, oboreno drveće, šumska prostirka, granje, panjevi, mahovina, lišajevi, trava i dr).

Klimatske promene znatno povećavaju opasnost od pojave šumskih požara.

Šume su različito ugrožene od šumskih požara. Četinarske sastojine su znatno osetljivije na paljenje i gorenje u odnosu na lišćarske. Izletničke i šume čija je funkcija rekreativna, kao i šume u blizini deponija smeća su najugroženije od šumskih požara.

U oblasti zaštite šuma od požara najvažnije je preventivno delovati i učiniti sve da do požara ne dođe i raznim edukativnim sadržajima uticati na svest stanovništva o značaju šuma i ekološkoj katastrofi koju požari donose, jer je čovek najčešći uzročnik pojave šumskih požara.

Staretgija zaštite šuma od požara u JP „Srbijašume“ baziran je na ostavrenju ciljeva: sprečiti pojavu šumskih požara, požar brzo otkriti i brzo ugasiti.

Ključne reči: Šumski požari, Srbija**,** ekološke posledice**,** ekonomske posledice