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GIS-BASED MODEL OF WOOD PROCUREMENT FROM STUMP TO SMALL SAWMILLS IN THE ALPINE REGION – A CASE STUDY

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Abstract

With wood logistics and forest operation modelling, we have connected a technologic chain of cutting, skidding and road wood transport operations. The goal of the paper is to present the possibilities of simulating forest operation activities including cost flow prediction. The case study regarding wood flow and forest operation cost modelling was conducted in four municipalities located in western Slovenia (bordering to Italy). Input data of forest inventory and basic forest data were used in order to predict the wood flow in the test area. We modelled the available cutting volumes with the capacities of local sinks – notably sawmills. Unbalanced hinterland areas of specific sinks that do not cover the local sink capacities were changed (reduced or enlarged) on account of the adjacent hinterland areas with surplus or shortage of wood volume. The hauling distances and wood volumes for covering the sawmills' capacities of the adopted (balanced) hinterland areas were studied.

Key words: wood procurement, forest operation, GIS modelling, logistics, wood flow, saw mill

PROSTORSKI MODEL OSKRBE MAJHNIH ŽAG Z LESOM NA OBMOČJU ALP – ŠTUDIJ PRIMERA

Izvleček

S pomočjo modela za logistiko in pridobivanje lesa smo povezali tehnološko verigo oskrbe z lesom od sečnje in izdelave, spravila ter prevoza lesa. Cilj prispevka je predstavitev možnosti predvidevanja (simulacije) aktivnosti v procesu pridobivanja lesa, vključno z vidika njihovih stroškov. Raziskava je bila narejena na primeru štirih občin v zahodni Sloveniji na meji z Italijo. Na izbranem območju je bil uporabljen gozdarski informacijski sistem, vključno z osnovnimi podatki popisa gozdov z namenom napovedovanja pridobivanja in transporta lesa. Modelno smo primerjali razpoložljive količine možnih sečenj s kapacitetami lokalnih porabnikov – predvsem žag. Na osnovi neuravnoteženih razmerij med kapacitetami porabnikov in zaledjem gozdov smo posameznim porabnikom spremenili zaledja (pomanjšali ali povečali) na račun sosednjih zaledij s pribitkom ali pomanjkanjem lesa. Na osnovi sprememb so bili analizirani stroški prevoza lesa.

Ključne besede: oskrba z lesom, pridobivanje lesa, prostorsko modeliranje, logistika, transport lesa, žage

INTRODUCTION AND OBJECTIVES
PREDSTAVITEV IN CILJI RAZISKAVE

Characteristic of some parts of Slovenia is the presence of small sawmills, especially in the northern part of the county located in the Alpine and sub-Alpine regions (Sevnik, 1965, Žumer, 1968). Sawmills are usually small, with their capacities not exceeding 10,000 m^3/year (Sgerm, 1990). These small sawmills are highly significant for a sustainable development of local communities and entrepreneurship in these narrow valleys. The economy of small sawmills is under pressure by the growing global market, which means that their competitiveness is being reduced owing to the small scope of their activities (Kovač, 2003). Additional problem to those of technological character are forestry related difficulties regarding wood supply. There are some old solutions associated with forestry, especially logistics dealing with the benefit of vicinity of the source and sinks of wood raw material (i.e. LeDoux, 1985). Wood procurement efficiency is permanent and it is growing with the help of modern sophisticated technology and knowledge (i.e. Mikkonen, 2006, Heinimann, 2007). Computer programs today can simulate dynamic processes and involve risk in future decisions (Lohmander, 2000) or take more static approach (Olson, 2004), where harvesting schedule is adaptive, but demand is static variable. In order to better understand the logistic phenomena, even Wood Supply Games have been developed. They simulate the actions in the forest product supply chain. In this way, we can understand the dynamics of work and the importance of information shared by players involved (Haartveit, Fjeld, 2002).

Modern approach considers the requirements of wood industry for specific quality and quantity of roundwood (Helstad, 2006, Becker *et al*. 2007). Forest industry in northern countries normally utilizes roundwood and chips procurement programs, some of them GIS-based with different levels of optimization (Frisk *et al*. 2008, Gerasimov *et al*. 2008).

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Supply of forest biomass involves some specific problems, but has basically the same logistic approach (Palander *et al*., 2008, Spinelli, 2008). It may be assumed that the problems of small sawmills are, to some extent, similar to those of bigger sawmills. We suppose that the results of the present paper could be useful in the management of raw material provision for bigger subjects in forest based industry. Through an enlargement of the territory, the reality is much more complex in the logistic part of the models considering the choice of transport means (harbours, railway, river traffic). The future upgrading of the presented algorithm will also help to solve logistic problems associated with optimal truck routes (Liden *et al*. 2007) and problems associated with wood chain traceability (Haartveit, Knotten, 2007).

To identify the forest resources potentials and possibilities for their use at the regional and possibly interregional levels should be of great importance for dynamic but stable and long-term management in environmental, economic and social points of view. Wood as raw material that is frequently processed locally despite the infrastructure, logistics and modern transportation possibilities enables round wood and chip market of a broader geographical scope. Every community and its economy benefit from domestic use of wood material and wood processing activities. Activation of the renewable energy local resources is also of great importance to be efficient in using the local environment's potentials. Procurement of chips for energy purposes has some specifics (Ahtikoski *et al.* 2007) that have not been dealt with as yet. Maximization the wood added value by using local wood resources is important for the support of local forestry and forest based industry together with their services. We have to stress, however, the great competition between small sawmills that fight for raw materials with all means (Kovač, 2003). In this article, the sawlog prices are not taken into consideration. We shall follow the goal of adjusted wood flow at the global level, too – especially nowadays in the period of the increasingly growing importance of environmentally sound behaviour and efforts to reduce and optimize energy consumption. Market-oriented timber production is on the large European market – beside better logistics – the only way to improve the economy (Nybakk *et al.* 2007).

Local authorities and all stakeholders associated with forest based industry have an interest to use forest resources professionally, sustainable and cost efficient. There are many obstacles arising in technological, social, ownership and other points of view with significant influence on forest related stakeholders. Knowledge of relations between forest operations and their costs on the one hand and the capacities of forest based industry on the other hand can improve, in a regional economy, decision making processes in forestry and forest related activities.

Computer supported simulation is normally used in contemporary approach in planning and decision making activities in the field of natural resource management (Košir, 1996, LeDoux *et al*. 2001). Today, GIS based systems that use remote data transfer are being developed very fast indeed (Rongzu, Mikkonen, 2004). Such systems, however, are suitable for large companies or at the national and regional levels. Small-scale industry in remote places is in permanent lack of attention. Several models have already been developed and used to assist decisions regarding a better adaptation of the human activities to nature processes (Krč, 1999). The analysis of activities related to the planned and predicted wood flow and connected cost flow of forest operation from stump to mill will be, in our case, simulated in order to identify differences between the potentials of forest resources (based on forest inventory data) and wood consumers as sawmills, all kinds and sizes of heating plants and forest based industry at the local level. Another purpose of the study was to simulate wood flow at the regional level with possible use at the interregional level and to remove potential bottlenecks in wood flow. For different reasons (developed international wood trade activities, three border regions: Slovenia, Italy, Austria), the western part of Slovenia has been chosen as a case study for this simulation.

METHOD
METODA DELA

STUDY AREA
OBMOČJE

For testing purposes, part of the Soča river valley adjacent to the Italian side of the Southern Alps was chosen as (Slovenian) part of the region dealt with in the study of logistics costs in a cross-border evaluation (Lubello *et al.* 2007). Geographically, the chosen Alpine valley changes towards the south to a hilly and towards the east typically mountain landscape. Its northernmost part is very narrow and dedicated primarily to tourism. Logistically, the chosen area has one major transport axis, which connects the network of individual forest roads. In the previous study (Lubello *et al.* 2007), the regions on both sides of the state border have already been considered from other points of view.

The chosen area – a sparsely populated Alpine valley - is typical of this part of Slovenia. The test area includes four municipalities: Kobarid (46°14'46.44"N, 13°34'47.11"E), Tolmin (46°10'57.59"N, 13°43'56.28"E), Kanal (46° 5'7.17"N, 13°38'3.49"E) and Brda (46° 0'58.30"N, 13°33'15.62"E) with forest area of 62,867ha out of a total 118,875 ha (the forest share is 53%). As far as its ownership structure is concerned, it is in favour of private property (78%), with the remaining part divided between the state (18%) and local communities (4 %). Following the Forest management plan, the annual allowable cut is 12,581 m^3 of coniferous and 117,368 m^3 broadleaved three species.

From the forest operation point of view, we considered the traditional skidding method for coniferous trees (lengths between 8 and 12 m), which is carried out motor manually. The terrain characteristics conditioned the skidding method: tractors in easy terrain and cable crane in difficult terrains. The detailed criterion and procedure for the selection of wood skidding method was already described (Krč, 1996). The selected wood skidding method was taken into consideration in cost calculation for wood skidding operation from stump to forest road.

DESCRIPTION OF THE MODEL

OPIS MODELA

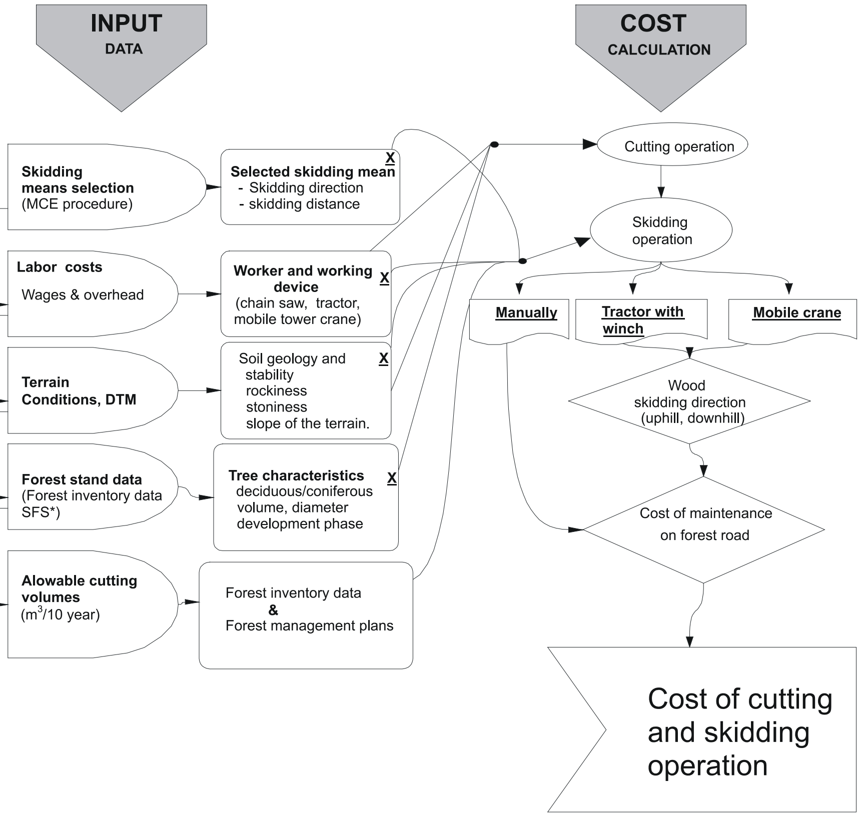
Deterministic model for the simulation of forest operation processes in cutting, skidding and hauling activities has been developed to describe relations between different phases of forest operation costs and capacities of the potential forest resources (= sources), wood processing and consuming destinations (sinks).

We studied the example based on real data where only sawmills appeared in the role of local sinks. The model is capable to include also other sinks, such as heating plants (HP), combined heating plant (CHP) and any other forest based industry (FBI) in a larger area. As far as sources are concerned, only the annual cutting volume in a commercial forest regardless of ownership was considered. In case of sawmills, the considered sources have sufficient information, but in case of some other possible sinks (HP, CHP), the sources out of the region and out of the forest in the region should be added (farmland residues, communal waste, wood processing residues), which are currently the most important sources for energy purposes of wooden biomass in Slovenia.

The model was composed of different modules with program combination of database management and module in GIS environment (Figure 2).

Fig. 1: Geographical position of the municipalities of Kobarid, Tolmin, Kanal and Brda

Slika 1: Lega občinskih središč Kobarida, Tolmina, Kanala in Brd



*SFS-Slovenian Forest Service

Fig. 2: Data sources and modules with their interconnections for forest operation calculation costs from stump to the forest road

Slika 2: Moduli in viri podatkov, združeni v diagram poteka za izračun stroškov pridobivanja lesa do kamionske ceste

The model assumes that only roundwood is produced for delivery to the market. Production of chips for energy is therefore not taken into consideration. The selection of skidding method and skidding direction is derived by GRID based model, which determines the most suitable skidding means and skidding direction (uphill, downhill) using the Multi-Criteria Evaluation (MCE) method (Eastman, 1993) The selection procedure uses set of influential factors (terrain slope, skidding distance, rockiness, soil bearing capacity) derived directly or indirectly from forest inventory and other national spatial computer databases (Krč 1996). Basic forest information carrier unit in database is forest compartment with specific set of variables (influential factors), derived from forest inventory. Average size of forest compartment in the tested area was 29.53 ha.

INPUT DATA
VHODNI PODATKI

Slovenian forest inventory database consists of extended set of field obtained and/or assessed data on compartments base (Letna poročila ..., 2008). Regardless of ownership, the data about site and stand conditions such as growing stock, increment and allowable annual cutting volume are available, as well as data on terrain conditions such as terrain slope, rockiness and stoniness, type of bedrock, etc. Some of these data are very important for forest operations modelling (rockiness, soil type, felling type – final cut, thinning, skidding distance, average terrain slope).

Several significant terrain characteristics could be described by using Digital Terrain Model (DTM) more precisely than from the forest inventory base – data important to evaluate suitability and cost of forest operations (terrain slope, skidding direction, characteristic terrain points – for example ridge or valley positions). Slovenia has at the moment a state wide 100 m and 25 m resolution DTM.

Road network constitutes a backbone of forest operation and wood flow modelling. Database, consisting of digitized roads that can be used for wood transport, has been digitalized on the basis of available information (Letna poročila ..., 2008). In our case study we have had some problems to assure error-free data on the existing road network, as there are several different sources of digital database for roads (public, community owned and private forest roads), which were not well matched. Sinks (SM, HP, CHP, and FBI) are connected by forest roads to the wood sources and have been used as destination points for wood assortments transport.

Felling and skidding operation costs have been calculated using national standard times (Odredba o določitvi ..., 1999) and machine hourly costs for different systems (motor manual, tractor, cable crane) in forest operation processes (Klun *et al*. 2007). In this process, we have had to develop procedures for computing standard times for each specific condition with specified set of influential factors (i.e.: mean tree volume, skidding distance, bunching distance etc.) and system hourly cost. Logging systems have been defined with typical machine and work organization for each technology including road transport to the customer. Cutting and skidding costs for cable skidding (modern mobile tower yarders), which have not yet been included in the national standard times, have been calculated by using adequate time studies (Košir, 2003) and system hourly cost.

Wood transport from forest to the sinks. Cost calculation for wood transport from cutting units (sources) to the consumers (sinks) has been made by using IDRISI GIS software (Eastman 1993). GIS raster environment enables assigning corresponding weights to every specified road section. Cost distance modules were used to evaluate costs of wood transport from forest to forthcoming destination – sink. Transport distances with forestry trucks have been weighted by road network classification – public, local (paved) and forest roads separately. It was assumed that transport costs (flat terrain, paved road) are value given by multiplying the cost related to the transport distance and cost in dependence to the road quality.

Wood industry – sinks have been collected with the aid of local forest managers. They also furnished us with data on sawmill location and production capacities. Furthermore, we have not included possible wood flow from outside, or vice versa, as small sawmills normally buy wood from small areas. Roundwood flow has been analysed at a larger scale (Piškur, M., Krajnc, N. 2007) and the model at this stage is not aimed to give such answers.

RESULTS
REZULTATI

We assumed a 75% realization of allowable annual cut (Slovenian Forest Service reports 50 to 100% ratio between allowable and actual, realized cutting volumes for different Forest Management Units in the year 2006). The share of saw logs is 25% (deciduous species) and 47% (coniferous species) out of total cutting volumes (Kavčič *et al*. 1989). The results of such assumption are quantities shown in Table 1. Out of a total allowable cutting quantity of 129,950 m^3/year in the study area, only 43,731 m^3 are softwood saw logs. The rest is comprised of hardwood sawlogs, fuelwood for households and small diameter softwood assortments.

We defined logging model and calculated the costs for each compartment separately. A low variability of the calculated felling costs in the study area can be noticed (Figure 3). Low variability can be explained by the fact that only motor manual felling was considered. Forest compartments, which were taken as basic fields for cost calculation, have mixed structures of forest stands (development phases). The average tree breast height diameter and mean tree volume do not show a great variability among compartments and consequently exert low influence on standard time determination.

Much higher variability than in the case of cutting cost operation can be noticed by observing skidding costs (Figure 4). Skidding systems in comparison have been:

1. ground hand (manual) skidding downhill at short distances,
2. skidding with tractor or
3. all terrain mobile tower cable cranes.

Table 1: Sawmill locations with their capacities and characteristics of corresponding source areas (Scenario I)

Preglednica 1: Seznam žag in njihovih letnih kapacitet s potencialnimi stroški pridobivanja lesa po scenariju I

Sink ID	Capacity of Sink [m^3/year]	Cutting cost [€/m^3]	Skidding cost [€/m^3]	Road transport cost [€/m^3]	Total cost [€/m^3]	Annual cut in source area [m^3/year]	Source - Sink Difference [m^3/year]
A	4,000	9,15	21,45	5,31	35,91	1,069	-2,931
B	8,000	9,07	25,71	16,88	51,66	12,290	4,290
C	15,000	9,03	25,88	17,07	51,97	8,407	-6,593
D	700	9,02	16,05	17,11	42,18	12,853	12,153
E	1,000	9,10	27,27	9,99	46,35	414	-586
F	1,000	9,09	24,12	5,18	38,39	2,992	1,992
G	5,000	9,30	23,05	13,88	46,23	5,706	706
Total	34,700					43,731	9,031

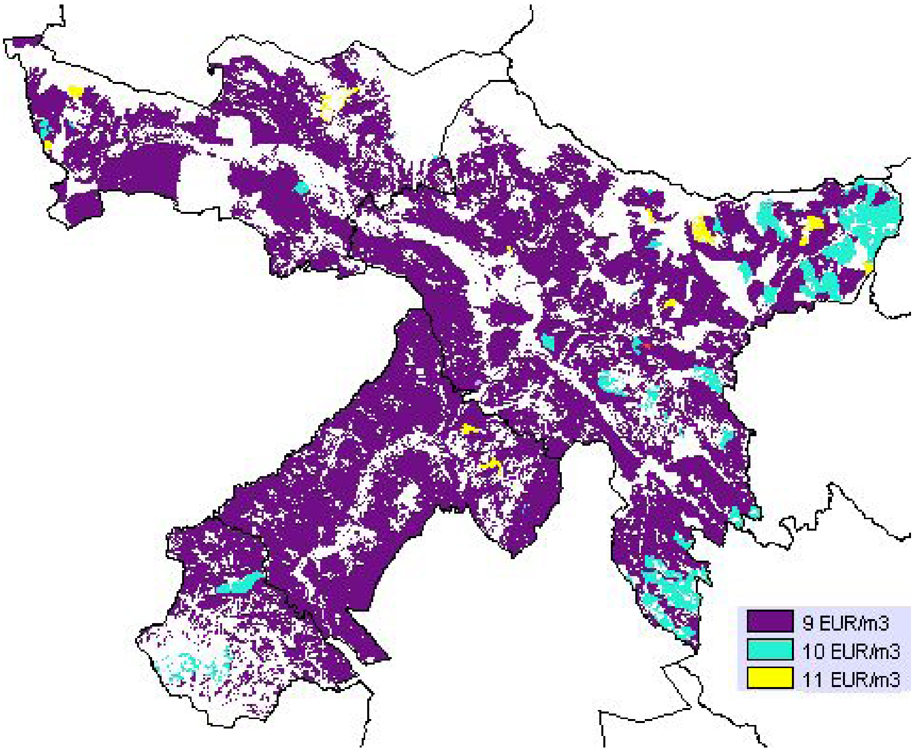


Fig. 3: Cost of cutting operation on compartment base for tested area

Slika 3: Stroški sečnje in izdelave dreves po odsekih za obravnavano območje

Last two skidding options could by applied uphill and downhill. Most suitable skidding system for a compartment has been chosen with the aid of a model (Krč, 1999).

The entire study area was later divided into sub-regions in view of road transport costs. Growing costs from every specific sink towards the more remote hinterland area can

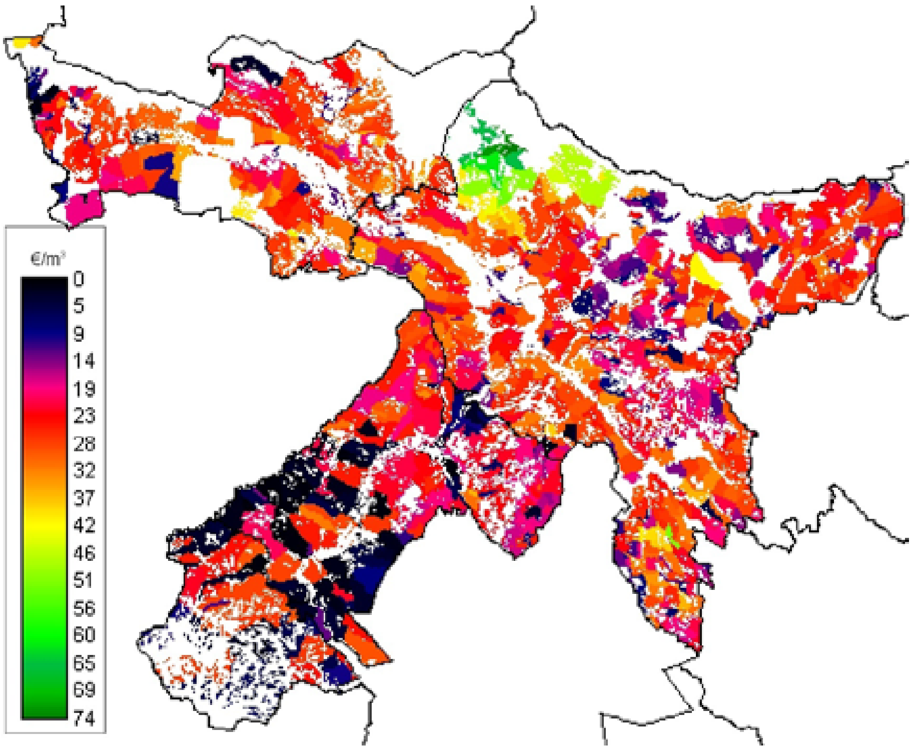


Fig. 4: Cost of skidding operation on compartment base for the tested area

Slika 4: Stroški spravila lesa po odsekih za obravnavano območje

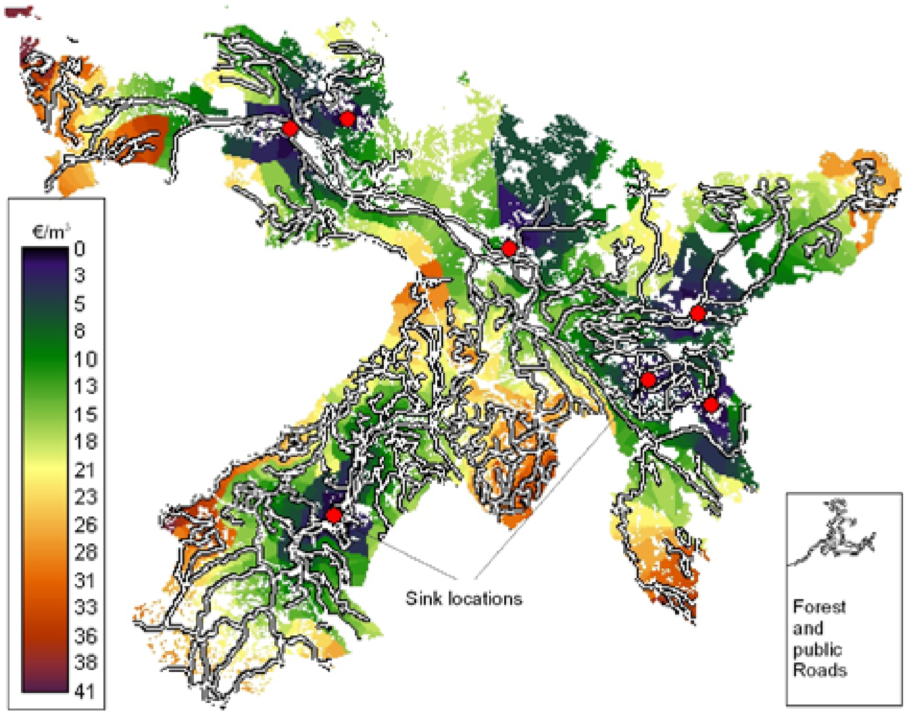


Fig. 5: Road transport cost from forest to the closest sink (saw mill)

Slika 5: Stroški prevoza lesa iz gozda do najbližjega porabnika (žage)

be noticed (Figure 5). Areas beyond the end of roads – also unopened areas – have the same value regardless the logging costs, which corresponds to the cost of road transport to the end of forest roads.

Every sink has its area – hinterland area for wood supply. The hinterland area is determined by wood transportation costs. Forest roads were split into sections (between junctions and branches). For every section, as part of the forest with

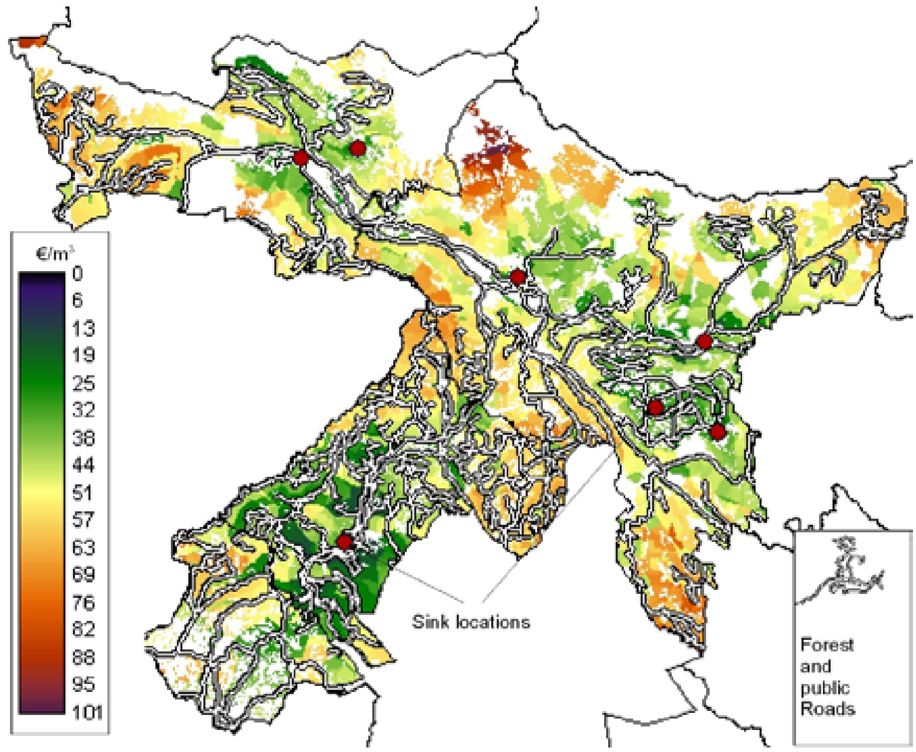


Fig. 6: Total forest operation cost from stump to saw mill

Slika 6: Skupni stroški pridobivanja lesa, vključno s prevozom do porabnika corresponding annual cut, the distance and costs to the nearest sink destination were calculated (Figure 5).

Using Overly option addition (Eastman 1993) module on cutting, skidding and hauling cost raster files, the forest operation cost of specific (study) area was obtained. As we can see (Figure 6), the majority of total logging costs range between 25 and 55 €/m^3. There are some distant and steep terrains with higher logging and transport costs – which are not convenient for wood production.

The entire study area was divided into hinterland areas of each sink (sawmills, Figure 7) on the basis of road transportation costs. Total forest operation costs and available wood volumes compared to the capacities of local sink are shown in Table 1.

In scenario II, we changed the model to improve balance of the wood input (source) – output (sink) ratio. The systematic enlargements of corresponding forest areas were chosen around the sinks with wood volume shortages (sinks A, C and E; see Table 1). The source areas, where sink capacities were not covered by the corresponding annual cut volumes, were spread into adjacent sink hinterland areas with wood volume surpluses. The allocation scenario II was made by using buffering function of an individual sink hinterland area (Figure 8).

Table 2: Balanced capacities and average transportation distances for modified allocation of wood sources regarding sink capacities

Preglednica 2: Količine in transportne razdalje v primeru spremenjenih zaledij oskrbe porabnikov v sorazmerju z njihovimi zmožnostmi predelave lesa

Sink ID	Capacity of sink [m^3/year]	Annual cut in source area [m^3/year]	Source - Sink Difference [m^3/year]	Average distance (Scenario I) km	Average distance (Scenario II) km	Average Road transport Distance ratio (Sc. II / Sc. I)
A	4,000	4,008	8	2,9	5,2	182%
B	8,000	9,916	1,916	14,0	13,9	99%
C+E	16,000	16,084	84	9,6	18,3	190%
D	700	6,793	6,093	9,4	8,7	93%
F	1,000	1,791	791	3,4	2,7	77%
G	5,000	5,139	139	7,7	8,2	107%
			9,031			

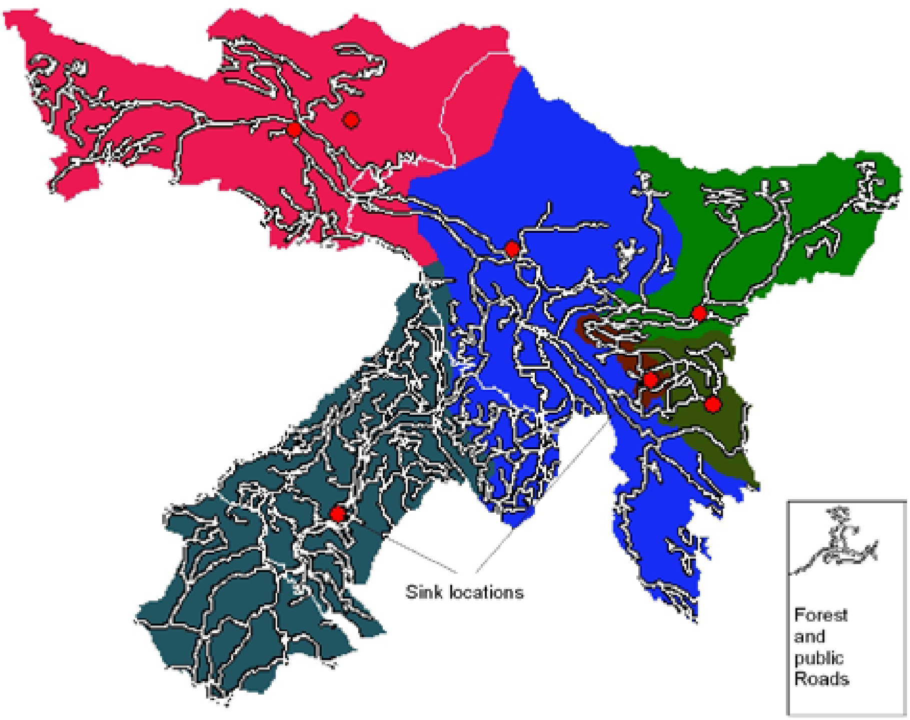


Fig. 7: Hinterland area of sinks (sawmills) with existing road network

Slika 7: Zaledja porabnikov (žag) s cestnim omrežjem

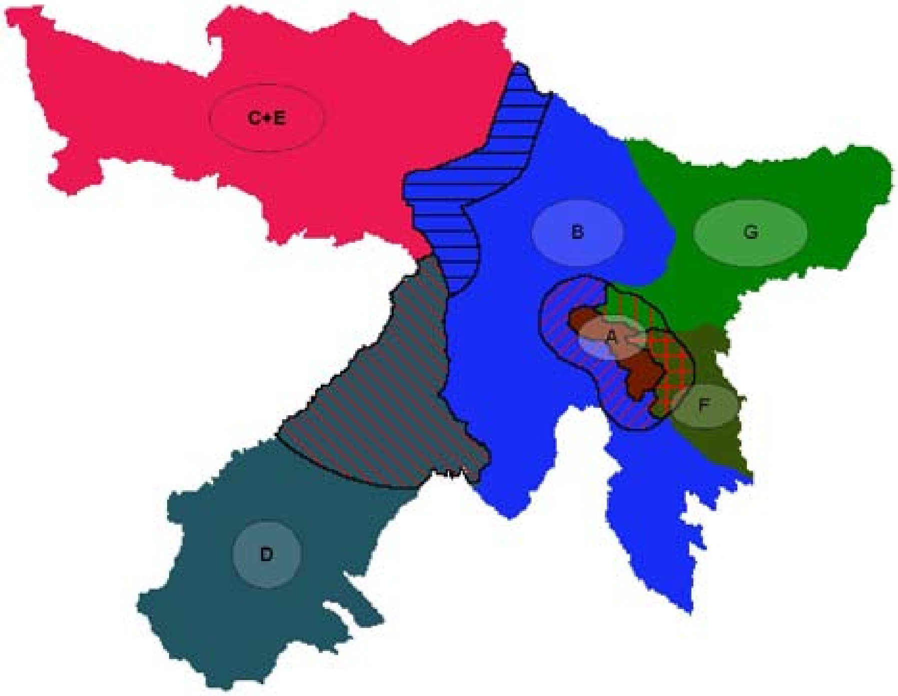


Fig. 8: Allocation model for balancing the input – output ratio (Scenario II)

Slika 8: Model prerazporeditve količin za uravnavanje razmerja med razpoložljivimi količinami lesa in kapaciteto porabnikov lesa (scenarij II)

The enlargement from the hinterland of sinks C+E into the hinterland of sinks B and D was made to cover the capacities of sinks C+E. Sink A enlarged its hinterland (forest area) into adjacent areas of sinks B, G and F. The results of scenario II following a new allocation of wood volumes together with comparison between sink capacities and their balanced adopted hinterland areas are presented in Table 2.

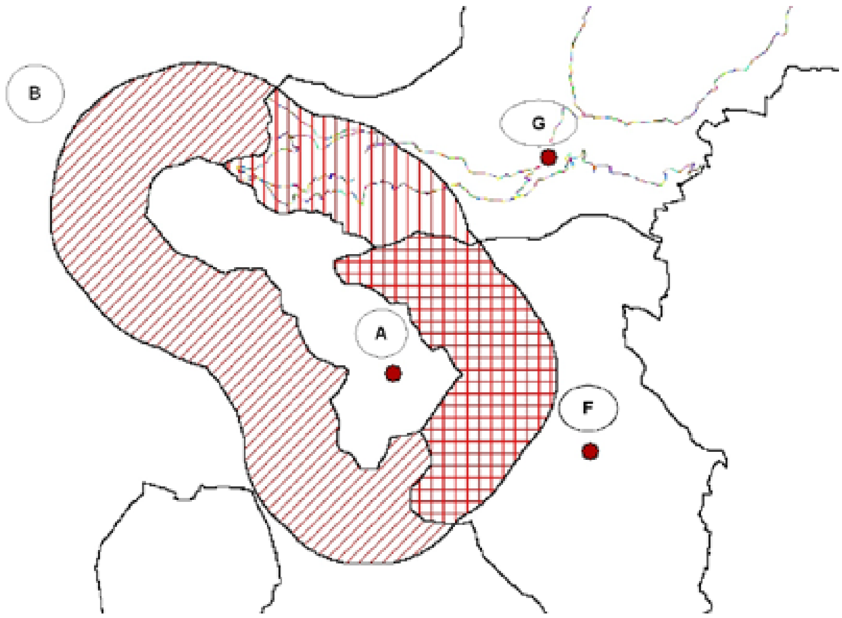


Fig. 9: Enlargement of the hinterland area of sink A into previous (Scenario I) B, F and G sink areas and, in turn, the reason for the extension of average transportation distance in sink G.

Slika 9: Primer povečanja zaledja porabnika A na račun zaledij porabnikov B, F in G (scenarij I) ter posledično vzrok za podaljšanje povprečne transportne razdalje pri porabniku G.

The expected ratio between compared scenario average transportation distances is noticed in the majority of cases (sinks). In sink G, average transport distance increased by 6.5% in spite of the hinterland area reduction. The enlargement of the hinterland area of sink A incorporated part of forests stand, which were initially located relatively close to sink G. In this way, average transportation distance in sink G was consequently increased (Figure 9).

DISCUSSION
RAZPRAVA

Every model is only an approximation of reality. Forestry and forest related activities are very common objects of modelling activities. In the presented research, we wished to predict the allocation of wood at the local level, where small processing capacities are available. Sawlogs are raw material that is not suitable for long distance transportation. Despite the relatively small size of the study area, we presented an example of potential annual wood cutting volume distribution and its cost for forest operation activities from stump to local mills. Advantages and drawbacks of the presented model can be summarized by the following main influential factors on model construction and validation: forestry resources related data of the available wood volumes at different locations, terrain conditions together with traffic infrastructure capabilities for connecting forest and wood processing capacities, data on sinks (their location and capacities), data on efficiency and costs of forest operation and wood transportation operations.

Allowable cutting volumes were taken from forest national inventory database, collected at the level of forest compartment and expressed in m^3/ha/year. Data on cutting volumes are important for wood flow modelling (in our case not for cost calculation). The concentration of allowable cutting volumes has not been taken into consideration by the presented forest operation cost calculation. We are aware of the great influence of wood volume spatial concentration. The improved version of the model shall also incorporate the influence of wood cut concentration. The validation process of cost calculation in the case of cable skidding has already showed a great influence of wood concentration.

An important source of input data is Digital Terrain Model (DTM). The applied resolution of 25 m does not belong to a high precise DTM – we know that fairly precise (dense) DTM is available with even 0.5 m resolution. It is a great challenge for precision in forestry and other branches of forest science in the use of precise data (LIDAR) in order to achieve a more efficient support for forest resources management.

In the conditions of fast growing national economy and social development, as is the case of the study region, it is difficult to acquire a complete set of different sinks. For a further development of wood flow model it is necessary to involve type of sinks and their capacities regarding wood assortments and quality. To overcome the above mentioned shortage of destination data, we can utilize the option of setting a central storage place or terminal, which shall be within the function of wood collection from the broader hinterland forested areas (Lubello *et al.* 2007). The central storage place shall be located close to a high capacity transportation communication (better roads, railway station or harbour), which enable fast and efficient further distribution of the available wooden raw material.

Several modelling possibilities and approaches are available to connect basic input data (forestry, transportation and wood processing) in order to simulate wood and related cost flow. In reality, all forest operations are greatly influenced by the forest ownership structure. In private forests, the dependence on income from forest and ability for forest work (cutting, skidding and transporting activities) strongly influences the forest operation activities. In our model we assumed traditional harvesting technologies that are carried out through efficiency based on national standard times for forestry.

Many influences can be studied using cost calculation of different possibilities when using contemporary technical means and technological approaches. The costs of different forest operations and options (construction of forest roads, cutting, wood extraction and road transportation activities) are under a great influence of work organization and calendar time utilization (for instance share of effective working hour per year and equipment maintenance).

POVZETEK

Logistika je bistveni in najpomembnejši del proizvodnega procesa pridobivanja lesa, zato mora biti učinkovita ter prilagojena razpoložljivim količinam lesa, infrastrukturi in porabnikom lesa. Obravnavani primer analizira možnosti lokalne oskrbe z lesom z vidika primarne predelave lesa. Območje obsega štiri občine na zahodu Slovenije (Kobarid, Tolmin, Kanal in Brda), za katere so bili zbrani podatki o gozdnih fondih ter zmogljivosti primarne predelave lesa. Uporabljana so bila sodobna prostorska informacijska orodja in baze

podatkov, s katerimi smo predvideli potencialne tokove lesa in vzporedno z njimi stroške gozdne proizvodnje na primeru možnih sečenj in simulacije njihovega transporta ter porabe na lokalni ravni. Z vidika posnetka realnih možnosti smo se omejili le na lokalno rabo, kar zagotovo ni v skladu z dejanskimi tokovi lesa v regiji. Ideja sloni na podmeni, da je les surovina, ki v okroglem stanju ni primerna za daljši transport, saj s tem naraščajo stroški, po drugi strani pa se ne izkoriščajo možnosti razvoja lokalnih skupnosti.

Analizirani proizvodni proces pridobivanja lesa na lokalni ravni s pomočjo modeliranja pokaže možnosti uravnavanja količin na strani virov in ponorov. Tako smo izdelali dva scenarija, po katerih smo razporejali količine možnih sečenj na lokalne porabnike. Po prvem scenariju smo sledili samo načelu minimalnih stroškov pridobivanja lesa in na osnovi teh razmejili območje med dejanske ponore lesa na lokalni ravni. Analiza scenarija I je pokazala, da so kapacitete lokalnih predelovalcev premajhne in da je tudi členitev na osnovi proizvodnih stroškov neprilagojena trenutnim potrebam lokalnih predelovalcev (viški in pomanjkanje lesa po posameznih porabnikih lesa). Zato smo v drugem scenariju naredili prostorsko prilagoditev zaledij posameznim predelovalcem na lokalni ravni. V ta namen smo sistematično širili zaledja porabnikom, ki jim je primanjkovalo lesa, v zaledja sosednjih porabnikov z viški lesa. Tako smo pridobili uravnoteženo razmerje med zaledji z vidika lokalne porabe lesa. Sledila je analiza obeh scenarijev, v kateri smo predvideli spremenjene stroške pridobivanja ter kazalce, ki nanje vplivajo. Spremenjena razmerja med zaledji so kazala logične vrednosti, razen v primeru zaledja G, kjer so se kljub zmanjšanju njegove površine skrajšale povprečne prevozne razdalje. Prostorska analiza primera zaledja G v scenariju II je pokazala, da je vzrok skrajšanja povprečne prevozne razdalje v širitvi sosednjega zaledja z oznako A na območju katerega so obema porabnikoma blizu gozdni fondi. Izpad bližnjih gozdnih fondov v porabniku v zaledju G, ki je sicer razpotegnjen, je podaljšal povprečno prevozno razdaljo v primerjavi s scenarijem I.

Študija primera je pokazala prednosti in slabosti metode, v kateri smo uporabili simulacijo in prostorsko modeliranje. V diskusiji obravnavamo posamezne ugotovitve z vidika ustreznosti rabe gozdarskega informacijskega sistema, posnetka terenskih razmer oz. digitalnega modela reliefa skupaj s prometno infrastrukturo, ki povezuje gozd z lokalnimi porabniki lesa, podatke o porabnikih lesa ter možnosti modeliranja uporabe različnih tehnologij, s katerimi vplivamo na višino stroškov gozdne proizvodnje. Model ne vključuje analize socialnih dejavnikov ter lastniške strukture gozdov, saj bi posledica zlasti strukture gozdov lahko bili številni novi scenariji, ki so povezani z možnimi oblikami vključevanja posameznih kategorij gozdnih posestnikov v trg lesa in gozdnih lesnih proizvodov.

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