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
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.

| Region                        | Land area km² | Forest area km² | 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.

| Year | Forest roads (km) | Public roads (km) | Total km |
|------|-------------------|-------------------|----------|
|      | total             | contemporary      | soft     | solid    | total | contemporary | soft | solid | total |
| 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.

| Year | Forest roads (km) | Public roads (km) | Total km |
|------|-------------------|-------------------|----------|
|      | total             | contemporary      | soft     | solid    | total | contemporary | soft | solid | total |
| 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 |

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    | 2011 | 51    | 6     | 28   | 17    | -     | -     | -    | -     |
| Voj    |      | 20253 | 25    | 1403 | 28825 | 140   | 123   | 15   | 2     |
| SZS    |      | 4759  | 50    | 1921 | 2788  | 212   | 174   | -    | 38    |
| JIS    |      | 2720  | -     | 1875 | 845   | 5     | -     | -    | 5     |
| Beo    | 2012 | 51    | 6     | 17   | 28    | -     | -     | -    | -     |
| Voj    |      | 20269 | 25    | 1416 | 18828 | 140   | 123   | 15   | 2     |
| SZS    |      | 4848  | 50    | 1934 | 2864  | 212   | 174   | -    | 38    |
| JIS    |      | 2821  | 5     | 944  | 872   | 6     | -     | -    | 6     |
| Beo    | 2013 | 53    | 6     | 17   | 30    | -     | -     | -    | -     |
| Voj    |      | 20283 | 25    | 1416 | 18842 | 140   | 123   | 15   | 2     |
| SZS    |      | 684   | 50    | 1938 | 2696  | 212   | 174   | 0    | 38    |
| JIS    |      | 3124  | 5     | 2198 | 921   | 6     | -     | -    | 6     |
| Beo    | 2014 | 56    | 6     | 20   | 30    | -     | -     | -    | -     |
| Voj    |      | 20329 | 25    | 1403 | 18901 | 158   | 140   | 16   | 2     |
| SZS    |      | 2577  | 16    | 970  | 1591  | 150   | 112   | -    | 38    |
| JIS    |      | 2941  | 339   | 934  | 668   | 190   | 90    | 30   | 70    |
| Beo    | 2015 | 59    | 6     | 23   | 30    | -     | -     | -    | -     |
| Voj    |      | 20425 | 29    | 1494 | 18902 | 163   | 145   | 16   | 2     |
| SZS    |      | 2709  | 25    | 1641 | 1043  | 38    | -     | -    | 38    |
| JIS    |      | 2319  | 96    | 1516 | 707   | 196   | 90    | 36   | 70    |
| Beo    | 2016 | 59    | 6     | 23   | 30    | -     | -     | -    | -     |
| Voj    |      | 20425 | 29    | 1494 | 18902 | 163   | 145   | 16   | 2     |
| SZS    |      | 2709  | 25    | 1641 | 1043  | 38    | -     | -    | 38    |
| JIS    |      | 2319  | 96    | 1516 | 707   | 196   | 90    | 36   | 70    |
| Beo    | 2017 | 59    | 6     | 23   | 30    | -     | -     | -    | -     |
| Voj    |      | 9355  | 21    | 2243 | 17091 | 1715  | 27    | 1679 | 9     |
| SZS    |      | 3219  | 54    | 2022 | 1143  | 150   | 112   | 38   | 0     |
| JIS    |      | 1949  | 191   | 826  | 932   | -     | -     | -    | -     |
| Beo    | 2018 | 59    | 6     | 23   | 30    | -     | -     | -    | -     |
| Voj    |      | 19943 | 21    | 2823 | 17099 | 1911  | 28    | 1682 | 201   |
| SZS    |      | 3406  | -     | 1367 | 2039  | 116   | 33    | 51   | 32    |
| JIS    |      | 1523  | 43    | 625  | 855   | -     | -     | -    | -     |
| Beo    | 2019 | 18    | 6     | 6    | 6     | -     | -     | -    | -     |
| Voj    |      | 19371 | 22    | 2243 | 17106 | 1919  | 30    | 1684 | 205   |
| SZS    |      | 2801  | -     | 858  | 1943  | 33    | 33    | -    | -     |
| JIS    |      | 1859  | 38    | 985  | 836   | 135   | 135   | -    | -     |

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

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

| Region                        | Belgrade | Vojvodina | Sumadija and W. Serbia | South. and E. Serbia |
|-------------------------------|----------|-----------|------------------------|-----------------------|
| Year                          | 2011     | 2019      |                        |                       |
|                               | 1.0      | 0.35      | 125.8                  | 131.5                 |
|                               |          |           | 4.7                    | 2.8                   |
|                               |          |           | 2.6                    | 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≤30                                                     | Very good                           |
| >30≤60                                                     | Good                                |
| > 60≤ 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.
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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BIOGRAPHY of the first author
Stanimir Živanović was born in 1960. He obtained B.Sc., M.Sc. and Ph.D. from the Faculty of Occupational Safety in Niš. He worked in the Ministry of Internal Affairs – Emergency Management, Department in Bor as a fire safety specialist, from 1983 to 2013. He is the 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.

ŠUMSKE SAOBRAĆAJNICE U FUNKCIJI ZAŠTITE ŠUMA OD POŽARA

Stanimir Živanović, Darko Zigar, Janko Ćipev

Rezime: Planiranje, izgradnja i održavanje šumskih puteva je od izuzetnog značaja za uspešno gašenje požara na određenom prostoru. Ova studija se fokusira na sagledavanje postojeće tehničke infrastrukture u državnim šumama Srbije. Prosečna otvorenost šuma 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), a 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 najbolji na podlogom (kameni ili šljunčani tvrdi donji sloj) ako je poklopac zaštitni, iako je potrebno da se na taj način uvede ohijska zaštitna koja čini šuma od požara.

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