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FOREST ROADS AS THE KEY TO FOREST PROTECTION AGAINST FIRE

Abstract: *Planning, construction and maintenance of forest roads is extremely important for successful firefighting in a certain area. This study focuses on the current technical infrastructure in the state forests of Serbia. The average openness of forests in Serbia at the end of 2019 was 20.14 m/ha, while 21.89 m/ha was occupied by public roads. In the period from 2011 to 2019, the average openness of state forests with public roads in Serbia decreased by 3.12 m/ha, or by 1.67 m/ha. The openness of forests by forest roads is the largest and optimal in the Vojvodina region (131.5 m/ha) and significantly lower and insufficient in Belgrade regions (0.35 m/ha), Sumadija and Western Serbia (2.8 m/ha), and Southern and Eastern Serbia (1.8 m/ha). Compared to 2011, the openness of forests in 2019 increased in the Vojvodina region and decreased in other regions in Serbia. Forest roads that have asphalt, concrete or cobblestone lanes are the least represented, about 0.27%. The largest representation of forest roads with a base (stone or gravel hard bottom layer) is about 82.7%.*

Key words: forest openness, forest roads, forest fire, Serbia

INTRODUCTION

The total forest area in Serbia is 2,252,400 hectares, of which 1,194,000 hectares or 53.0% are state-owned and 1,058,400 hectares or 47.0% are privately owned [2]. The total area of protected natural assets is 5,471.76 km², which is about 6.19% of the total territory of the Republic of Serbia [22].

Forest fires have a major impact on ecosystem stability. Onur and his colleagues [12] state that forest fires are one of the most important factors of environmental risk. Sekulić et.al [15] point out that forest fires in Serbia can pose a serious threat to certain ecosystems and some species, as well as to human safety. Forest fires occur in Serbia almost every year and are a limiting factor in the sustainable development of forestry [27].

Many studies [4, 19, 20, 26, 28, 29, 30, 31] have indicated that there is a correlation between the occurrence of forest fires in Serbia and climate conditions. The distribution of the fire-affected areas and the dynamics of fire outbreaks can be correlated with the climatic characteristics of certain areas [25]. The origin and development of forest fires are conditioned by several constantly changing factors, which define the assessment of forest fire risk. A certain impact on the threat of forests fire also depends on the implementation of measures of forest management, [21] such as the construction and maintenance of averages and the forest roads as well. The total amount of forest roads and locations in the area are important for the services in charge of fire protection. Stefanović [16] points out the importance of planning network roads in forest areas to provide the most efficient fire protection in terms of the most

favorable position in space, which achieves efficient preventive and timely repressive protection against forest fires. The aim of this research was to review the construction of technical infrastructure in the forests of Serbia, in order to work on the prevention and control of forest fires.

MATERIALS AND METHODS

The data of the Republic Statistical Office (2021) from 2011 to 2019 were used in this paper. The openness of forest complexes is conditioned by the presence of roads and their interconnection. The openness of forests in the territory of the Republic of Serbia is expressed in m/ha.

The openness of the forest to the road network (OS) is calculated as follows:

$$O_s = L / A \quad (1)$$

where O_s is the openness of the forest to the road network (m/ha), L is the calculated length of the forest roads (m) and A is the area of the forest complex (ha).

The internal openness of the forest complex is the connection of the interior of the forest areas with the roads. External openness or public communications is the construction of roads that pass through the forest or directly lean on it. Forest roads are facilities (roads and trains) primarily built for the purpose of forest management and especially for the protection of forest fires (for the passage of fire vehicles and equipment), [23]. Forest roads include only permanent forest roads. Public roads are roads that pass through the forest or directly lean on it. Modern roads are roads that have a road made of asphalt, concrete or stone cubes. An

example of roads with a hard lower layer (stone or gravel) is hard forest roads with a base. The examples of unpaved roads (soft forest roads - dirt roads) and roads without a hard lower layer are shown. The territory of Serbia is divided into 5 statistical regions: Belgrade (Belgrade), Vojvodina (Voj), Sumadija and Western Serbia (SSS), Southern and Eastern Serbia (JIS), and Kosovo and Metohija (KM), [24]. Since Serbia does not have the data for the statistical region of Kosovo and Metohija, they are not included in the coverage of data for the Republic of Serbia (total). Statistical data are considered only for the state forests, since the SBS does not have the data for forests roads of other forms of ownership. The data from the National Forest Inventory (2009) on the area of state-owned forests in Serbia were used for the purposes of this paper.

RESULTS AND DISCUSSION

Forest roads in Serbia and the openness of forest complexes to roads

Data from the National Forest Inventory, which was conducted in the 2004-2006 period and published in 2009, indicate that the degree of forest cover in Serbia is 29.1%, while the optimal forest cover should be 41.4%.

The statistical region of Vojvodina with forests areas has the lowest degree of forest cover in Serbia, Table 1.

Table 1. Forest regions in Serbia

Region	Land area km ²	Forest area km ²	Forestry %
Region of Southern and Eastern Serbia	26.255	10.456	40,3
Sumadija region and Western Serbia	26.483	10.020	37,4
Belgrade region	3.227	508	15,7
Vojvodina	21.506	1.540	7,1

Forest infrastructure is one of the basic conditions for the successful leading of the forest ecosystem.

Table 2 shows the roads of state forests in Serbia for the period from 2011 to 2019. There is a significant decrease in the total length of traffic infrastructure at the end of 2019 compared to the period from 2011 to 2013.

Table 2 shows a significant increase in the length of public roads from 2016-2019 compared to the period 2011-2015.

Table 2 Roads within the state forests in Serbia, 2011-2019.

Year	Forest roads (km)				Public roads (km)				Total km
	total	contemporary	soft	solid	total	contemporary	soft	solid	
2011	27783	81	5227	22475	357	297	15	45	28140
2012	27989	86	5311	22592	358	297	15	46	28347
2013	28144	86	5569	22489	358	297	15	46	28502
2014	25903	386	4327	21190	498	342	46	110	26401
2015	25512	156	4674	20682	397	235	52	110	25909
2016	24071	65	4628	19378	1946	118	39	1789	26017
2017	24582	272	5121	19189	1865	139	1717	9	26447
2018	24931	70	4838	20023	2027	61	1733	233	26958
2019	24049	66	4092	19891	2087	198	1684	205	26136

Observing the traffic infrastructure in regions in Serbia, it can be seen that the largest representation of forests is Vojvodina region, Table 3.

Table 3 shows a significant increase in the length of public roads in Vojvodina region compared to other regions in Serbia. It is noticed that the length of public roads was much longer in 2019 compared to 2011 in Vojvodina region and Southern and Eastern Serbia and smaller in the Sumadija region and Western Serbia, Table 3.

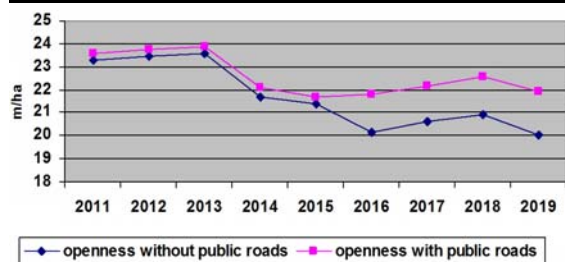
Based on the data of forest area and built road network, the openness of state-owned forests is shown in Figure 1.

The average openness of forests in Serbia at the end of 2019 is 20.14 m/ha, or 21.89 m/ha including the public roads.

For example, the openness of forests in Republika Srpska is 9.28 m/ha and 11.21 m/ha including the public roads, [6]; in Slovenia, it is 24.8 m/ha, [10]; in Bulgaria, it reaches 7.90 m/ha, [18]; in Romania 13.73 m/ha, [3]; in Slovakia, it is 20.1 m/ha, [1]; and, in Austria, it is 45 m/ha, [8].

Table 3 The length of roads in the statistical regions in Serbia, 2011-2019.

Region	Year	Forest Roads (km)				Public roads (km)			
		total	cont.	soft	solid	total	cont.	soft	solid
Beo		51	6	28	17	-	-	-	-
Voj		20253	25	1403	18825	140	123	15	2
SZS	2011	4759	50	1921	2788	212	174	-	38
JIS		2720	-	1875	845	5	-	-	5
Beo		51	6	17	28	-	-	-	-
Voj		20269	25	1416	18828	140	123	15	2
SZS	2012	4848	50	1934	2864	212	174	-	38
JIS		2821	5	944	872	6	-	-	6
Beo		53	6	17	30	-	-	-	-
Voj		20283	25	1416	18842	140	123	15	2
SZS	2013	684	50	1938	2696	212	174	0	38
JIS		3124	5	2198	921	6	-	-	6
Beo		56	6	20	30	-	-	-	-
Voj		20329	25	1403	18901	158	140	16	2
SZS	2014	2577	16	970	1591	150	112	-	38
JIS		2941	339	934	668	190	90	30	70
Beo		59	6	23	30	-	-	-	-
Voj		20425	29	1494	18902	163	145	16	2
SZS	2015	2709	25	1641	1043	38	-	-	38
JIS		2319	96	1516	707	196	90	36	70
Beo		59	6	23	30	-	-	-	-
Voj		20425	29	1494	18902	163	145	16	2
SZS	2016	2709	25	1641	1043	38	-	-	38
JIS		2319	96	1516	707	196	90	36	70
Beo		59	6	30	23	-	-	-	-
Voj	2017	9355	21	2243	17091	1715	27	1679	9
SZS		3219	54	2022	1143	150	112	38	0
JIS		1949	191	826	932	-	-	-	-
Beo		59	6	23	30	-	-	-	-
Voj		19943	21	2823	17099	1911	28	1682	201
SZS	2018	3406	-	1367	2039	116	33	51	32
JIS		1523	43	625	855	-	-	-	-
Beo		18	6	6	6	-	-	-	-
Voj		19371	22	2243	17106	1919	30	1684	205
SZS	2019	2801	-	858	1943	33	33	-	-
JIS		1859	38	985	836	135	135	-	-

**Figure 1.** Average openness of state forests in Serbia, 2011-2019.

It is worth noting in Table 4 that on the territory of Serbia there is an expressed unevenness of openness of forest areas and that there are many insufficiently open forest areas, so it is necessary to consider the density of forest roads of smaller spatial units.

Forest openness (excluding public roads) is highest in Vojvodina region and significantly lower and insufficient in other regions (see Table 4). It has been shown in Table 4 that the openness of forests in three regions in Serbia is significantly lower than the

recommended density of 7 to 10 m/ha of forest roads in the low relief plains, [7].

Table 4 Internal openness of state forests in statistical regions of Serbia (m/ha)

Year	Region			
	Belgrade	Vojvodina	Sumadija and South. and W. Serbia	E. Serbia
2011	1,0	125,8	4,7	2,6
2019	0,35	131,5	2,8	1,8

Danilović and Stojnić [5] state that calculating the density of the road network only on the basis of the ratio of the length of roads passing through the department and the area of the department does not yield precise data, so the spatial distribution of roads is much more important. Pichman and Pentek [13] state that absolute (classical) openness gives a rough picture of the quantitative state of forest roads in an area without information about their spatial distribution.

Importance of forest roads to fire protection

Through careful planning, design and maintenance of the road network, forest opening is of primary importance to forest use and crucial for sustainable management [9]. Krč and Beguš [10] point out that the construction of a network of forest roads is considered a key element for successful forest management. Stefanović et al. [17] state that one segment of the process of planning the forest road network is achieving effective prevention and fire suppression. Good communication in forest areas is extremely important in risk management during forest fire protection. Forest roads play a key role in firefighting activities [11]. Built infrastructure, if it is denser and of good quality, enables access to all forest areas, a shorter arrival and the beginning of firefighting intervention, and rapid delivery and use of firefighting equipment, as well as the possibility to determine the location of a fire barrier. The disadvantage is the passage of the road through the forest area due to the possibility of triggering fires by passengers and vehicles [21]. An overview of the impact of the openness of the forest complex on fire risk, expressed by points, is shown in Table 5.

Table 5 Impact forest complex openness on forest fire risk

Openness of the forest complex	Points
The forest complex is open (most areas are accessible by a built road network, fire lines are regularly maintained)	5
The forest complex is partially open (larger parts of the forest complex are poorly accessible, or are accessible by forest roads unsuitable for fire trucks, fire lines are poorly maintained)	20
The forest complex is not open, there are no fire trucks	40

The efficiency of extinguishing forest fires largely depends on the time that elapses from the occurrence of the fire until the arrival of the team at the place of intervention. The period from the moment of fire detection to the notification of the competent services, their arrival and the beginning of fire extinguishing can be quite long. As a consequence, fire can develop without control and significant areas can be caught by fire. If the period from fire occurrence to brigade arrival was shorter, the efficiency of fire extinguishment would increase and the required extinguishing time would be reduced, and thus the area affected by the fire. Table 6 shows the interdependences between the efficiency of extinguishing forest fires and the time of fire occurrence until the arrival of the team at the place of intervention.

Table 6 Fire extinguishing efficiency depending on the time of occurrence to the beginning of extinguishing

Time from the beginning of fire to arrival at the scene (min)	Forest fire extinguishing efficiency
≤ 15	Extremely good
$>15 \leq 30$	Very good
$>30 \leq 60$	Good
$> 60 \leq 90$	Depending on several factors
> 90	Unpredictable

Roads, as a natural barrier in the vicinity of a fire, can be used to determine the location of obstacles to the spread of fire, Figure 2.



Figure 2. Location of fire barrier depending on natural barriers

CONCLUSION

Forest fires are a very significant threat to the stability of forest ecosystems and the environment as a whole. The construction and maintenance of roads in forest areas are of exceptional importance to risk management in forest fire protection. The construction of new roads increases the external and internal openness of the forest areas, and thus provides better communication, which is a prerequisite for the efficiency and effectiveness of the organization of firefighting. On the territory of Serbia, the uneven distribution of the road network is evident, as well as the openness of forest areas. It is a worrying fact that the forest areas which are in Sumadija, Western Serbia, Belgrade, Southern and Eastern Serbia have minimal openness, which means it is difficult to access the places on fire. The fact that the road network did not increase in the 2011-2019 period indicates that this aspect was not taken into account.

For this reason, it is necessary to:

- compile a detailed register of the existing forest road infrastructure of the state and private forests,
- define the criteria to determine the density of the existing forest road infrastructure,
- undertake activities for the construction of new roads in order to achieve optimal openness of the region's forests: Belgrade, Southern and Eastern Serbia, and Sumadija and Western Serbia.

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ŠUMSKE SAOBRAĆAJNICE U FUNKCIJI ZAŠTITE ŠUMA OD POŽARA

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Rezime: *Planiranje, izgradnja i održavanje šumskih puteva je od izuzetnog značaja za uspešno gašenje požara na odredjenom prostoru. Ova studija se fokusira na sagledavanje postojeće tehničke infrastrukture u državnim šumama Srbije. Prosečna otvorenost šuma u Srbiji na kraju 2019. godine iznosi 20,14 m/ha i 21,89 m/ha sa javnim putevima. U periodu od 2011. do 2019. godine prosečna otvorenost državnih šuma u Srbiji je smanjena za 3,12 m/ha, odnosno za 1,67 m/ha otvorenosti sa javnim putevima. Otvorenost šuma šumskim putevima je najveća i optimalna na području regiona Vojvodina (131,5 m/ha) a znatno manja i nedovoljna u regionima: Beogradski (0,35 m/ha), Šumadija i Zapadna Srbija (2,8 m/ha), i Južna i Istočna Srbija (1,8 m/ha). U poređenju sa 2011. godinom otvorenost šuma 2019. godine je uvećana u regionu Vojvodine a smanjena u drugim regionima u Srbiji. Šumski putevi koji imaju kolovoz od asfalta, betona ili kamene kocke su najmanje zastupljeni, oko 0,27%. Najveća je zastupljenost šumskih puteva sa podlogom (kameni ili šljunčani tvrdi donji sloj) oko 82,7%.*

Ključne reči: otvorenost šuma, šumski putevi, šumski požar, Srbija