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OPTIMIZATION OF PRIMARY FOREST ACCESSIBILITY IN HIGH FORESTS WITH NATURAL REGENERATION

OPTIMIZIRANJE OTVORENOSTI VISOKIH ŠUMA S PRIRODNOM OBNOVOM

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SUMMARY

Optimization of primary forest accessibility is observed from the point of intensity of forest management and terrain relief conditions of the forest area. Optimization of primary forest accessibility is the first phase of the planning of primary forest traffic infrastructure. The second phase is designing of new primary forest traffic infrastructure. The high forests with natural regeneration (high forests) in the public forests are selected for optimization of accessibility because they are the most valuable forest category from the point of quantity and quality of timber. Planning of primary forest traffic infrastructure implies analysis of actual primary forest accessibility of high forests, determination of optimal density of primary forest traffic infrastructure, defining of suitability of high forests area for construction of primary forest traffic infrastructure and upgrading of actual primary forest traffic infrastructure with new routes of primary forest traffic infrastructure. Optimization of primary forest accessibility in hilly and mountainous high forests was done in two Management Units, Prosara and Bobija-Ribnik. Optimal density of primary forest traffic infrastructure ranges from 24 to 26 m/ha. Results showed that high forests have potential for sustainable forest management.

KEY WORDS: primary forest traffic infrastructure, GIS, multicriteria evaluation

1. INTRODUCTION AND RESEARCH PROBLEM
1. UVOD I PROBLEMATIKA ISTRAŽIVANJA

Sustainability and durability of timber production, as well as other forest products, and the use of forest area can be determined as an optimal forest management. From the aspect of forest harvesting, optimization is utilization of the timber with the minimal total costs of transportation (Dobre 1995). Transport of timber is a very significant and the most expensive part of the forest harvesting. According to Sokolović and Bajrić (2013a) the transport costs make around 80 % of total harvesting costs. Determination of the optimal forest road location in forest landscape is an important part of harvesting planning, especially from the point of economic and environmental aspect (Akay et al. 2013). The planning of primary forest accessibility is a spatial issue of forest management optimization (Kaya et al. 2016).

According to Sokolović and Bajrić (2013a) the average primary forest accessibility in BiH is 10.15 m/ha, while accessibility in primary forest traffic infrastructure in the high forests with natural regeneration (high forests) is 11 m/ha. Accessibility of the public forests by public and forest roads

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in entity of Republic of Srpska (RS) is around 9.4 m/ha. Accessibility of the high forests with primary forest traffic infrastructure is 11.6 m/ha. Average density of the primary forest traffic infrastructure is 9.28 m/ha in public forests (Soković and Bajrić 2013a, Anon 2017, Anon 2019).

Intensive forest management requires density of forest roads over 30 m/ha (Dobre 1995). The ground skidding is the most common timber extraction method in BIH (Marčeta et al. 2014). Density of forest roads depends on extraction type and it should be 25 m/ha for ground skidding in Europe (Dykstra and Heinrich 1996). Recent research in RS showed that the accessibility in some cases could be significantly higher than in official documents and can rise up to 14 m/ha (Potočnik et al. 2013), considering both aspects, production, and terrain characteristics in hilly area.

Pentek et al. (2014) determined the primary forest accessibility from 5 m/ha in karst region to 15 m/ha in mountainous region, and around 11 m/ha in hilly region. Actual density of forest, fire and public roads in Slovenia is around 25 m/ha (Krč and Beguš 2013). Trajanov et al. (2015) determined that primary forest accessibility is 13.43 m/ha in Northern Macedonia. Total primary forest accessibility is around 27 m/ha by forest roads in public forests of Republic of Serbia (Anon 2018). The average forest accessibility is 45 m/ha by forest roads in Austria (Ghaffarian et al. 2009, Findeis 2016).

The actual accessibility of the forest, to be more precise, public forests in RS is lower than in some neighbouring countries and it does not provide an opportunity for sustainable utilisation, regeneration and protection. The consequence of that is the fact that timber harvesting is carried out on a reduced area (Anon 2011). Accessibility of the forests in RS should be improved and it is necessary to approach to the planning of new forest roads. This action consists of planning of primary forest accessibility and designing of new forest roads.

The aim of planning of forest roads is achieving targeted density of forest roads from the point of intensity of forest management, terrain and stand conditions to reduce the average extraction distance. That can be achieved by planning of new routes of the forest roads in suitable areas which are not enough accessible.

General steps in improving of forest accessibility are:

1. analysis of actual primary forest accessibility,
2. defining of targeted forest density of primary forest traffic infrastructure based on forest management intensity and terrain conditions,
3. analysis of achieved primary forest accessibility.

In this study, these tasks will be implemented into two different relief areas and types of high forests.

2. MATERIAL AND METHODS
2. MATERIJAL I METODE

In high forests in RS (61 % of total area of public forests), there are about 5,440.50 km of forest roads and according to it, high forests belong to the most accessible forest category (Anon 2017). High forests with natural regeneration are usually managed by the group-selection management system. The application of this management system forms various age-structured and mixed stands. In this investigation for optimization of accessibility in hilly and mountainous high forests, based on their timber production, terrain and stand characteristics and intensity of forest management, two Management Units (MU), Prosara and Bobija-

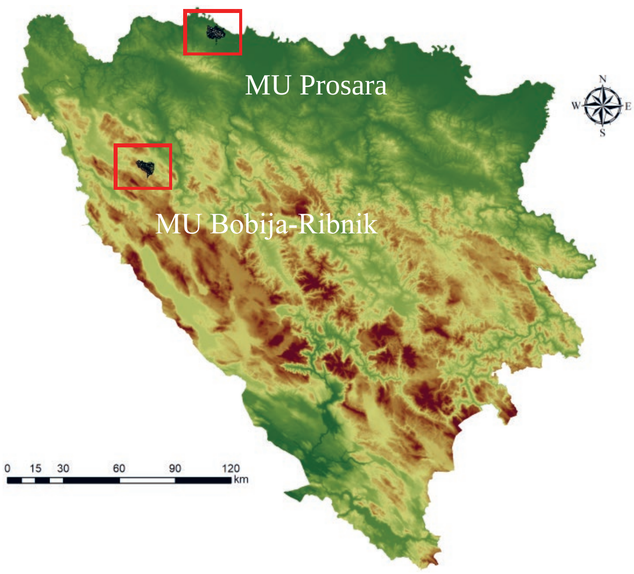

Figure 1. Location of MU Prosara and Bobija-Ribnik in BIH
Slika 1. Lokacija GJ Prosara i Bobija-Ribnik u BIH

Table 1 The characteristics of high forests in selected MUs (Anon 2013a, 2013b)
Tablica 1 Svojstva prirodnih šuma u odabranim GJ (Anon 2013a, 2013b)

MU	Area / *Površina* ha	Growing stock / *Drvna zaliha* m³/ha	Annual increment / *Godišnji prirast* m³/ha	Allowable cutting volume / *Sječivi etat* m³/ha			Primary accessibility / *Primarna otvorenost* m/ha
				Roundwood/ *Oblo drvo*	Fuelwood/ *Ogrijev*	Residue/ *Ostatak*	
Prosara	3,470	267.2	6.7	23.11	13.04	12.64	7.3
Bobija-Ribnik	4,180	413.1	11.27	47.5	13.98	23.95	15.66

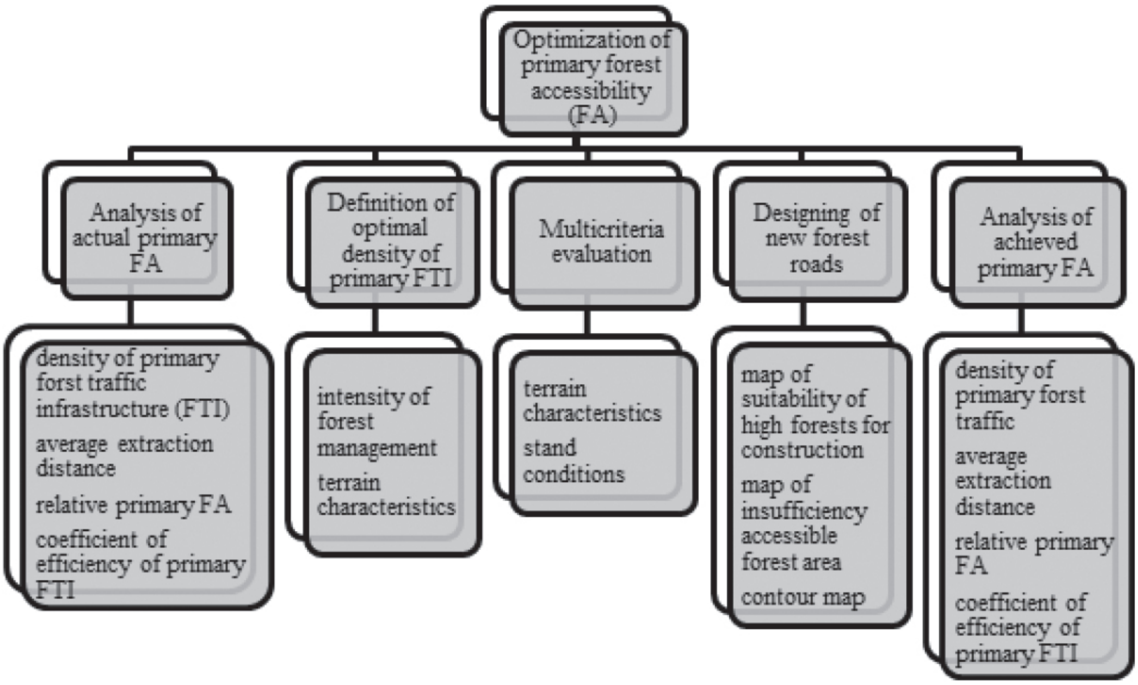

Figure 2. Flow of optimization of primary forest accessibility
Slika 2. Tok optimiziranja primarne otvorenosti šuma

Ribnik are selected (Figure 1). The high forests of the selected areas consist of mixed forests of beech and sessile oak, beech and fir with spruce and beech forests. Soil types range from deep and acidic to carbonate and dolomite soils as follows calcomelanosol, calcocambisol, luvisol and rendzina. As it can be seen, the high forests are diverse in the structure of tree species, plant communities, terrain and stand characteristics (Table 1).

The relative ratios of species are 59 % of beech, 29 % of sessile oak and 12 % of the other species of broadleaves in high forests with natural regeneration of MU Prosara. The relative ratio of broadleaves is 54 % and coniferous 46 % in high forests with natural regeneration of MU Bobija-Ribnik, and the ratio of fir is 33 %, spurce 13 % and beech 43 % respectively (Anon, 2013a, 2013b).

Research method is presented in the Figure 2.

2.1. Analysis of primary forest accessibility - Analiza primarne otvorenosti

The actual primary forest accessibility of forest area is usually expressed by density of primary forest traffic infrastructure, average extraction distance, relative primary forest accessibility and coefficient of efficiency of primary forest traffic infrastructure (Pentek et al. 2005, Sokolović and Bajrić 2013a).

Forest roads influence on the primary forest accessibility depending on its length, spatial distribution and extraction possibility. Poršinsky et al. (2017) defined four basic and five spatial criteria for determination of density of roads in forest. The basic criteria define the properties of roads which make a forest accessible. Spatial criteria determine an influence of roads on primary forest accessibility depending on their position in the forest area. The primary forest traffic infrastructure density is determined based on current length of forest roads, and in this investigation are recorded by GARMIN 62 ST hand held GPS device.

The second indicator of primary forest accessibility is extraction distance and it is observed like geometrical. The geometrical skidding distance is perpendicular distance from harvesting area to the forest road and it is shorter than the real one for value of skidding factor. The geometrical extraction distance is determined by method of Euclidean distance in ArcGIS 10. (Đuka et al. 2017). Harvesting technology that is most commonly used in BIH implies felling and processing of the trees at the stump by chainsaw and extraction of the assortments to the landing site. The most common harvesting method is the assortment method. Timber extraction is carried out by skidders mostly, so it can be spoken of a skidding distance (Marčeta et al. 2014).

Backmund (1966) introduced relative forest accessibility as an indicator of total forest accessibility, and it represents ratio between accessible forest area by primary forest traffic infrastructure and total forest area. That area is defined by width of buffer zone around of primary forest traffic infrastructure and it is equal to double targeted geometrical skidding distance (Pentek et al. 2005, Hayati et al. 2012, Sokolović and Bajrić 2013a). It is calculated by Equation 1:

$$O_R = \frac{P_O}{P_U} \times 100 \quad \text{... (1)}$$

where:

O_R – relative forest accessibility (%),
P_O – the accessible forest area (ha),
P_U – the total forest area (ha).

The forest is insufficiently accessible if relative primary forest accessibility is up to 55 %, it is poorly accessible if it is between 56 and 65 %, hardly well accessible if it is between 66 and 75 %, very well accessible if relative accessibility is between 76 and 85 % and excellent accessible if it is over 85 % (Pentek et al. 2005).

Efficiency coefficient of forest roads network represents the relation between ineffective surfaces, that are multiple accessible, and the total single accessible areas for double average targeted geometrical skidding distance (Pentek et al. 2005, Potočnik et al. 2013, Sokolović and Bajrić 2013a). The multiple accessible areas is obtained by using ArcGIS Geoprocessing tool Intersect as the extricate areas from single accessible areas of buffer zone around primary forest traffic infrastructure. It is calculated by Equation 2:

$$k_U = \left(1 - \frac{P_N}{P_O}\right) \times 100 \quad (2)$$

where:

k_U – efficiency coefficient of the forest road network (%),
P_N – surface of the inefficiency of bordered areas (multiple accessible areas) (ha),
P_O – accessible area for the chosen double aimed geometrical skidding distance (single accessible areas) (ha).

This coefficient represents grade of the impact of the forest roads on the accessibility. This efficiency coefficient should be as higher as possible, because lower coefficient means that roads are multiple overlapping and crossing.

2.2. Optimization of primary forest accessibility – *Optimiziranje primarne otvorenosti*

Optimization means determination of the optimal or targeted density of primary forest traffic infrastructure. The targeted density of primary forest traffic infrastructure will be determined on the basis of recommended density of primary forest traffic infrastructure for normal and intensive forest management and for certain relief regions. Targeted density of primary forest traffic infrastructure is 30 m/ha from the point of intensity forest management (Dobre 1995).

By local regulation provided targeted density of primary forest traffic infrastructure, based on the relief regions and local regulative should be:

- Lowland area – 12 km/1000 ha,
- Hilly area – 18 km/1000 ha,
- Mountainous area – 22.5 km/1000 ha and
- Karst area – 12 km/1000 ha (Anon 2015).

In general, the targeted density of primary forest traffic infrastructure is only a guide for planning of primary forest accessibility for MUs and FMA (Forest Management Administration) and it will be achieved depending on many factors. Multi-criteria evaluation of terrain and stand conditions of forest area is a convenient way for determining of relative strength of influence for each factor.

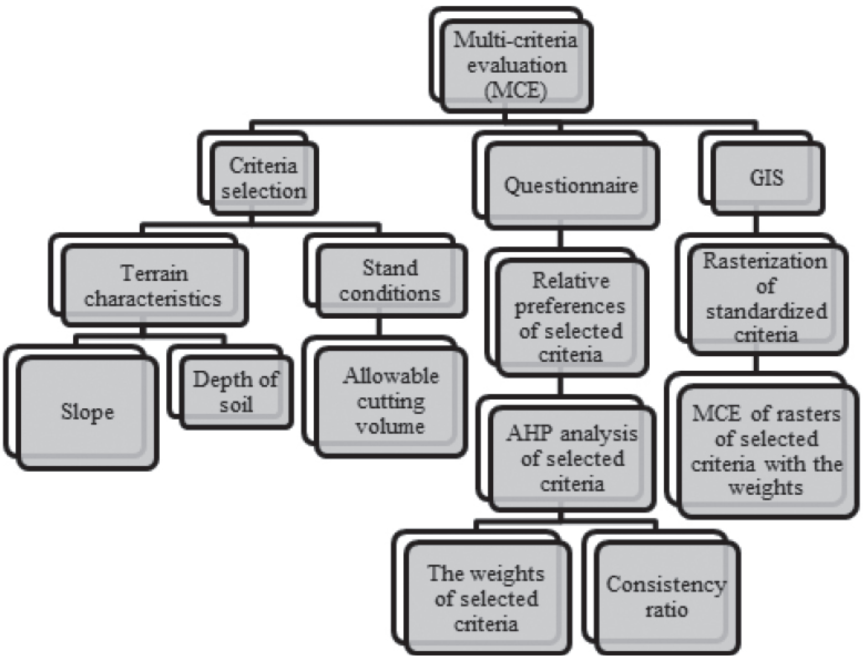

Figure 3. Process of multicriteria evaluation
Slika 3. Proces višekriterijske evaluacije

2.3. Multicriteria evaluation (MCE) – Multikriterijska evaluacija (MCE)

It is necessary to upgrade the actual with new routes of primary forest traffic infrastructure in order to achieve the targeted accessibility and reduce actually skidding distance. At this point, the question is in which area roads should be built. That issue could be solved by defining the suitability area for primary forest traffic infrastructure. The area suitable for construction of primary forest traffic infrastructure will be obtained by spatial analysis in ArcGIS 10 by using the tool Weighted Sum.

This analysis is based on multicriteria evaluation (MCE) of terrain and stand characteristics of forest area (Figure 3). The most common subcriteria used for defining suitability of area for primary forest traffic infrastructure construction in other researches are: terrain slope, growing stock and soil depth (Figure 3) (Abdi et al. 2009, Sokolović et al. 2009, Mohammadi et al. 2010, Caliskan 2013, Lepoglavec 2014, Petković and Potočnik 2018, Petković 2019, Petković et al. 2019). The suitability of area for construction was obtained by addition of standardized raster of influential factors (by Equation 3), which are weighed for each factor. Thematic maps of influential factors with resolution of 5x5 m were obtained by spatial analysis of DTM or data collected from field research and forest management documentation in ArcGIS 10. The weight of each factor means its influence on the suitability of area for forest road construction. These weights were obtained by AHP method. In order to determine weights of influential factors in defining of suitability area for forest road construction in this research a Questionnaire was prepared for assessing the impact of criteria. It was sent to relevant forest-engineering scholars for assessing. The influence of the slope, soil and timber growing stock on determination of area suitability for forest road construction is determined on the basis of opinion of 14 respondent. The average scores which were obtained by questionnaire for each criterion were standardized by Equation 3 and compared to pairwise matrix according to AHP methodology. This method was developed by Tomas Saaty (1980, 2008) and it was created as an auxiliary tool of multicriteria decision-making.

$$X_i = \frac{(R_i - R_{\min})}{(R_{\max} - R_{\min})} \times X_{\max} \qquad (3)$$

where:

x_i – standardized value,
R_i – basic value,
R_{min} – lower value of basic scale,
R_{max} – upper value of basic scale,
X_{max} – upper average value of standardized scale.

Based on the level of suitability and spatial distribution of insufficient accessible forest areas into MU, the new routes of primary forest traffic infrastructure are planned.

2.4. Designing of new routes of primary forest traffic infrastructure – *Projektiranje novih trasa primarnih šumskih prometnica*

The new routes of primary forest traffic infrastructure have to fulfil minimal technical requirements regulated by the Manual for designing of truck roads (Anon 2002). At the general level, they are designed by setting up the zero line on contour map by method of equal length of segments of zero line between contour lines, under constant longitudinal slope. In order to set up of zero line, it is necessary to form contours based on DTM resolution 5x5 m with equidistance of 5 m using ArcGIS 10 tool Extraction Contour. Then, contour lines should be connected with segments of zero line with equal lengths with constant longitudinal grade. The most important constructive element of zero line is maximal longitudinal grade of forest road surface, and it is 8 % (Anon 2002, Petković and Potočnik 2018, Petković et al. 2019). According to previous, minimal length of a segment of zero line is 62.5 based on contour equidistance and road maximal longitudinal grade. Setting up the zero lines is done in insufficient accessible and areas suitable for construction of forest roads in high forests. It is necessary to check a quality of upgraded forest roads network from the point of indicators of primary forest accessibility based on average targeted density of primary forest traffic infrastructure.

3. RESULTS AND DISCUSSION
3. REZULTATI I DISKUSIJA

Two MUs have been chosen from PFC ŠUME RS, which are in two different FMAs, with different terrain and stand characteristics, which are managed by group-selection forest management system. The results of spatial analysis of DTM show that MU Prosara belongs to lowland-hilly area (91 – 362 m a.s.l.) (Figure 4) and MU Bobija-Ribnik belongs

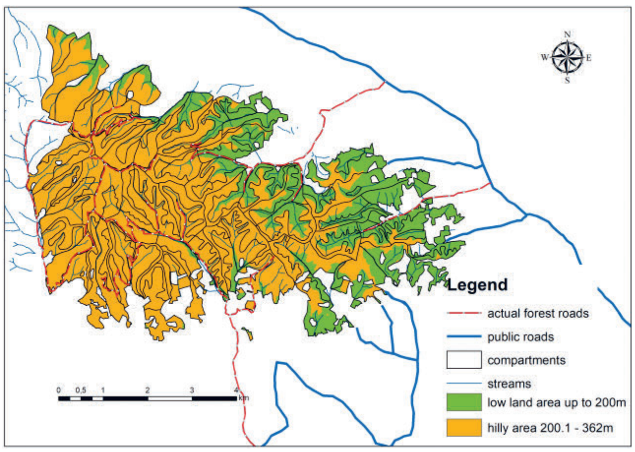

Figure 4. Relief regions in Prosara
Slika 4. Reljefna područja u Prosari

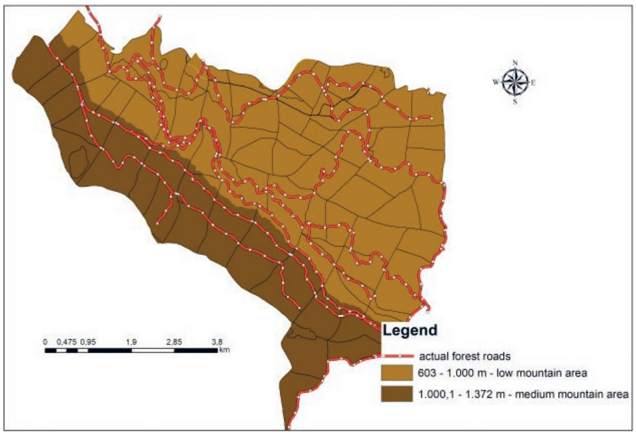

Figure 5. Relief regions in Bobija-Ribnik
Slika 5. Reljefna područja u Bobiji-Ribnik

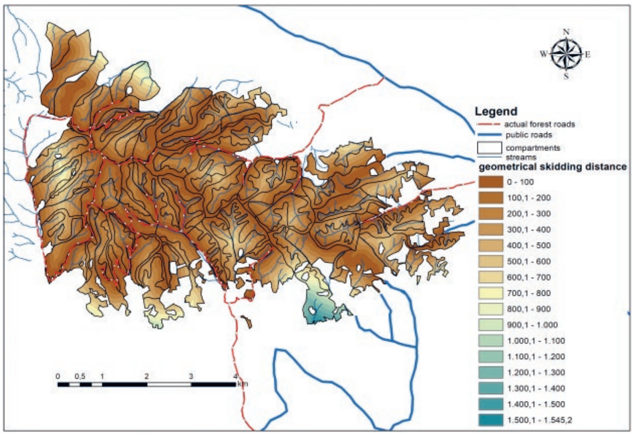

Figure 6. Actual geometrical skidding distance in Prosara
Slika 6. Trenutna geometrijska daljina privlačenja u Prosari

to low and average mountain relief area (603 – 1372 m a.s.l.) (Bertović 1999) (Figure 5).

The results show that accessibility of high forests is higher than one in Forest Management Plans (FMP) (Anon 2013a, 2013b) (Table 1) because of higher vector length of forest roads (Table 2).

These values allow only extensive forest management (Dobre 1995). As it was shown in Table 2, the actual forest road density is higher in mountainous than in lowland-hilly areas. The reason for this is the fact that public and forest railways were intensively built in some period in the past because of intensively utilization of timber from fir and spruce forests in mountainous area. Considering relief areas, Anon (1998) recommends density of primary forest traffic infrastructure from 7 to 10 m/ha in hilly areas and up to 35 m/ha on steep terrain. Enache et al. (2016) determined that density of forest roads is 18.5 m/ha in mountainous region of Europe. According to that, it can be concluded that investigated MUs have the recommended forest accessibilities. That means that overall primary forest accessibility is achieved considering relief areas to which both selected MUs belong.

The average geometrical Euclidean skidding distances (Figure 6 and 7) (Table 2) are lower for 23 m in MU Prosara and 38 m in MU Bobija-Ribnik than the geometrical skidding distances obtained by method of distance of gravity centre of compartments from route of the forest road, which are 510 m and 281 m respectively (Petković and Potočnik 2018, Petković et al. 2019).

The average values of targeted densities in selected MUs (Table 3), allow normal forest management and they are suitable for ground skidding extraction according to Dykstra and Heinrich (1996). The average targeted densities of primary forest traffic infrastructure, which are based on total cost of transport and allowable cut volume of roundwood, are 16 m/ha for MU Prosara and 26.5 m/ha for MU Bobija-Ribnik (Petković and Potočnik, 2018, Petković , 2019, Petković et al., 2019). According to Master plan of for-

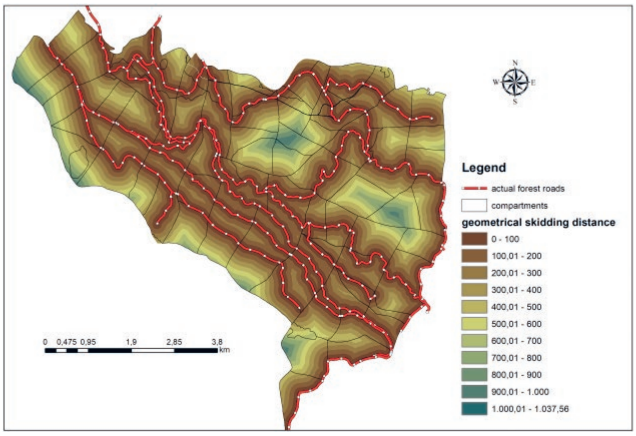

Figure 7. Actual geometrical skidding distance in Bobija-Ribnik
Slika 7. Trenutna geometrijska daljina privlačenja u Bobiji-Ribnik

Table 2. Indicators of actual primary forest accessibility
Tablica 2. Pokazatelji trenutne primarne otvorenosti šuma

MU/*GJ*	Density of primary forest traffic infrastructure / *Gustoća primarne šumske prometne infrastrukture* (m/ha)	Average geometrical skidding distance / *Srednja geometrijska daljina privlačenja* (m)	Relative primary accessibility / *Relativna primarna otvorenost* (%)	Coefficient of efficiency of primary forest traffic infrastructure / *Koeficijent efikasnosti primarne šumske prometne infrastrukture* (%)
Prosara	9	487	49	73
Bobija-Ribnik	17	243	91	10

Table 3. Average targeted densities of primary forest traffic inftastructure
Tablica 3. Prosječna ciljna gustoća primarnih šumskih prometnica

Density / *Gustoća* (m/ha)	Normal and intensive forest management / *Normalno i intenzivno gospodarenje šumama*	Relief region / *Reljefni region*	Average / *Prosjek*
MU Prosara	30	18	24
MU Bobija-Ribnik	30	22.5	26

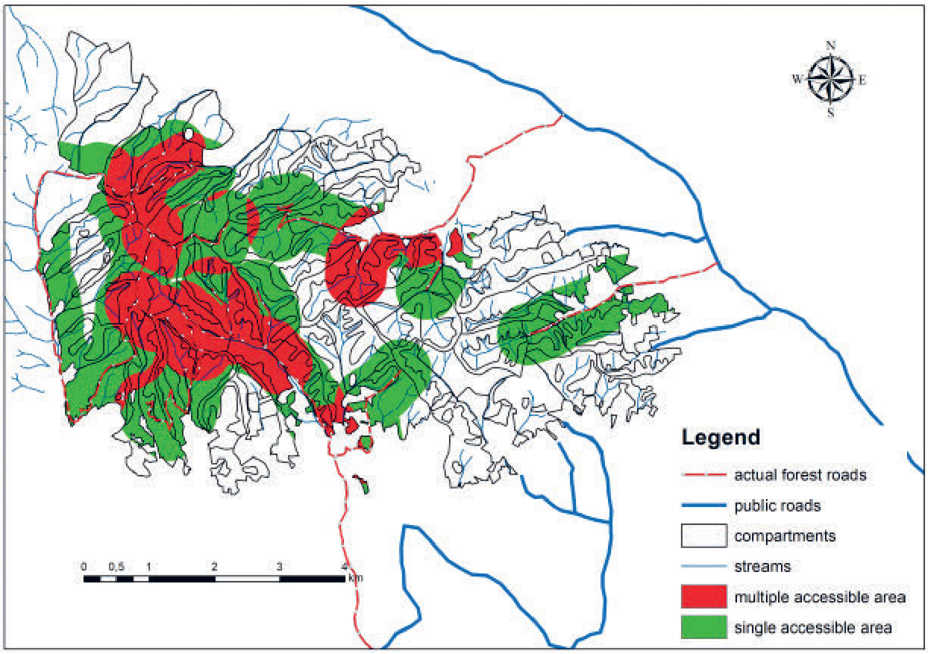

Figure 8. Efficiency of actual forest roads network in Prosara
Slika 8. Kvaliteta trenutne mreže primarne šumske prometne infrastrukture u Prosari

est roads in RS average targeted densities for these two MUs are 17.47 m/ha and 19.85 m/ha (Anon 2019). Thus, the actual forest road density is lower than the targeted one and the targeted density of primary forest traffic infrastructure is higher in mountainous than in the hilly areas (Table 3).

The real skidding distance for obtained average targeted densities in of these MUs ranges from 250 to 308 m. The average targeted geometrical skidding distance is 189 m in MU Prosara and 283 m in MU Bobija-Ribnik. They are calculated by Rebula's (1981) equation and they are lower than values of actual geometrical skidding distances.

The single accessible high forests area is 1,666.073 ha and multiple accessible area is 442.26 ha in Prosara (Figure 8). The single accessible high forests area is 3,817.94 ha, and multiple is 3,427.15 ha in MU Bobija-Ribnik for double-targeted geometrical skidding distance (Figure 9). The grade of relative primary forest accessibility ranges from poorly to excellent. The coefficient of efficiency should be as high as possible because it is the indicator of quality of designing of forest roads (Table 2).

Multicriteria evaluation of the terrain slope, growing stock and soil depth of the chosen areas determined suitability of investigated forests area for construction of primary for-

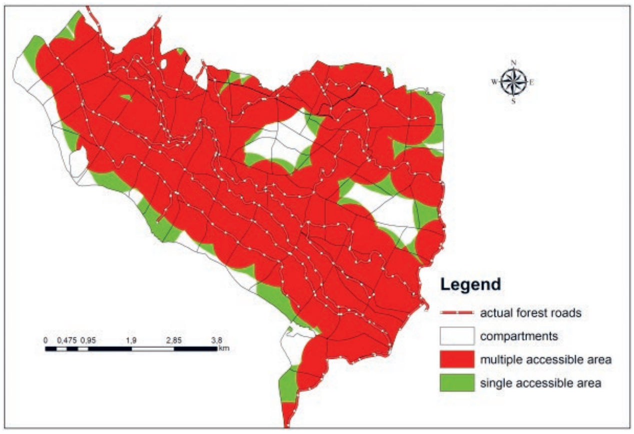

Figure 9. Efficiency of actual forest roads network in MU Bobija-Ribnik
Slika 9. Kvaliteta trenutne mreže primarne šumske prometne infrastrukture u Bobiji-Ribnik

est traffic infrastructure. Slope of terrain ranges from 0 to 122 %, depth of soil ranges up to 340 cm, and growing stock ranges from 150 to 455 m^3/ha. The influence of the selected subcriteria was obtained by AHP method. Based on the average original values for each subcriterion from questionnaire (slope 2.57, depth of soil 1.71 growing stock 2.5), actually their standardized values (slope 0.786, depth

Table 4. Pairwise matrix sub-criteria
Tablica 4. Matricauspoređivanja podkriterija

	slope	depth of soil	growing stock
slope	1	2.2	1.047619048
depth of soil	0.4545455	1	0.476190476
growing stock	0.9545455	2.1	1
sum	2.4090909	5.3	2.523809524

of soil 0.357 growing stock 0.75), and the results of the pairwise comparison (Table 4) weights of the subcriteria are slope 0.42, depth of soil 0.19 and growing stock 0.40 (Table 5). This is input for determination of suitability of high forests area for construction of primary forest traffic infrastructure (Petković, 2019, Petković et al. 2019). The suitable forest areas for the primary forest traffic infrastructure cover 99 % surface in the both MUs.

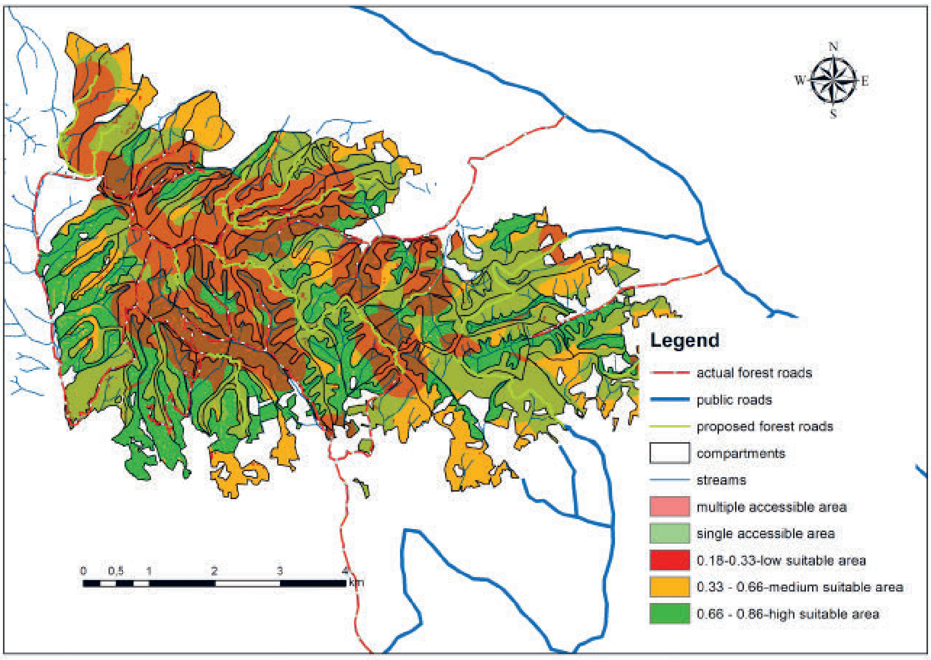

Figure 10. Indicators of achieved primary forest accessibility in Prosara
Slika 10. Pokazatelji dostignute primarne otvorenosti šuma u Prosari

Table 5. Matrix normalized vectors
Tablica 5. Matrica normaliziranih vektora

	slope	depth of soil	growing stock	weight	sum	consistency of matrix
slope	0.415	0.415	0.415	0.415	1.245	3
depth of soil	0.189	0.189	0.189	0.189	0.566	3
growing stock	0.396	0.396	0.396	0.396	1.189	3
sum	1	1	1	1	λ_{max}	3
					CI	0
					RI	0.58
					CR	0

λ_{max} – maximum value of pairwise matrix, CI –consistensy index, RI-random index, CR – consistency ratio

Table 6. Indicators of achieved primary forest accessibility
Tablica 6. Pokazatelji dostignute primarne otvorenosti šuma

	Density of primary forest traffic infrastructure / *Gustoća primarne šumske prometne infrastrukture* (m/ha)	Average geometrical skidding distance / *Srednja geometrijska daljina privlačenja* (m)	Relative primary forest accessibility / *Relativna primarna otvorenost* (%)	Coefficient of efficiency of primary forest traffic infrastructure / *Koeficijent efikasnosti primarne šumske prometne infrastrukture* (%)
MU Prosara	13.5	247	79	56
MU Bobija-Ribnik	21	158	97	9.1

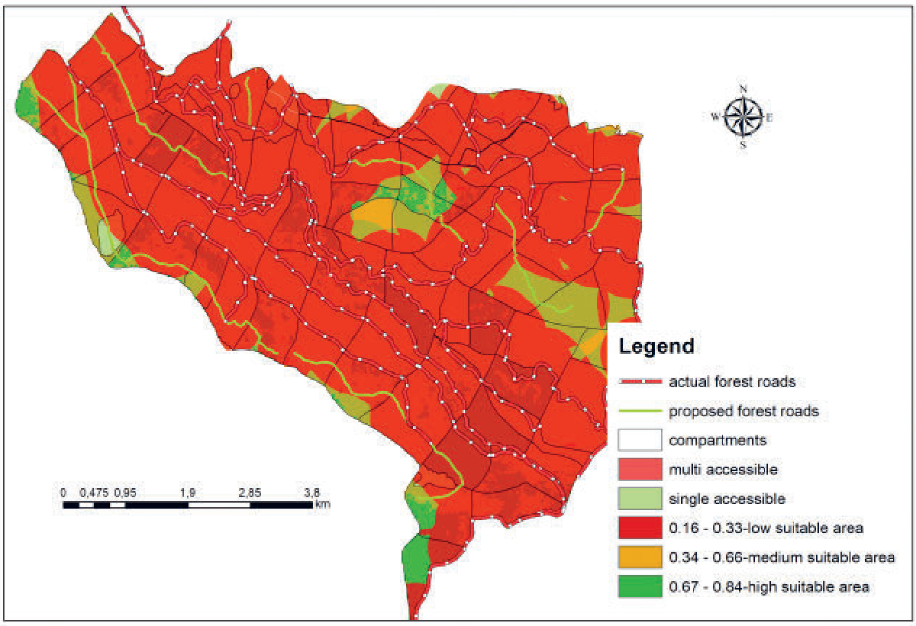

Figure 11. Indicators of achieved primary forest accessibility in Bobija-Ribnik
Slika 11. Pokazatelji dostignute primarne otvorenosti šuma u Bobiji-Ribnik

In this way starts the phase of forest roads designing at the general level where its set up zero lines on suitability maps. Zero lines are placed in areas suitable for the construction and insufficiently accessible at the same time, considering watercourse protection and prescribed horizontal and vertical alignments of the forest roads (Figures 10 and 11).

Thus, in MU Prosara is set up 21 km of zero lines for new primary forest traffic infrastructure and around 22 km in MU Bobija-Ribnik. Density of primary forest traffic infrastructure is enlarged for 6.24 m/ha and 5.15 m/ha (Table 6).

The achieved geometrical skidding distance obtained by Euclidean's algorithm (Table 5) are lower than the actual ones. The multiple accessible high forests area is 1,202.82 ha and single accessible is 2,719.215 ha for double average targeted geometrical skidding distance in MU MU Prosara. In MU Bobija-Ribnik single accessible area is 4,247.513 ha and the multiple accessible high forests area for double average targeted geometrical skidding distance is 3,860.64 ha (Figure 10 and 11). The grades of relative primary forest accessibility for upgraded forest roads network range from very well in MU Prosara to excellent in MU Bobija-Ribnik for double average targeted geometrical skidding distance and they are increased in comparison with actual primary forest traffic infrastructure. The coefficients of efficiency of upgraded primary forest traffic infrastructure are slightly decreased in comparison with coefficients of efficiency for the actual one (Table 6).

Summarizing the results of research, it can be said:

- Actual primary forest accessibility is insufficient for normal and intensive forest management. This statement is based on analysis of actual primary forest traffic infrastructure from the point of its density.
- Analysing of achieved primary forest accessibility on the basis of upgraded primary forest traffic infrastructure from the point of its density, it can be confirmed that achieved primary forest accessibility is lower than targeted, but the quality of achieved primary forest accessibility is raised.

4. CONCLUSIONS
4. ZAKLJUČCI

Today a comprehensive process of planning of primary forest accessibility is present which includes all of the aspects of usage of forests and forest area. Apart from timber production and usage of the other forest resources, terrain and stand characteristics, it includes protection of forest environment, usage of forest area in health, sports and cultural purpose. That is a large number of numerical and descriptive data whose collection, surveying and analysis require usage of the achievements in the field of IT technology. The devices and software's such as GIS, SPSS, RoadEng programme packages and GPS are necessary for modern planning of forest roads and their management.

Using of GIS software's (ArcGIS, GlobalMapper or QGIS) requires quality data for spatial and statistical analysis. Quality of these data can be provided by Light Detection Airborne Ranging (LiDAR) system. On the basis of LiDAR scanning of ground Digital Elevation Model (DEM) could be made.

Here, the focus was on the primary forest traffic infrastructure designing in the public forests. The reason for this is that the private forests are small and fragmented, scattered on wide area. Often, for private forests, the property relations are not resolved. The mobilization of the private forest-owners can be increased then when a better logistics, infrastructure and organizational conditions are provided (Pezdevšek Malovrh et al. 2017).

The results of the research suggest the necessity of making of the studies of the primary forest accessibility for MUs based on comprehensive analysis of terrain characteristics, stand conditions, traffic infrastructure and the other criteria. The analysis requires making of GIS analysis of MUs based on data collected from FMPs, surveyed in the field or obtained from DTM. The results of should be embedded into FMPs in which is necessary to do analysis, comparison and monitoring of the planned and realized activities in optimization of forest accessibility.

This increase of primary forest accessibility will be burdened with the higher costs of timber harvesting and transport due to introduction of new technology and the planning of forest traffic infrastructure on steep terrain and inaccessible areas because the timber is no longer readily available.

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SAŽETAK

Optimiziranje primarne otvorenosti šuma promatrano je sa stajališta inteziteta gospodarenja njima i terenskih, odnosno reljefnih karakteristika određenog šumskog područja. Proces optimiziranja primarne otvorenosti šuma je prvi dio procesa planiranja primarne šumske transportne infrastrukture, a drugi dio je projektiranje novih trasa primarne transportne infrastrukture. Ovaj proces je neophodan, jer trenutačna primarna otvorenost šuma u BIH omogućava tek ekstenzivno gospodarenje šumama. Visoke šume s prirodnom obnovom odabrane su za optimizaciju primarne otvorenosti, zbog toga što je ova kategorija šuma najvrijednija s kvantitativnog i kvalitativnog gledišta drvne mase. Planiranje primarne transportne infrastrukture podrazumijeva: analizu trenutačne primarne otvorenosti visokih šuma s prirodnom obnovom, određivanje optimalne gustoće primarne šumske transportne infrastrukture, definiranje pogodnosti šumskog područja za gradnju primarne transportne infrastrukture na osnovi višekriterijske analize i projektiranje novih trasa primarne šumske transportne infrastrukture kao nadogradnja trenutačne. Optimiziranje primarne otvorenosti brdskih i planinskih visokih šuma s prirodnom obnovom obavljeno je u dvije gospodarske jedinice, GJ Prosara i GJ Bobija-Ribnik. Korištena je AHP metoda višekriterijske evaluacije i GIS. Određena je optimalna gustoća primarne šumske transportne infrastrukture od 24, odnosno 26 m/ha za prvu odnosno drugu jedinicu, što će omogućiti normalan intezitet gospodarenja visokim šumama u odabranim GJ.

KLJUČNE RIJEČI: primarna šumska transportna infrastruktura, GIS, višekriterijska analiza