Comparison of Two Skidding Methods in Beech Forests in Mountainous Conditions

Dane Marčeta, Vladimir Petković, Boštjan Košir

Abstract – Nacrtak

Investigation of different skidding methods was done in the northwestern part of the Republic of Srpska, in the area of municipality of Ribnik. Two skidding methods were compared, assortment (short-log) method and half-tree length method. Investigation was conducted in four sample plots, in two compartments of beech forests. The difference between sample plots was based on working methods and mean DBH of felled trees. The aim of this research was to compare the productivity and costs of assortment method, which is currently dominant in the forestry of the Republic of Srpska, and half-tree method as a modification of tree length method. Skidding was done with forest skidder LKT 81T in winter conditions with almost no snow. Time and work study was performed. Different statistical methods were used for investigating the influence of different variables on the work process. Multiple linear regression analysis showed that work operations mainly depend on distance and load volume in both methods. Loaded drive depends on distance and load volume. Strength of correlation relationship is similar in both methods. These findings are in compliance with other investigations that can be found in literature. The results showed higher productivity and lower costs in half-tree-length method than in the assortment method. For the skidding distance of 250 m and similar stand conditions, the productivity is 42.29 m$^3$/day for assortment method (A1) and 50.50 m$^3$/day for half-tree length (A2) method, and 62.93 m$^3$/day (B1) and 83.64 m$^3$/day (B2), respectively.

Costs are 17% (A2 against A1) and 40% (B2 against B1) lower for half-tree length method when all other conditions are the same. The difference in cost increases with the increase of the difference of the average piece volume of the two skidding methods.

Keywords: tractor skidding, harvesting methods, work study, cost calculation, B&H

1. Introduction – Uvod

The limiting factors in forest operations in mountainous stands of B&H are terrain slope, micro-relief with obstacles, bearing strength of deep soils during periods of increased moisture, snow and ice conditions in winter and selection management. Forests are mainly natural, mixed and uneven-aged, and managed by individual and group selection felling, with a 10-year rotation. European silver fir, Norway spruce, European beech and sessile oak are the most important commercial species. Strip roads and skid trails represent the basic network of secondary forest openness, which provides the quickest and shortest way to felled and processed trees and are constructed on forest terrain with the slope gradient ranging between 30 and 60% with the terrain rockiness reaching up to 90% due to karst conditions (Sabo and Pošinsky 2005).

The current harvesting technology in the forestry of B&H consists of felling and processing trees at the stump using chainsaw and skidder for roundwood extraction. In specific conditions, animals and cable yarders are used to a lesser extent. Stacked wood (traditional firewood) is extracted by animals in traditional way. Harvesting technology and method is still a question of research and discussion. The aim of this research is to compare the productivity of skidding in two harvesting methods: 1) tree felling and processing at the stump, and extracting the assortments to the landing and 2) tree felling, partial processing at the stump and skidding to the landing. The first harvesting method is understood as a short-wood (assort-

ment) method and the second as a half-tree-length method – a modification of tree-length method. The aim of the research was to identify advantages and disadvantages of introducing a half-tree-length method and the need for possible modification of the present assortment method.

2. Literature review – Pregled literature

Researchers have already suggested that it would be better to organize skidding of firewood together with roundwood, as this would cause lower transport costs (Košir et al. 2009). In the area of B&H, several studies have been conducted on introducing tree-length and half-tree-length harvesting method (Kulušić et al. 1980, Kulušić 1981, Ljubojević 1990). The results of these investigations led to the conclusion that tree-length and half-tree-length methods are recommended along with a better organization of production process. Also, it has been proved that the tree-length method demands heavier machines and causes higher damages to the stand, the standing trees, juvenile plants and soil. This is probably a reason why the tree-length method has not been widely accepted in local forestry practice. There are also other reasons for not accepting tree-length skidding, such as hard terrain conditions and selective forest management based on cutting single trees. As an optimal solution, the half-tree-length harvesting method is recommended. The half-tree-length method differs from tree-length method in the way that the stem is cut in one or more pieces in order to shorten the stem and facilitate the skidding. Bucking at the stump is made according to »transport lengths« taking into account quality changes along the tree and the final use (roundwood, firewood).

Mousavi (2009) compared the effects, economical efficiency and stand damages in using the tree-length and short wood harvesting method. It was concluded that higher efficiency was achieved at lower costs when applying the tree-length method, provided that for- estry planners and workers are extremely well trained to keep the efficiency without causing unacceptable stand damage. Zečić and Marenčě (2005) examined the characteristics of work and efficiency of team work. They established standard times for two tractors, which ranges between 25.05 min/m³ for the skidding distance of 150 m and 33.20 min/m³ for the distance of 650 m. The coefficients of allowance time for the tractors used in the study were between 1.24 and 1.29.

Most of the studies on skidding operations indicate that skidding distance, piece size, load volume, winching distance and slope of the skid trail have a significant impact on the production of tractor skidding (Ghaffariyan et al. 2013, Sabo and Poršinsky 2005, Zečić et al. 2005). Skidding time per cycle is a regression function of skidding distance, winching distance, trail slope and piece volume. The average net and gross productions were 18.51 and 14.51 m³/h, respectively (Ghaffariyan et al. 2013). They found that the productivity of processing, skidding and hauling increased when using the long timber method. Total unit cost of the long timber method in processing, skidding, loading and hauling is lower than the unit cost of the short-wood method (Mousavi 2009).

Ghaffariyan et al. (2012) showed that increasing the average load volume would result in lower cost of extraction. They emphasized that it is necessary to use the harvesting equipment with maximum working capacity. Also, they suggested that increasing the load volume may increase machine repair costs, an aspect that requires further investigation.

Bembenek et al. (2011) showed that, during extraction with tractors, the mean overall operational productivity was 30.5 m³/h, with an average of 1.8 m³ of wood obtained from the trees. The obtained productivity seems to be very good when compared with e.g. 11.6 m³/h achieved by Timberjack 240C in a mountainous fir stand when skidding roundwood from the fell- ing site, where the volume per mean marked tree was 3.9 m³ (Sabo and Poršinsky 2005). Using a cable skid­ der LKT 81 Turbo, the productivity can reach 7.15 m³/h in mountain conditions in an 82 year old fir stand (Port­ ter and Strawa 2006).

According to the calculation based on 1 600 operating hours per year, the machine rate of Timberjack 240C was 26.89 €/PMH. At skidding distance of 250 m, the productivity under the above work conditions is 12.0 m³/PMH (5.0 min/m³) with the skidding costs of 2.2 €/m³. Productivity depends on skidding distance and it ranges between 16.9 m³/h (50m) and 9.9 m³/h (400m). Skidding costs range from 1.6 to 2.7 €/m³ (Sabo and Poršinsky 2005).

Holmes et al. (2002) studied the productivity of a rubber-tyre skidder in conventional felling. They showed that the productivity of the skidder was 22.39 m³/h and the unit cost was 1.99 €/m³ in Amazon forests in Brazil.

Behjou et al. (2008) investigated skidding capacity of the wheeled skidder Timberjack 450C in Caspian forests. The skidding cycle time and the loaded travel time, as well as cable winching productivity were primarily affected by skidding distances and winching distances. The interaction between skidding distance and the ground slope was another major factor that influenced elemental times and productivity. The empty travel time was dominantly affected by skid-
ding distance. The achieved gross (SMH) and net (PMH) production rate was between 20.51 m$^3$/h and 22.93 m$^3$/h for different skidding distances. The average production cost, considering the gross and net production rate, was between 6.31 $/m^3$ and 6.22 $/m^3$.

Strip roads and skid trails represent the basic network of the secondary forest openness, which provides the quickest and shortest way to felled and processed trees.

### 3. Materials and methods – Materijal i metode

Investigation was conducted in the northern part of the Republic of Srpska in the area of municipality of Ribnik. The research was carried out in a hilly-mountainous area in winter period with almost no snow. The temperature varied from 0 to 7 °C. Sample plots were situated in two compartments (Table 1).

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Description of research site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stand description (Opis sastojina)</td>
<td>Sample plots A1 and A2 (Pokusne plohe A1 i A2)</td>
</tr>
<tr>
<td>Compartments (Odjel)</td>
<td>98; section a – M.U. Potoci-Resanovača</td>
</tr>
<tr>
<td>Altitude, m (Nadmorska visina, m)</td>
<td>970–1 150</td>
</tr>
<tr>
<td>Inclination, ° (Nagib, °)</td>
<td>15–30</td>
</tr>
<tr>
<td>Exposition (Ekspozicija)</td>
<td>S–SE</td>
</tr>
<tr>
<td>Geologic surface (Geološka podloga)</td>
<td>Limestone, medium or deep rocky land (Vapnenac, srednje duboko ili kamenito tlo)</td>
</tr>
<tr>
<td>Climate (Klima)</td>
<td>Mountain, humid (Planinska, humidna)</td>
</tr>
<tr>
<td>Stand (Sastojina)</td>
<td>GK 1210 – Forests of beech and fir with spruce on a series of limestone, predominantly deep soil (Picea-Abieti-Fagetum)</td>
</tr>
<tr>
<td>Site quality (Bonitet)</td>
<td>3</td>
</tr>
<tr>
<td>Canopy (Sklop)</td>
<td>Dense (0.7)</td>
</tr>
<tr>
<td>Management system</td>
<td>Group-selection</td>
</tr>
<tr>
<td>Growing stock, m$^3$/ha (Drvna zaliha, m$^3$/ha)</td>
<td>513.72</td>
</tr>
<tr>
<td>Cutting intensity, % (Intenzitet doznake, %)</td>
<td>14.53</td>
</tr>
<tr>
<td>Average diameter of marked trees, cm (Srednji promjer doznačenih stabala, cm)</td>
<td>21</td>
</tr>
<tr>
<td>Regeneration (Pomladak)</td>
<td>Medium dense</td>
</tr>
</tbody>
</table>

The research was carried out in a hilly-mountainous area in winter period with almost no snow. The temperature varied from 0 to 7 °C. Sample plots were situated in two compartments (Table 1).
Altitude varied from 690 m to 1 230 m. Terrain inclination was between 26 and 57%. Geologic surface was limestone and partially dolomite with medium or deep rocky land. The group-selection management system was used in both compartments. The average diameter of trees marked for felling was 21 cm in compartment 98 and 35 cm in compartment 65. Canopy cover was dense with medium dense regeneration for est. When choosing compartments, it was taken into consideration that stand conditions and characteristics of forest road network would be those prevailing in beech forests in the Republic of Srpska. In each compartment, 2 sample plots i.e. work fields were selected (A1, A2, B1 and B2). Sample plots were selected so as to have as much as possible similar stand and habitat conditions. Actually, the plots only differed with respect to felled tree diameter and harvesting method. In this way, only several factors were taken into consideration, which made the comparison of technologies more reliable. In each sample plot, timber was transported after cutting. To avoid the influence of the position of skidding roads, the position of each work field was linked to the skidding road. The width of the work fields was equal to two lengths of the skidding cable. The maximum cable length was 60 m. The skidder moved along the skidding road. The length of each work field (sample plot) was equal to the length of the skidding road, up to 500 m.

In the sample plots A2 and B2, a half-tree-length harvesting method was performed where cutting of trees and delimming was done at the site. Stem stayed whole or cut to the »transport lengths« to allow easier skidding. After that, stem or parts of the stem were skidded on the forest road where processing continued.

Skidder performance was measured by time and work study method (Björheden et al. 1995). Time was divided into work operations. Time consumptions for work elements were measured by snap-back chronometry method. The distance of unloaded and loaded travel were measured with the measuring tape, slope gradient was measured by clinometers and the load data were collected by measuring the diameter and length of each piece of roundwood, technical wood under bark and roundwood fuelwood over bark.

Statistical methods were used in data evaluation (Descriptive statistics, ANOVA Regression and Correlation analysis) with the help of software Statistica 7. Strength of correlation was defined according to Roemer-Orphal’s scale (Sabo and Poršinsky 2005).

4. Research results – Rezultati istraživanja

4.1 Description of sample – Opis uzorka

Table 2 presents the characteristics of the sample plots. Differences in the load characteristics between the plots are due to different characteristics of felled tree. The average number of pieces in a load was 9.94 and 9.00 on plots A1 and B1, respectively, and 11.09 and 9.57 on plots A2 and B2. The average volume of pieces in loads in assortment method was 0.28 m$^3$ and 0.57 m$^3$ and in half-tree-length method 0.33 m$^3$ and 0.75 m$^3$.

The average load volume in assortment method was 2.80 m$^3$ (A1) and 4.98 m$^3$ (B1), and 3.56 m$^3$ (A2) and 6.62 m$^3$ (B2) in half-tree-length method. The average length of the piece in assortment method was 5.38 m (A1) and 5.30 m (B1), and in half-tree-length method 8.97 m (A2) and 9.19 m (B2). In assortment method, the length of pieces varied from 3.83 m to 7.66 m. In half-tree-length method, the length of pieces varied from 6.12 m to 14.14 m.

The average skidding distance in assortment method was 250.15 m and varied from 90.00 to 460.00 m. In sample plots, where half-tree-length method was performed, the average skidding distance was 287.44 m and varied from 130.00 to 490.00 m.

4.2 Analysis of work operations – Analiza radnih operacija

The total work time is 2 132.75 min in sample plots with the assortment method and 1 505.47 min in sam-
The structure of work operations shows (Table 3) that the most time consuming operations in both methods were unloaded drive, loaded drive and hooking. An average cycle time for unloaded drive is 5.09 and
5.20 min/cycle for assortment and half-tree-length method, respectively. An average cycle time for loaded drive is 4.72 (assortment) and 5.53 min/cycle (half-tree-length) and the average time for hooking is 5.23 min/cycle (assortment) and 5.46 min/cycle (half-tree-length). The structure of productive work time shows that in both working methods the structure of working operations in productive work time is very similar (Fig. 2).

The structure of delays is presented in Table 4. Delay times are times that are not directly connected to skidding but are unavoidable in the working process. It can be seen that the preparatory-final time accounts for 35% (assortment) and 33% (half-tree-length) of delay times, followed by personal delays with 28% (assortment) and 29% (half-tree-length). Coefficients of delays are 1.30 for assortment and 1.31 for half-tree-length method. Reference can be made of early studies.

**Table 3: Descriptive analysis of work time**

<table>
<thead>
<tr>
<th>Work operation</th>
<th>Average per cycle, min</th>
<th>Standard deviation, min</th>
<th>Sum, min</th>
<th>Minimum, min/cycle</th>
<th>Maximum, min/cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radni zahvat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unloaded drive</td>
<td>5.09</td>
<td>5.20</td>
<td>2.51</td>
<td>1.75</td>
<td>345.78</td>
</tr>
<tr>
<td>Pulling out of cable</td>
<td>1.61</td>
<td>1.48</td>
<td>0.80</td>
<td>0.59</td>
<td>104.58</td>
</tr>
<tr>
<td>Hooking</td>
<td>5.23</td>
<td>5.46</td>
<td>2.50</td>
<td>1.90</td>
<td>355.31</td>
</tr>
<tr>
<td>Winching</td>
<td>2.92</td>
<td>3.32</td>
<td>1.40</td>
<td>1.63</td>
<td>198.78</td>
</tr>
<tr>
<td>Forming of load</td>
<td>2.04</td>
<td>1.95</td>
<td>1.51</td>
<td>0.83</td>
<td>89.56</td>
</tr>
<tr>
<td>Loaded drive</td>
<td>4.72</td>
<td>5.33</td>
<td>1.97</td>
<td>1.59</td>
<td>321.22</td>
</tr>
<tr>
<td>Unhooking</td>
<td>2.34</td>
<td>2.29</td>
<td>0.92</td>
<td>0.67</td>
<td>156.94</td>
</tr>
<tr>
<td>Landing bunching</td>
<td>0.98</td>
<td>1.34</td>
<td>0.51</td>
<td>0.53</td>
<td>61.83</td>
</tr>
<tr>
<td>Productive work time, min</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>1 638.28</td>
</tr>
<tr>
<td>Total delays, min</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>494.47</td>
</tr>
<tr>
<td>Total delays, %</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>30.18</td>
</tr>
<tr>
<td>Total work time, min</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>2 132.75</td>
</tr>
</tbody>
</table>

of tractor skidding (Krivec 1967), where preparatory time was presented as a special problem with known content, tractor preparation and maintenance.

4.3 Work time analysis – Analiza radnog vremena

The influence of different factors on work operations time was examined with regression and correlation analysis. Strength of the influence is presented with $R$, with the level of significance $p \leq 0.05$.

Regression models that show best the dependence between variables are presented in Table 6 and 7. These functions are used for comparison between methods and for productivity and cost calculation. In work operations, where no significant dependencies were recorded, mean values are used for productivity calculations.

4.3.1 Assortment method – Sortimentna metoda

Unloaded drive showed very strong dependence on the driving distance with the correlation coefficient $R = 0.82$. This correlation is presented with linear equation (Table 5). Strong correlation was established in dependence of hooking on load volume, $R = 0.58$. Medium correlations were established in dependence of pulling out of the cable on pulling distance ($R = 0.48$) and of loading bunching on load volume ($R = 0.44$). Very strong correlation was observed in the influence of driving distance and load volume on loaded driving ($R = 0.90$). Weak correlations were established in dependence of winching on winching distance ($R = 0.38$), unhooking on load volume ($R = 0.39$), and forming of load on load volume ($R = 0.36$).

4.3.2 Half-tree-length method – Poludeblovna metoda

Unloaded drive showed very strong dependence on the driving distance with the correlation coefficient $R = 0.87$. This correlation is presented with linear equa-
The significance level of all correlations is not dependent on any examined influencing factors. The sum of work operation times was multiplied with the delay time coefficient. For comparison, productivity is presented for all four sample plots for the mean distance of 250 m and average load volume in each sample plot (Table 7). Costs of the working day of skidder LKT 81 T was calculated on the base of official methodology used by the Public Company »Šume RS«, which is based on Myiata (1980). The cost of an 8-hour working day is 323.53 € (40.44 €/hour).

### 5. Discussion – Rasprava

The number of pieces in a load is similar in both methods, 9.94 (A1) and 9.00 (B1) in assortment method and 11.09 (A2) and 9.57 (B2) in half-tree-length method. It can be said that in this case the number of pieces in a load is rather the result of the skidder hooking capacity than of the volume or length of pieces. A possible explanation for that could be that in both methods the maximum volume and hence also the volume weight of the load is below the skidding capacity of the skidder.

The average volume of a log is notably bigger in half-tree-length method, 0.28 m³ (A1) against 0.33 m³ (A2) and 0.57 m³ (B1) against 0.75 m³ (B2). The difference is more noticeable in sample plots with larger average log pieces. Consequently, the average load volume in assort-

### Table 5 Time dependence analysis – assortment method

<table>
<thead>
<tr>
<th>Work operation</th>
<th>N</th>
<th>Independent variable</th>
<th>Model</th>
<th>F-test</th>
<th>R</th>
<th>p</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unloaded drive</td>
<td></td>
<td>x₁ - distance, m</td>
<td>Model</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neopterećeno kretanje</td>
<td>65</td>
<td>x₁ - udaljenost, m</td>
<td>y₁ = -0.189 + 0.0212x₁</td>
<td>134.62</td>
<td>0.82</td>
<td>0.000</td>
<td>1.449</td>
</tr>
<tr>
<td>Pulling out of cable</td>
<td>58</td>
<td>x₂ - distance, m</td>
<td>y₂ = 0.3208 + 0.047x₂</td>
<td>17.17</td>
<td>0.48</td>
<td>0.000</td>
<td>0.728</td>
</tr>
<tr>
<td>Hooking</td>
<td>65</td>
<td>x₃ - load volume, m³</td>
<td>y₃ = 1.2243 + 1.0536x₃</td>
<td>32.65</td>
<td>0.58</td>
<td>0.000</td>
<td>2.057</td>
</tr>
<tr>
<td>Winching</td>
<td>59</td>
<td>x₄ - distance, m</td>
<td>y₄ = 1.5973 + 0.0546x₄</td>
<td>10.38</td>
<td>0.38</td>
<td>0.002</td>
<td>1.294</td>
</tr>
<tr>
<td>Forming of load</td>
<td>42</td>
<td>x₅ - load volume, m³</td>
<td>y₅ = 0.5799 + 0.3672x₅</td>
<td>6.15</td>
<td>0.36</td>
<td>0.017</td>
<td>1.431</td>
</tr>
<tr>
<td>Loaded drive</td>
<td></td>
<td>x₆ - distance, m</td>
<td>y₆ = -0.1162 + 0.0171x₆ + 0.1469x₁</td>
<td>146.69</td>
<td>0.90</td>
<td>0.000</td>
<td>0.851</td>
</tr>
<tr>
<td>Opterećeno kretanje</td>
<td>65</td>
<td>x₆ - udaljenost, m</td>
<td>y₆ = -0.1162 + 0.0171x₆ + 0.1469x₁</td>
<td>146.69</td>
<td>0.90</td>
<td>0.000</td>
<td>0.851</td>
</tr>
<tr>
<td>Unhooking</td>
<td>61</td>
<td>x₇ - load volume, m³</td>
<td>y₇ = 1.4811 + 0.2462x₇</td>
<td>2.83</td>
<td>0.39</td>
<td>0.008</td>
<td>0.906</td>
</tr>
<tr>
<td>Landing bunching</td>
<td>60</td>
<td>x₈ - load volume, m³</td>
<td>y₈ = 0.4632 + 0.1357x₈</td>
<td>14.36</td>
<td>0.44</td>
<td>0.000</td>
<td>0.465</td>
</tr>
</tbody>
</table>
The daily efficiency ranged from 57.49 m$^3$/day to 35.54 m$^3$/day in the mountain working site, which is a little lower than established in this research. The load volume of Ecotrac 120V skidder in selective cutting is 5.34 m$^3$ and consists of 5.7 pieces in average, with the length of 7 m and volume of 0.93 m$^3$. They established that the daily efficiency ranged from 57.49 m$^3$/day (100 m) to 35.74 m$^3$/day (500) in hilly working site, which is a little lower than established in this research. In the mountain working site, the daily output of 48.53 m$^3$/day to 35.54 m$^3$/day can be achieved for the same distance (Horvat et. al. 2007).

When looking at the duration of individual work operations, it can be seen that unloaded drive, loaded drive and hooking are the most time consuming operations. Statistical analysis of the duration of work operations showed that only loaded drive differs significantly between treatments (Table 5 and Table 6).

Relative share of each individual operation in productive work time is very similar in both methods. The coefficients of allowance time for skidders obtained in this study, 1.30 and 1.31, are slightly bigger than those established by Zečić and Marenče (2005), 1.24 and 1.29.

Total allowance time of the skidder Ecotrac 120V in the hilly working site was 34.25% of the effective time and in the mountain working site 17.95% of the effective time. The factor of allowance time was 1.34 and 1.18, respectively (Horvat et. al. 2007).

Multiple linear regression analysis showed that work operations depend mainly on distance and load volume in both methods. Loaded drive depends on distance and load volume. Strength of correlation relationship is similar in both methods. These findings are in compliance with other researches referenced in literature review.

In half-tree-length method, only forming of load showed no significant dependence on any examined variable. The reason for that may be the consequence of small sample because this operation did not appear in each work cycle.

In this case, the productivity is 16 and 25% higher in half-tree length method than in assortment method.

### Table 6 Time dependence analysis – half-tree-length method

<table>
<thead>
<tr>
<th>Work operation Radni zahvat</th>
<th>N</th>
<th>Independent variable Nezavisna varijabla</th>
<th>Model Model</th>
<th>F-test</th>
<th>R</th>
<th>ρ</th>
<th>Standard error Standardna pogreška</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unloaded drive Neopterečeno kretanje</td>
<td>39</td>
<td>$x_1$ – distance, m $x_1$ – udaljenost, m</td>
<td>$y_1 = 0.4808 + 0.0169x_1$</td>
<td>119.14</td>
<td>0.87</td>
<td>0.000</td>
<td>0.869</td>
</tr>
<tr>
<td>Pulling out of cable Izvlačenje užeta</td>
<td>39</td>
<td>$x_1$ – distance, m $x_1$ – udaljenost, m</td>
<td>$y_2 = 0.8146 + 0.0246x_1$</td>
<td>11.77</td>
<td>0.49</td>
<td>0.001</td>
<td>0.522</td>
</tr>
<tr>
<td>Hooking Vozanje tovara</td>
<td>36</td>
<td>$x_1$ – load volume, m$^3$ $x_1$ – obujam tovara, m$^3$</td>
<td>$y_3 = 3.6482 + 0.4596x_1$</td>
<td>5.54</td>
<td>0.37</td>
<td>0.024</td>
<td>1.801</td>
</tr>
<tr>
<td>Winching Skupljanje vitlom</td>
<td>39</td>
<td>$x_1$ – distance, m $x_1$ – udaljenost, m</td>
<td>$y_4 = 0.9294 + 0.0918x_1$</td>
<td>26.29</td>
<td>0.64</td>
<td>0.000</td>
<td>1.305</td>
</tr>
<tr>
<td>Forming of load Formiranje tovara</td>
<td>19</td>
<td>–</td>
<td>$y_5 =$ average per cycle $y_5 =$ prosjek po turnusu</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Loaded drive Opterečeno kretanje</td>
<td>39</td>
<td>$x_1$ – distance, m $x_1$ – udaljenost, m $x_1$ – load volume, m$^3$ $x_1$ – obujam tovara, m$^3$</td>
<td>$y_6 = 0.3261 + 0.0157x_1 + 0.1483x_2$</td>
<td>74.08</td>
<td>0.90</td>
<td>0.000</td>
<td>0.002</td>
</tr>
<tr>
<td>Unhooking Odvezivanje tovara</td>
<td>30</td>
<td>$x_1$ – load volume, m$^3$ $x_1$ – obujam tovara, m$^3$</td>
<td>$y_7 = 1.4544 + 0.1417x_1$</td>
<td>4.78</td>
<td>0.38</td>
<td>0.037</td>
<td>0.613</td>
</tr>
<tr>
<td>Landing bunching Uhpavanje</td>
<td>38</td>
<td>$x_1$ – load volume, m$^3$ $x_1$ – obujam tovara, m$^3$</td>
<td>$y_8 = 0.5178 + 0.1556x_1$</td>
<td>20.69</td>
<td>0.68</td>
<td>0.000</td>
<td>0.404</td>
</tr>
</tbody>
</table>

Nova meh. šumar. 35(2014) 59
The costs are 17% (B1 against A1) and 25% (B2 against A2) lower for half-tree-length method when all other conditions are the same. In the research of Horvat et al. (2007), the costs were between 3.74 and 6.01 €/m$^3$ for preparatory felling and between 4.45 and 6.05 €/m$^3$ in the mountain site.

The difference in costs increases with the increase of the difference of the average piece volume of the two skidding methods.

6. Conclusions – Zaključci

Many researchers showed in their studies that skidding of long wood (half-tree-length and tree-length method) is more productive than skidding of short wood (assortment method). There are a few reasons why the assortment method is still dominant in the forestry of B&H. One of the most important is that local forestry regulations provide that it is not allowed to move the assortments away from the felling site unless they are marked (deboned). This is a matter of regulations and can be easily changed. Also, stacked wood, which remains in the forest when using the assortment method, is usually removed by animals. Another reason is that the density of the secondary forest road network is still not satisfactory and that the forest road network is often not designed optimally. Consequently, the possibility of manipulating longer pieces of wood is limited.

Also, there is the opinion that skidding of long wood causes more damage to the stand. This is partially true but investigations show that the damage can be kept at an acceptable level if work is performed by well trained and skilled workers. It is getting harder and harder for forest managers to find animals on the labor market, so often stacked wood remains unused in the forest. This is unacceptable considering the tendency of increasing forest biomass utilization. Regarding the constant need for increasing the work productivity and efficiency, it is necessary to improve the whole harvesting system and start practicing the tree-length or half-tree-length harvesting method in felling and processing. As a result of that, the skidded wood would be as long as allowed by other stand conditions.

7. References – Literatura


traktorskih vlaka i putova, što je limitirajući čimbenik za manipulaciju duljim komadima. Sve teže pronalaženje animalne radne snage za iznošenje prostornoga drva i težnja za što većim postotkom iskorištenosti biomase debla te stalna potreba za povećanjem proizvodnosti i učinkovitosti vodić će ka uvođenju u praksu metoda privlačenja u kojima su komadi drva duži nego je to sadašnja praksa.

Ključne riječi: privlačenje drva skiderom, metode pridobivanja drva, studij vremena, kalkulacija troška, BIH

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