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PLANNING OF FOREST ROADS NETWORK: CASE STUDY IN THE MOUNTAIN NATURAL FORESTS AREA OF BOSNIA AND HERZEGOVINA

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Abstract: The natural forests (NF) are usually named high forests and they regenerate naturally from the seeds. A natural forest accessibility and overall forest accessibility are insufficient for sustainable forest management. It is a reason for research of planning of forest roads (FR), actually planning of forest accessibility and designing of forest roads. This task requires quantity and quality analysis of actual forest roads network, determination of optimal density of forest roads, determination of suitability of forest area for construction of forest roads and designing of forest roads at the end. Planning of forest roads is carried out at strategic level. The tools of Geographic information system (GIS) allow complete spatial and statistical analysis and management of data which are collected from forest management plans, measured in the field and obtained from Digital terrain model (DTM). Planning of forest roads will be done in the Forest management unit (FMU) "Bobija-Ribnik" and Forest Management (FM) "Oštrelj-Drinić", Petrovac municipality, Bosnia and Herzegovina. The total length of forest roads in natural forests is 64.14 km. According to that, actual accessibility of natural forests is 15.66 m/ha. Optimal average density of forest roads should be 26.5 m/ha. Length of new forest roads which are designed into FMU is around 22 km, and achieved natural forest accessibility is 21 m/ha.

Key words: density of forest roads, optimization, DTM, GIS, AHP

INTRODUCTION AND RESEARCH ISSUES

Sustainability and durability of timber production, as well as of the other forest products and the use of forest area can be determined with the term optimal forest management. In a mathematical way, optimization is defining the minimal or maximal value of the real function. From the aspect of using timber, optimization is utilization of the forests with the minimal total cost of transportation (Dobre, 1995; Potočnik, 2004) considering the rest of the forest users. Transport of timber is a very significant and the most expensive part of the harvesting operations. According to Sokolović and Bajrić (2013a), the transport cost makes around 80 % of total cost of the harvesting operations.

Actual primary forest accessibility

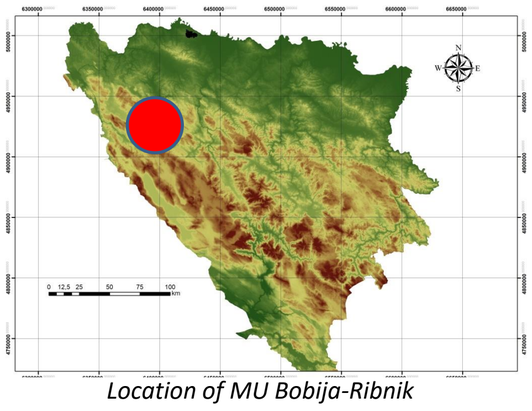
Items	BIH	RS	FBIH
Length of FR (km)	21,000	9,464	11,422
Forest accessibility (FA) (m/ha)	10.15	9.4	10.9
Accessibility of NF (m/ha)	11	11.4	10.5

The actual accessibility of the forests, to be more correct public forests in RS and BIH, is less than the accessibility in the neighbouring countries and it is insufficient for intensive forest management. The conclusion is that the accessibility of the forests in our country should enlarge, that is, it is needed to execute the planning of forest roads. Planning of forest roads consists of planning of 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 in the order to reduction of average extraction distance and average extraction cost.

MATERIAL AND METHODS

Case study MU Bobija-Ribnik (Public Forest Company (PFC) "Forests of Republic of Srpska")
The natural forests are usually named high forests and they regenerate naturally from the seeds. This forest category is environmentally and economically the most valuable forest category and it is observed from the aspect of its actual and potential accessibility by forest roads.



Location of MU Bobija-Ribnik

Stand and infrastructure characteristics of natural forests

Items	MU BOBIJA-RIBNIK
Area (ha)	4,194
Allowable cut of total timber volume (m³/ha)	85.43
Allowable cut of volume of roundwood (m³/ha)	47.5
Length of FR (km)	64
FA (m/ha)	15.7

Methods

- Analysis of natural forest accessibility from the point of density of forest roads and determination of skidding distances,
- Determination of optimal forest roads density by graphical and mathematical methods based on costs of transport and allowable cut volume,
- Definition of suitability of natural forests area for construction of forest roads by AHP method and using of GIS tools,
- Designing of new forest roads using GIS tools, and
- Analysis of achieved forest accessibility.

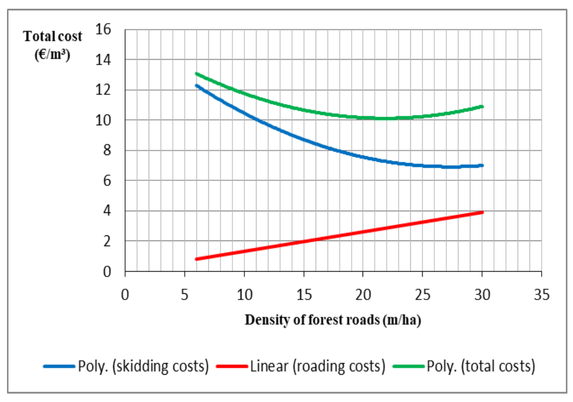
RESULTS AND DISCUSSION

Indicators of actual natural forest accessibility

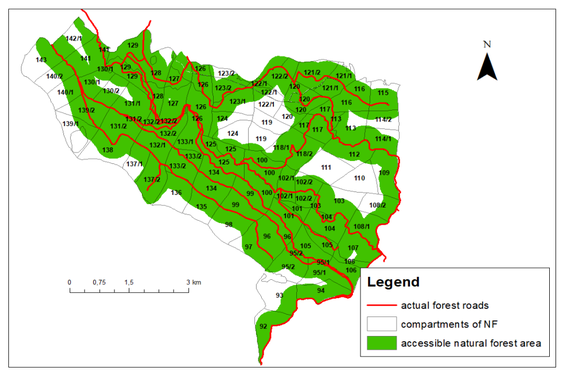
Items	MU BOBIJA-RIBNIK
Relief area (Bertović, 1999)	Mountain (603 – 1372 m a.s.l.)
Actual geometrical skidding distance (m)	281
Skidding factor	1.4
Actual real average skidding distance (m)	393
Actual skidding costs (€/m³)	7.7
Skidding direction downhill/uphill (%)	65/35

Optimization of density of forest roads

Items	MU BOBIJA-RIBNIK
Minimal transport cost (€/ m³)	8.3-12.1
Optimal density of forest roads based on minimal total transport cost (m/ ha)	15-29 (22)
Calculated optimal density of forest roads (m/ ha) FAO (1998)-COFORD (2000)	27-35.5 (31)
Average (m/ha)	26.5
Real targeted skidding distance (m)	303
Geometrical targeted skidding distance (m)	216
Cost of skidding (€/m³)	6.95
Relative FA (%)	89
Coefficient efficiency (%)	20



Minimal total transport cost



Relative natural forest accessiblity

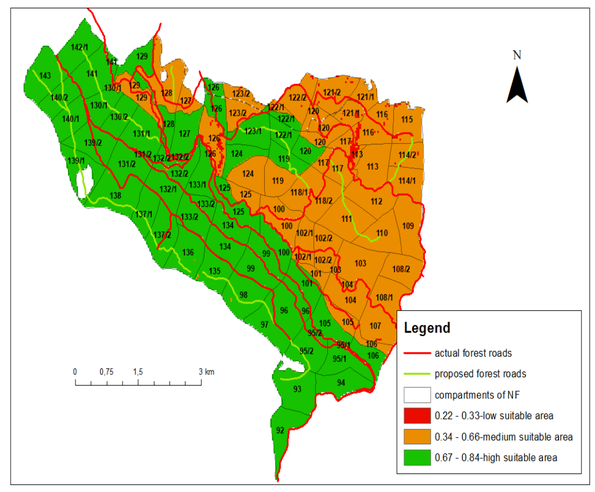
Suitability of natural forest area for construction of forest roads

Results of AHP method

Influential factors	Weights
Slope	0.42
Depth of soil	0.19
Growing stock	0.40

Forest road designing

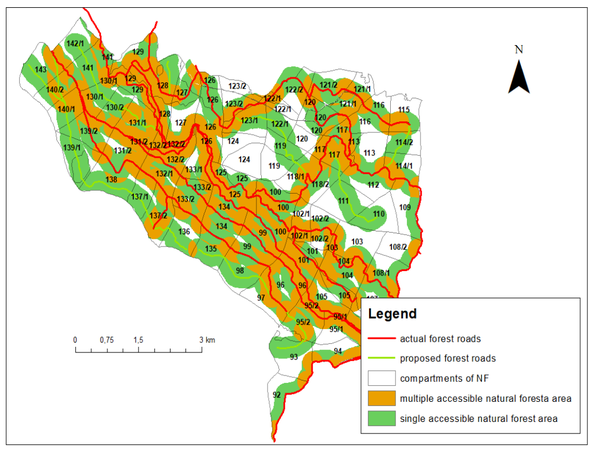
Forest road designing on the level of zero line is realised on the basis of results of the AHP method in areas which are medium or high suitable for their construction on the map of suitability of natural forests area for construction of forest roads and insufficient accessible for double aimed geometrical skidding distance, too.



Proposed forest roads in suitable natural forest areas for construction of forest roads

Achieved forest accessibility

Items	MU BOBIJA-RIBNIK
Length of FR km	22
Achieved density of forest roads (m/ ha)	22
Acieved real skidding distance (m)	242
Skidding cost (€/m³)	6.5
Economic analysis	
Savings in skidding cost (€/m³)	1.1
Total savings (€)	306,000
Period (years)	11



Single and multiple accessible natural forest area

CONCLUSIONS

- **it is necessary to establish GIS department at the PFC or the FMs,**
- **it is necessary to make GIS of MUs based on data collected from FMPs, surveyed in the field or obtained from DTM,**
- **to make the studies of the forest accessibility for MU based on comprehensive analysis and MCE of terrain and stand conditions and the other factors,**
- **the results of the implemented plans should be embedded into FMP, it is necessary to do analysis, comparison and monitoring of the planned and realized activities in optimization of forest accessibility,**
- **concentration of timber at the landings because of cheaper production of timber biomass for energy,**
- **introduction of adapted agricultural tractors for timber skidding.**