

Methodology for Development of Secondary Forest Traffic Infrastructure Cadastre

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Abstract – Nacrtak

Nowadays, under conditions in which forest areas are being opened with increasing number of forest roads due to great need for forest resources, the need for a well-kept system of forest roads becomes a necessary prerequisite in the process of intensification of forest ecosystems management. Cadastre of primary forest traffic infrastructure on the territory of the Republic of Croatia has already been established, and now the need for secondary forest road cadastre arises. Development of secondary forest road cadastre methodology will make a great and important step in inventarisation of the entire secondary forest traffic infrastructure. Although this is a comprehensive and very demanding job, it will result in numerous benefits to forest profession. Once established, a comprehensive forest traffic infrastructure cadastre will be able to easily and relatively quickly supplement newly built forest communications. Based on numerous analyses of primary and secondary forest traffic infrastructure, forest experts can enhance the quality of forest communications spatial configuration and direct the process of further primary and secondary forest opening up with the final goal of establishing the optimal primary and secondary forest network from technical-technological, economic, environmental-ecological and sociological-aesthetic point of view.

Key words: *cadastre of forest traffic infrastructure, secondary forest roads, secondary relative openness, GIS*

1. Introduction – Uvod

Under the conditions of contemporary intensive forest resources management, there is an increased need for forest communications, both primary and secondary ones. The construction of a larger number of primary forest roads contributes to a decrease of the mean skidding distance, which results in smaller costs of timber harvesting. On the other hand, technology selection for timber harvesting (forwarders, skidders, tractors) has its effect on the increased number of newly built skid roads.

The newly arisen situation, where an increased number of forest communications is met, requires taking of an inventory of forest traffic infrastructure and establishment of a complete forest communications cadastre.

Establishment of the forest traffic infrastructure cadastre enabled precise and detailed insight in the existing traffic resources of the forest area (Pentek et al. 2007), analysis of the existing conditions in the

primary and secondary openness of forests, observing of possible deficiencies and shortcomings (Pentek et al. 2005a), quality primary and secondary opening of unopened and insufficiently opened areas (Pičman et al. 2006a), planning (Pentek et al. 2005b) and cost-control in the construction and maintenance of forest roads (Pentek et al. 2007), planning and cost-control in the construction and repair of skid roads (Pentek 2002), preparing of harvesting plan and similar.

If there is no such a cadastre or if it is incomplete (Pentek et al. 2003), then it is necessary to carry out field inventory of the primary (all forest roads and public roads that can be used during forest management works) and secondary forest traffic infrastructure (skid roads and skid trails).

According to Pičman et al. (2006b) the preparing of secondary forest communications cadastre has not taken hold in the practice yet, as opposed to the primary forest traffic infrastructure cadastre. How-

ever, the necessity of starting such a process, under the unquestionable profits to be achieved upon completion of the job, is only a question of days. During the construction of new forest communications, the existing cadastre should be systematically updated in order to dispose with the actual conditions of the forest traffic infrastructure.

2. Research issues – *Problematika istraživanja*

Secondary forest roads (Šikić *et al.* 1989) are constructed facilities, which are occasionally used for performing the tasks provided by the Management Plan. They are, primarily, intended for skidding or forwarding operations. Secondary forest traffic infrastructure may be divided into skid roads and skid trails.

Skid roads are constructed facilities, in which earth-moving works are present, whereby the upper layer is missing. Skid trails are temporary constructed facilities, obtained by intersection through the forest and by successive tractor passing over the same track. After they have completed their function, the forest takes them over again. The term »skid road« dates back to the 19th century, when it referred to a corduroy road made of logs, used to skid or drag logs through woods and bog (Turner 1986).

The existence of a secondary forest road network is a precondition for timber transport in hilly, highland, upland and mountain forests. Under extremely heavy terrain conditions, secondary forest roads most often have to be constructed (skid roads), and more rarely they arise by multiple tractor passing over the same track (skid trails). Without well prepared skid roads, operating on such terrains would be almost impossible for the ground moving machines used for timber extraction (cable skidders).

The density of the secondary forest road network and their arrangement depend on many factors (Nevčerel *et al.* 2007):

- ⇒ Technical means used in timber harvesting,
- ⇒ Configuration,
- ⇒ Terrain rockiness,
- ⇒ Number of trees on a specific surface,
- ⇒ Dimensions of trees,
- ⇒ Position of the main truck forest road, to which timber is extracted.

Rebula (1983) comes to the conclusion that the secondary forest communications openness, i.e. the necessary density of skid roads and trails amounts to 250–300 m/ha in young forest stands, while in the

older forest stands, where the tree distance is larger, it amounts to 100–180 m/ha.

For the area of selective forests in Gorski Kotar, an optimal density of secondary forest traffic infrastructure of 150 m/ha (Zdjelar 1990) was established.

Depending on their horizontal (position) and vertical (altitude) route development, the following skid roads can be distinguished:

- ⇒ Lowlands skid roads,
- ⇒ Valley skid roads,
- ⇒ Hillside, and
- ⇒ Ridge skid roads.

When selecting the skid road route, efforts are made to use the gravitational force in the direction of timber extraction. In downhill travel, the tractor is far less burdened, faster movement is possible, and skidding of a larger load quantity is possible. The result is the reduction of timber transport costs. Uphill skidding of timber is not justified, if the possibility for downhill skidding of timber exists. A skid road adjusts itself to terrain configuration to a higher extent than a primary forest road, and the width of the driving surface on a skid road is less than on the truck forest road. Consequently, it is understandable that during the construction of skid roads, the scope of the earth-moving works is less than during the construction of truck forest roads.

According to Jeličić (1983) 10 to 30 times less financial funds are necessary for the construction of the same length of a skid road under similar terrain conditions than for the construction of a primary forest road.

The first step that should be made, before the beginning of the opening up procedure for a certain forest area with secondary forest roads, is the analysis of the existing secondary forest road network. In order to perform the analysis procedure, the cadastre of secondary forest traffic infrastructure should be prepared in digital format.

According to Pičman *et al.* (2006b), the secondary forest traffic infrastructure is categorized in the following manner:

- ⇒ Skid roads/trails of the I order – all skid roads/trails diverging from the public or primary forest roads,
- ⇒ Skid roads/trails of the II order – all skid roads/trails diverging from skid roads/trails of the I order,
- ⇒ Skid roads/trails of the III order – all skid roads/trails diverging from skid roads/trails of the II order,

⇒ Skid roads/trails of the IV order – all skid roads/trails diverging from skid roads/trails of the III order.

3. Goals and Research Methods – *Cilji metode istraživanja*

3.1 Goal of research – *Cilj istraživanja*

The goals of this research are defined by the following phases of work:

- ⇒ Establishment of GIS for the research area,
- ⇒ Preparing the cadastre of secondary forest roads,
- ⇒ Defining the criteria for categorization of secondary forest traffic infrastructure,
- ⇒ Analysis of secondary relative openness.

3.2 Method of research – *Metode istraživanja*

3.2.1 Establishment of GIS for the research area – *Uspostava GIS-a istraživanoga područja*

For the management unit of Veprinačke šume, Forestry Office Opatija, a geographic information system (GIS) was established in such a manner that layered maps to the scale of 1: 5000 were scanned, whereby data processing and digitalization of the management division (borders of management unit, compartment and subcompartment) was performed. Then the physical units of a subcompartment, as the smallest accounting forestry units, were joined with the data from the Management Plan. The processing was performed by ArcGIS program package.

3.2.2 Preparing the cadastre of secondary forest roads – *Formiranje katastra sekundarnih šumskih prometnica*

The whole job of preparing the secondary forest road cadastre is divided in two basic parts: the first one includes terrain measurement for the required data, and the second part includes computer data processing (data entry, transformation, preparation for drawing on forest-management maps in digital format).

During the survey of secondary forest roads, we have used a contemporary method of work – GPS device, Trimble, GeoExplorer 3 with the use of an internal antenna, whereby the recording interval was 5 seconds.

The surveying was performed by the so-called snap-back method, in which the surveying is performed by walking in both directions, which enables a better fitting of data in the space.

The data obtained were processed by the program package GPS Pathfinder Office 2.80., and then drawn in on the previously prepared basis.

3.2.3 Defining the criteria for categorization – *Utvrđivanje kriterija za kategorizaciju*

The prerequisite for defining the categorization criteria was a way of separating certain secondary forest roads. For each secondary forest roads, a specific sequence of opening up was provided for each area.

3.2.4 Analysis of secondary relative openness (method of bordered surfaces) – *Analiza sekundarne relativne otvorenosti (metoda omeđenih površina)*

During evaluation of and commenting on the secondary relative openness, the modified evaluation system of primary relative openness will be used (Pentek 2002). The modified evaluation system of secondary relative openness looks as follows:

- ⇒ Up to 60 % – insufficient openness (1),
- ⇒ From 60 to 70 % – poor openness (2),
- ⇒ From 70 to 80 % – barely good openness (3),
- ⇒ From 80 to 90 % – very good openness (4) and
- ⇒ Over 90 % – excellent openness (5)

4. Area of research – *Područje istraživanja*

Compartments of the management unit Veprinačke šume, situated between 45°20' and 45°24' of the northern geographic latitude, and 14°11' and 14°16' of the eastern geographic longitude, have been selected as the area of research (Fig. 1). The total sur-

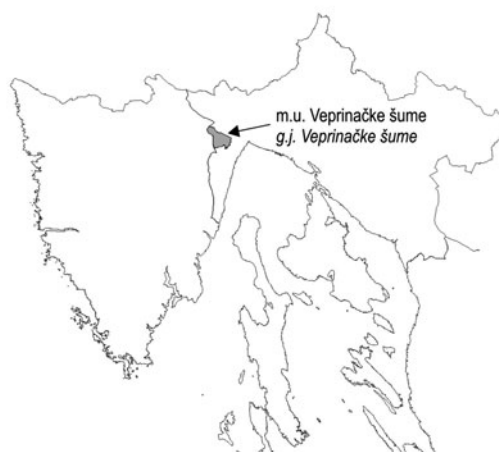


Fig. 1 Management unit Veprinačke šume

Slika 1. Gospodarska jedinica Veprinačke šume

face of the management unit is 1,950.87 ha, of which 1,899.23 ha is overgrown, 43.36 ha productive, not overgrown, 3.12 ha unproductive, not overgrown, and 5.16 ha unfruitful.

During felling and processing, half-tree-length method is used. Timber is extracted by skidders with cable winches. This method of primary timber transportation requires a well-developed secondary openness. Due to the terrain configuration and a developed orography, skid roads have to be constructed. The scaling of roundwood is performed at the felling site.

The basic characteristics of forest opening-up and timber harvesting are steep and orographically diverse mountainous terrain, richness of the karst relief phenomena, shallow soils, rocky bedrock and heavy construction material categories. The average slope inclination of the terrain ranges between 5 and 30°. The mentioned features indicate the need for a good primary and secondary openness. The annual cut (8,100 m³/year) is of a very good quality, and the main economic species is beech.

The primary forest openness amounts to 16.78 m/ha, and the secondary forest openness is 101.94 m/ha.

5. Results of research – *Rezultati istraživanja*

5.1 Methodology for development of secondary forest road cadastre – *Metodologija uspostave katastra sekundarnih šumskih prometnica*

Determination of cadastre numbers for the secondary forest roads is performed according to a unified system, while observing the management unit as a whole. The marking of the secondary forest roads (Fig. 2 and Fig. 3) is performed by combining the management unit code, capital letters and Arabic numerals (they represent the significance and the sequence of the traffic route).

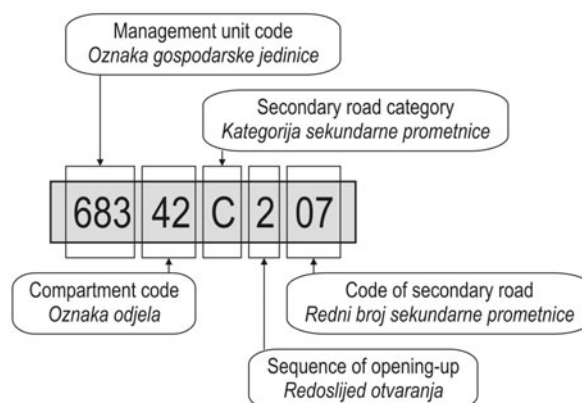


Fig. 2 Cadastre code of secondary forest roads

Slika 2. Katastarska oznaka sekundarnih šumskih prometnica

The first marking is an Arabic numeral (three digits) and represents the number of the management unit, given to it in the management division of the forest/management area of Croatia.

The second marking is an Arabic numeral and represents the number of the compartment within the management unit.

The third marking is a capital letter, by which the manner of construction of the secondary forest road is defined: C – skid road, D – skid trail and an Arabic numeral (1–4), which represents the marking of the sequence of opening-up.

The fourth marking (two digits) defines the sequence of the secondary road route in the management unit. The sequence of the secondary road is determined separately for the manner of construction, and for every secondary road category.

The secondary forest traffic infrastructure is categorized observing the principle of the opening sequence, i.e. separation of lower order skid roads/tracks from the higher order skid roads/tracks.

Table 1 Analyses results of secondary relative openness in the selected subcompartments

Tablica 1. Rezultati analize sekundarne relativne otvorenosti u odabranim odsjecima

Rope length <i>Duljina užeta</i>	Corrected rope length <i>Korigirana duljina užeta</i>	Open surface <i>Otvorena površina</i>	Relative openness <i>Relativna otvorenost</i>	Evaluation of relative openness <i>Ocjena relativne otvorenosti</i>
m		ha	%	
30	24	78.38	64.11	2
40	32	95.89	78.42	3
50	40	107.82	88.18	4
60	48	115.24	94.25	5

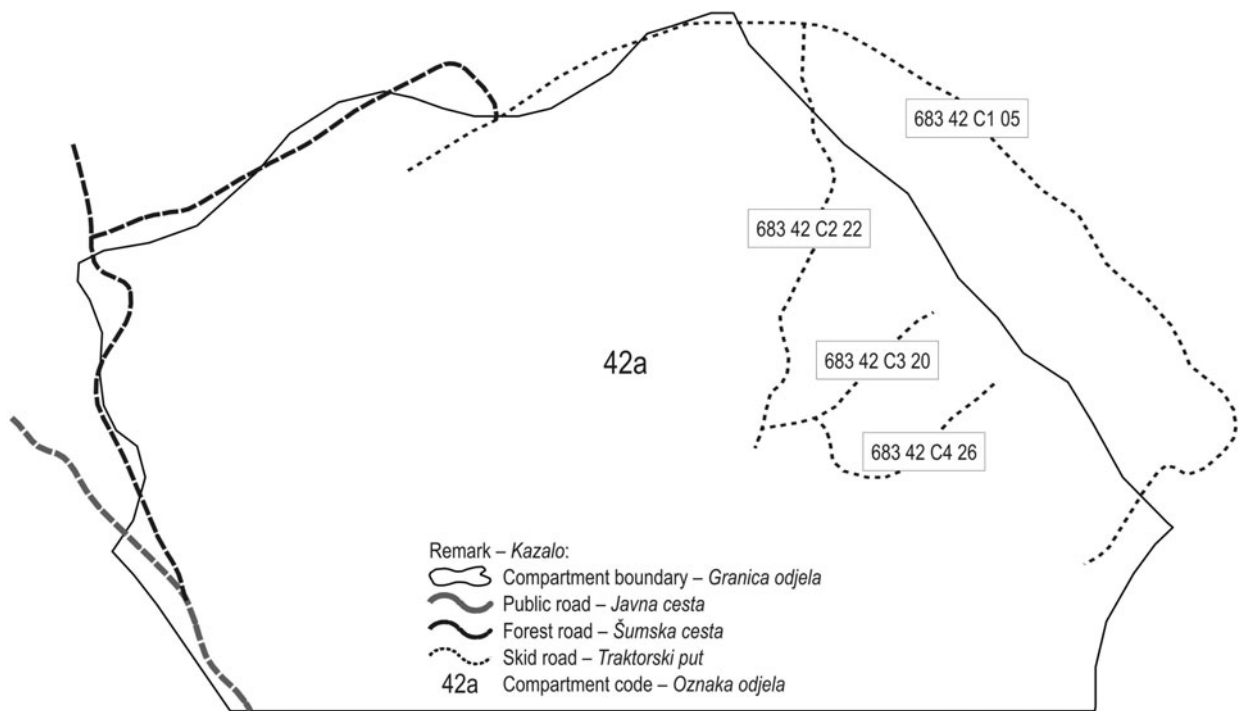


Fig. 3 Cadastre of secondary forest roads - scheme

Slika 3. Katastar sekundarnih šumskih prometnica - shema

5.2 Analysis of secondary relative openness – Raščlamba sekundarne relativne otvorenosti

During the analysis of the secondary relative openness, four different values of approach to the forest area were selected – 30, 40, 50 and 60 meters, which represent the length of the skidder winch rope. For the purpose of this research, inclinations of skid roads were established, as well as inclinations perpendicular to skid roads, which represent the direction of the rope extraction and winching. Terrain configuration with surface obstacles and spatial arrangement of trees in the forest stand were also considered. Going around the horizontal obstacles, and the difference in inclination in relation to the place of winching shortens the length of the winch rope by 20%, whereby the distances of the approach to the forest area are also changed.

Taking into consideration the totally open area (Fig. 4) of single variants in relation to the total area, the values of average secondary relative openness were obtained (Table 1).

6. Discussion – Rasprava

In Croatia, timber harvesting is performed on the ground, by movable machinery, while cable-yarders

are very rare, and helicopters and other forms of aerial transport have not gained any broader use. Because of such an orientation of the forestry profession, good primary openness is necessary, as well as an especially good secondary openness. Skidders are the most frequent means of work in timber harvesting, which may be explained by the conditions of work and costs. The obtained results are quality information, suggesting which length of winch rope should be chosen, and how many new skid roads should be constructed, so as to achieve the maximum openness. In the selected area, the length of the winch rope of 40 m was selected because of terrain configuration, horizontal obstacles, and humanization of forest work. For the mentioned variant, relative openness should be increased by 11.58% for an excellent openness (21.58% for a maximum openness), which would amount to 23.03 km of newly constructed skid roads on the level of the management unit. The calculation is based on the optimal planning of new skid roads, where the length of newly constructed skid roads would definitely increase because of inevitable multiple opened areas. The end result would certainly be within the limits of optimal density of secondary forest traffic infrastructure, as established by Rebula (1983) and Zdjelar (1990).

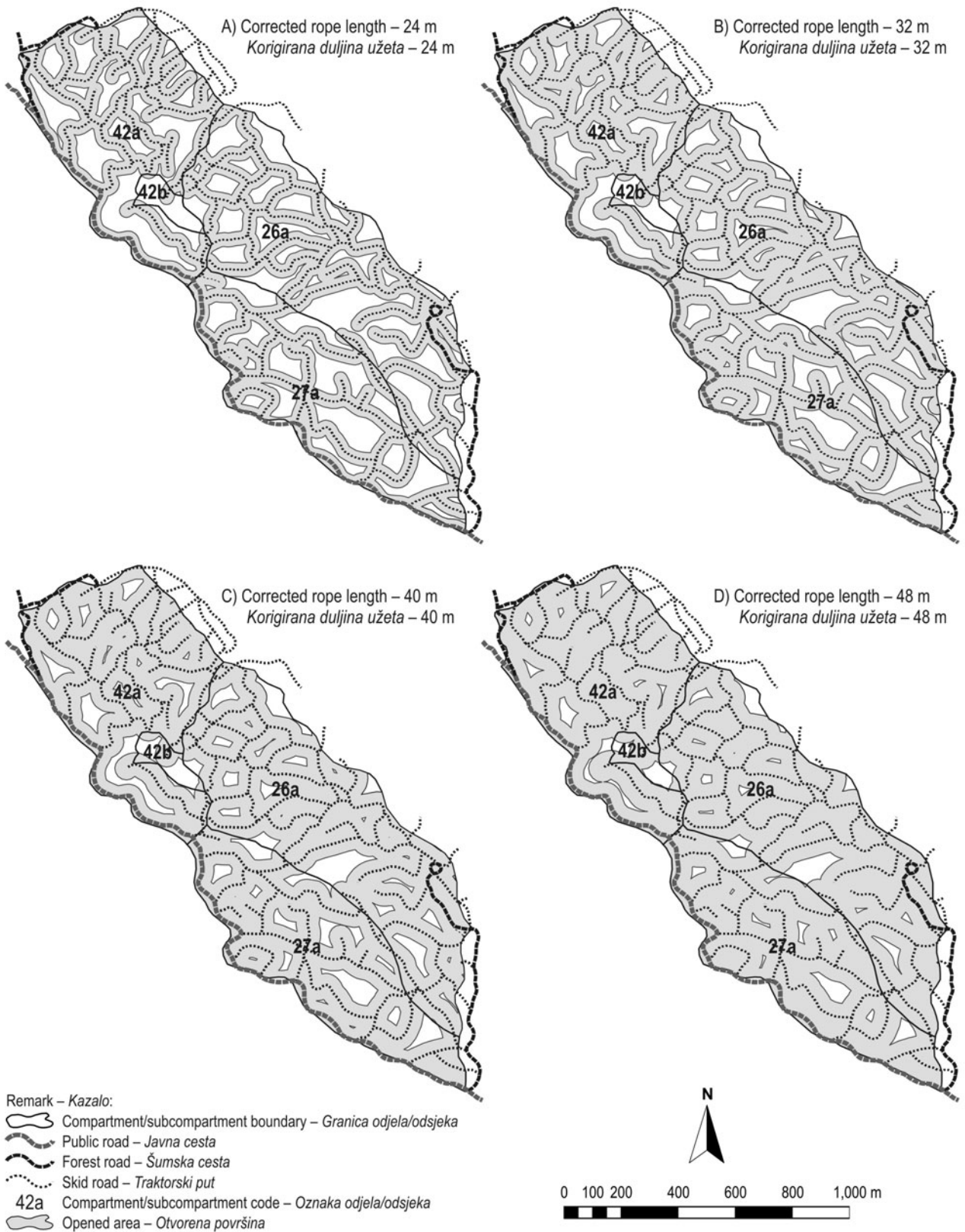


Fig. 4 Analyses of secondary relative openness in the selected subcompartments

Slika 4. Raščlamba sekundarne relativne otvorenosti u odabranim odsjecima

7. Conclusions – Zaključci

Terrain measurement of the secondary forest roads by a GPS receiver, with the use of the snap-back method of surveying, represents a sufficiently quick and exact method for the establishment of the secondary forest traffic infrastructure cadastre (for drawing in of secondary forest roads in digital maps up to 1:5,000).

The methodology for preparing the secondary forest road cadastre is a safeguard for a unified system of coding of the components at the level of the whole Republic of Croatia.

The presented pilot project for the formation of the secondary forest road cadastre, in the m.u. of Veprinačke šume, is a guidepost for forestry experts as to the manner and methods to be used in preparing the secondary forest road cadastre at the level of the public company of »Hrvatske šume« d.o.o., Zagreb, as well as of privately owned forests.

The benefits of the cadastre are numerous because insight in the actual resources is gained, a quality analysis of the existing secondary forest traffic infrastructure is made possible, and guidelines are set defining further opening-up, as necessary.

The cadastre also serves as the basis for the selection of contractors, who dispose of adequate machinery and equipment.

The variant selection (40 m) with a smaller length of winch rope contributes to a significant humanization of forest work because in timber harvesting steel ropes are used, and they are heavy to manipulate under severe terrain conditions.

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Sažetak

Metodologija izrade katastra sekundarne šumske prometne infrastrukture

Sažetak

Pri današnjem intenzivnom gospodarenju šumama povećana je potreba za šumskim prometnicama, i primarnima i sekundarnima. Izgradnja većega broja primarnih šumskih prometnica pridonosi smanjenju srednje udaljenosti privlačenja, što pak smanjuje troškove pridobivanja drva. S druge strane odabir načina pridobivanja drva (forvarderi, skideri, traktori) utječe na povećanje broja izgrađenih traktorskih putova.

Novonastala situacija, u kojoj se susreće povećani broj šumskih prometnica, zahtijeva inventarizaciju šumske prometne infrastrukture te uspostavu potpunoga katastra šumskih prometnica.

Ako taj katastar ne postoji ili je nepotpun (Pentek i dr. 2003), tada je potrebno obaviti inventarizaciju primarne (sve šumske ceste i one javne ceste koje se mogu koristiti pri radovima u šumarstvu) i sekundarne šumske prometne infrastrukture (traktorski putovi i traktorske vlake) na terenu.

Ciljevi su ovoga istraživanja definirani sljedećim fazama rada: uspostava GIS-a istraživanoga područja, stvaranje katastra sekundarnih šumskih prometnica, definiranje kriterija za kategorizaciju sekundarnih šumskih prometnica, analiza sekundarne relativne otvorenosti.

Katastarski se brojevi sekundarnih šumskih prometnica (slika 2) utvrđuju po jedinstvenom sustavu promatrajući gospodarsku jedinicu kao cjelinu. Sekundarne se šumske prometnice označuju kombinacijom šifre gospodarske jedinice, velikih slova i arapskih brojeva (predstavljaju značenje i redoslijed prometnice). Prova je oznaka arapski broj (tri znamenke) i predstavlja broj gospodarske jedinice koji ona ima u gospodarskoj podjeli šumskogospodarskoga područja Hrvatske. Druga je oznaka arapski broj i predstavlja broj odjela unutar gospodarske jedinice. Treća je oznaka veliko slovo kojim je definiran način izgradnje sekundarne šumske prometnice: C – traktorski put, D – traktorska vlaka i arapski broj (1 – 4) koji predstavlja oznaku redoslijeda odvajanja. Četvrta oznaka (dvije znamenke) određuje redoslijed prometnice u gospodarskoj jedinici. Redoslijed prometnice određuje se posebno za način gradnje te za svaku kategoriju.

Sekundarnu šumsku prometnu infrastrukturu kategoriziramo poštujući načelo redoslijeda otvaranja, odnosno odvajanja traktorskih putova/vlaka nižega reda od traktorskih putova/vlaka višega reda.

Pri analizi sekundarne relativne otvorenosti odabrane su četiri različite vrijednosti pristupa površini – 30, 40, 50 i 60 metara, koje predstavljaju duljine užeta vitla zglobnoga traktora. Za potrebe ovoga istraživanja utvrđeni su nagibi traktorskih putova te nagibi okomito na traktorske putove koji predstavljaju smjer izvlačenja užeta i privitlavanja. Konfiguracija terena s površinskim preprekama te prostorni razmještaj stabala u sastojini također su uzeti u obzir. Zaobilaženje horizontalnih prepreka te razlika u nagibu u odnosu na mjesto privitlavanja skraćuje duljinu užeta vitla za 20 %, čime se mijenjaju i udaljenosti pristupa šumskoj površini. Uzeto u obzir ukupno otvorenu površinu (slika 4) pojedine inačice u odnosu na ukupnu površinu, dobivene su srednje sekundarne relativne otvorenosti (tablica 1).

U Hrvatskoj se pridobivanje drva obavlja po zemlji kretnim strojevima, dok su šumske žičare vrlo rijetke, a helikopteri i drugi oblici zračnoga transporta nisu ušli u širu primjenu. Zbog takve orijentacije šumarske struke

potrebna je dobra primarna otvorenost šumskim prometnicama te osobito dobra sekundarna otvorenost. Zglobni su traktori najčešće sredstvo rada pri pridobivanju drva, što se može objasniti uvjetima rada i troškovima. Dobiveni su rezultati kvalitetan podatak koji nam sugerira koju duljinu užeta vitla odabrati te koliko je potrebno novih traktorskih putova izgraditi da bi se postigla maksimalna otvorenost. Na odabranom je području, zbog konfiguracije terena, horizontalnih prepreka te humanizacije rada odabrana duljina užeta vitla od 40 m. Za navedenu je varijantu do odlične otvorenosti potrebno za 11,58 % povećati relativnu otvorenost, što bi na razini gospodarske jedinice iznosilo 23,03 km novoizgrađenih traktorskih putova. Izračun je baziran na optimalnom planiranju novih traktorskih putova, pri čemu bi se definitivno povećala duljina novoizgrađenih traktorskih putova zbog neizbježnih višestruko otvorenih površina. Krajnji bi rezultat zasigurno bio u granicama optimalne gustoće sekundarnih šumskih prometnica do koje su u svojim istraživanjima došli Rebula (1983) i Zdjelar (1990).

Temeljem dobivenih rezultata istraživanja mogu se donijeti ovi zaključci:

- ⇒ Metodologija izrade katastra sekundarnih šumskih prometnica jamstvo je ujednačenoga sustava šifriranja sastavnica na razini čitave Republike Hrvatske.
- ⇒ Predstavljeni pilot-projekt stvaranja katastra sekundarnih šumskih prometnica u GJ Veprinačke šume putokaz je šumarskim stručnjacima na koji način te kojim metodama treba pristupiti izradi katastra sekundarnih šumskih prometnica na razini javnoga poduzeća »Hrvatske šume«, d.o.o. Zagreb, a zatim i u šumama privatnih šumovlasnika.
- ⇒ Koristi su od katastra šumske prometne infrastrukture brojne jer se dobiva uvid u stvarne resurse, a omogućena je i analiza kakvoće postojeće sekundarne šumske prometne infrastrukture te po potrebi definiranje smjernica daljnjega otvaranja.
- ⇒ Katastar također služi kao podloga pri odabiru izvoditelja radova koji imaju odgovarajuće strojeve i opremu.
- ⇒ Izbor varijante (40 m) s manjom duljinom užeta vitla pridonosi znatnoj humanizaciji rada jer se u pridobivanju drva upotrebljava čelična užad kojom je u zahtjevnim terenskim uvjetima teško manipulirati.

Ključne riječi: katastar šumskih prometnica, sekundarne šumske prometnice, sekundarna relativna otvorenost, GIS

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