Comparison of Two Skidding Methods in Beech Forests in Mountainous Conditions

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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 Poršinsky 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 (assortment) 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 at 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 forestry planners and workers are extremely well trained to keep the efficiency without causing unacceptable stand damage. Zečić and Marenče (2005) examined the characteristics of work and efficiency of team work. They established standard times for two tractors, which ranges between 25.05 min/m^3 for the skidding distance of 150 m and 33.20 min/m^3 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 m^3/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 m^3/h, with an average of 1.8 m^3 of wood obtained from the trees. The obtained productivity seems to be very good when compared with e.g. 11.6 m^3/h achieved by Timberjack 240C in a mountainous fir stand when skidding roundwood from the felling site, where the volume per mean marked tree was 3.9 m^3 (Sabo and Poršinsky 2005). Using a cable skidder LKT 81 Turbo, the productivity can reach 7.15 m^3/h in mountain conditions in an 82 year old fir stand (Porter 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 m^3/PMH (5.0 min/m^3) with the skidding costs of 2.2 €/m^3. Productivity depends on skidding distance and it ranges between 16.9 m^3/h (50m) and 9.9 m^3/h (400m). Skidding costs range from 1.6 to 2.7 €/m^3 (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 m^3/h and the unit cost was 1.99 \$/m^3 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-

Table 1 Description of research site
Tablica 1. *Opis objekta istraživanja*

Stand description *Opis sastojina*	Sample plots A1 and A2 *Pokusne plohe A1 i A2*	Sample plots B1 and B2 *Pokusne plohe B1 i B2*
Compartment *Odjel*	98; section a – M.U. Potoci-Resanovača *98; odsjek a – G.J. Potoci-Resanovača*	65; section a – M.U. Šiša-Palež *65; odsjek a – G.J. Šiša-Palež*
Altitude, m *Nadmorska visina,* m	970–1 150	690–1 230
Inclination, ° *Nagib,* °	15–30	15–30
Exposition *Ekspozicija*	S–SE	W–NW
Geologic surface *Geološka podloga*	Limestone, medium or deep rocky land *Vapnenac, srednje duboko ili kamenito tlo*	Limestone and dolomite, medium or deep rocky land *Vapnenac i dolomit, srednje duboko ili kamenito tlo*
Climate *Klima*	Mountain, humid *Planinska, humidna*	Mountain, humid *Planinska, humidna*
Stand *Sastojina*	GK 1210 – Forests of beech and fir with spruce on a series of limestone, predominantly deep soil *(Picea-Abieti-Fagetum)* *GK 1210 – Bukovo-jelove šume sa smrekom na seriji vapnenačkih, pretežno dubokih tala* (Picea-Abieti-Fagetum)	GK 1114 – High beech forests on predominantly deep limestone and illimerized soil *(Fagetum montanum illyricum)* *GK 1114 – Visoke bukove šume na pretežno dubokim vapnenačkim i ilimeriziranim tlima* (Fagetum montanum illyricum)
Site quality *Bonitet*	3	2
Canopy *Sklop*	Dense (0.7) *Gust (0,7)*	Dense (0.8) *Gust (0,8)*
Management system *Način gospodarenja*	Group-selection *Skupinasto-preborni*	Group-selection *Skupinasto-preborni*
Growing stock, m^3/ha *Drvna zaliha,* m^3/ha	513.72	343.74
Cutting intensity, % *Intenzitet doznake,* %	14.53	20.94
Average diameter of marked trees, cm *Srednji promjer doznačenih stabala,* cm	21	35
Regeneration *Pomladak*	Medium dense *Srednje gust*	Medium dense *Srednje gust*

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).

Fig. 1 Skidding with LKT 81T skidder
Slika 1. *Privlačenje skiderom LKT 81T*

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 forest. 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 A1 and B1, short-wood (assortment, un-mechanized cut-to-length) harvesting method was performed, where cutters cut the trees with chainsaw and wood processing was done at the site. Also, stacked wood (traditional 1 m length firewood) was produced and piled. Assortments were skidded on the forest road with the skidder LKT 81T (Fig. 1).

In the sample plots A2 and B2, a half-tree-length harvesting method was performed where cutting of trees and delimbing 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-

Table 2 Load parameters
Tablica 2. *Značajke tovara*

Sample plot *Pokusna ploha*	Method *Metoda*	Number of cycles *Broj turnusa*		Mean *Srednja vrijednost*	Sum *Zbroj*	Minimum *Najmanja vrijednost*	Maximum *Najveća vrijednost*	Variance *Varijanca*	Standard deviation *Standardna devijacija*	Standard error *Standardna pogreška*
A1	Assortment *Sortimentna*	34	Number of pieces in load *Broj komada u tovaru*	9.94	338.00	6.00	13.00	2.42	1.56	0.27
			Average volume of piece, m^3 *Prosječni obujam komada,* m^3	0.28	–	0.19	0.40	0.00	0.04	0.01
			Load volume, m^3 *Obujam tovara,* m^3	2.80	95.33	1.65	4.12	0.33	0.58	0.10
			Piece length, m *Duljina komada,* m	5.38	–	4.28	7.31	0.74	0.86	0.18
A2	Half-tree-length *Poludeblovna*	22	Number of pieces in load *Broj komada u tovaru*	11.09	244.00	8.00	15.00	2.85	1.69	0.36
			Average volume of piece, m^3 *Prosječni obujam komada,* m^3	0.33	7.20	0.16	0.49	0.00	0.07	0.01
			Load volume, m^3 *Obujam tovara,* m^3	3.56	78.36	0.82	5.43	1.28	1.13	0.24
			Piece length, m *Duljina komada,* m	8.97	–	8.08	10.53	0.52	0.72	0.20
B1	Assortment *Sortimentna*	34	Number of pieces in load *Broj komada u tovaru*	9.00	306.00	5.00	12.00	3.27	1.81	0.31
			Average volume of piece, m^3 *Prosječni obujam komada,* m^3	0.57	19.42	0.25	1.02	0.05	0.22	0.04
			Load volume, m^3 *Obujam tovara,* m^3	4.98	169.25	1.27	8.68	2.68	1.64	0.28
			Piece length, m *Duljina komada,* m	5.30	–	3.83	7.66	0.80	0.89	0.18
B2	Half-tree-length *Poludeblovna*	23	Number of pieces in load *Broj komada u tovaru*	9.57	220.00	5.00	13.00	4.35	2.09	0.43
			Average volume of piece, m^3 *Prosječni obujam komada,* m^3	0.75	17.22	0.20	1.64	0.10	0.32	0.07
			Load volume, m^3 *Obujam tovara,* m^3	6.62	152.31	2.03	8.48	1.91	1.38	0.29
			Piece length, m *Duljina komada,* m	9.19	–	6.12	14.40	4.08	2.02	0.54

ple plots with half-tree-length method. Total productive time is 1 638.28 min (assortment) and 1 147.93 min (half-tree-length) with the share of delays of 30.18% and 31.15%, respectively (Table 3).

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

Table 3 Descriptive analysis of work time
Tablica 3. *Opis radnoga vremena*

Work operation *Radni zahvat*	Average per cycle, min *Prosječno po turnusu,* min		Standard deviation, min *Standardna devijacija,* min		Sum, min *Zbroj,* min		Minimum, min/cycle *Najmanja vrijednost,* min/turnus		Maximum, min/cycle *Najveća vrijednost,* min/turnus	
Method *Metoda*	Assortment *Sortimentna*	Half-tree-length *Poludeblovna*	Assortment *Sortimentna*	Half-tree-length *Poludeblovna*	Assortment *Sortimentna*	Half-tree-length *Poludeblovna*	Assortment *Sortimentna*	Half-tree-length *Poludeblovna*	Assortment *Sortimentna*	Half-tree-length *Poludeblovna*
Unloaded drive *Neopterećeno kretanje*	5.09	5.20	2.51	1.75	345.78	234.01	1.48	2.33	12.34	9.58
Pulling out of cable *Izvlačenje užeta*	1.61	1.48	0.80	0.59	104.58	66.52	0.37	0.33	5.53	2.87
Hooking *Vezanje tovara*	5.23	5.46	2.50	1.90	355.31	245.54	1.20	1.50	12.06	10.02
Winching *Skupljanje vitlom*	2.92	3.32	1.40	1.63	198.78	149.24	0.73	0.48	8.28	7.30
Forming of load *Formiranje tovara*	2.04	1.95	1.51	0.83	89.56	42.98	0.16	0.67	8.00	4.00
Loaded drive *Opterećeno kretanje*	4.72	5.53	1.97	1.59	321.22	248.94	0.31	1.85	9.16	8.87
Unhooking *Odvezivanje tovara*	2.34	2.29	0.92	0.67	156.94	103.05	0.90	1.00	6.00	4.22
Landing bunching *Uhrpavanje*	0.98	1.34	0.51	0.53	61.83	57.65	0.25	0.55	2.88	2.57
Productive work time, min *Proizvodno radno vrijeme,* min	–	–	–	–	1 638.28	1 147.93	–	–	–	–
Total delays, min *Dodatno vrijeme,* min	–	–	–	–	494.47	357.54	–	–	–	–
Total delays, % *Dodatno vrijeme,* %	–	–	–	–	30.18	31.15	–	–	–	–
Total work time, min *Ukupno radno vrijeme,* min	–	–	–	–	2 132.75	1 505.47	–	–	–	–

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 shortest work operations are pulling out of the cable and landing bunching. The time for pulling out of the cable is 1.61 (assortment) and 1.48 min/cycle (half-tree-length) and for landing bunching 0.98 (assortment) and 0.34 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

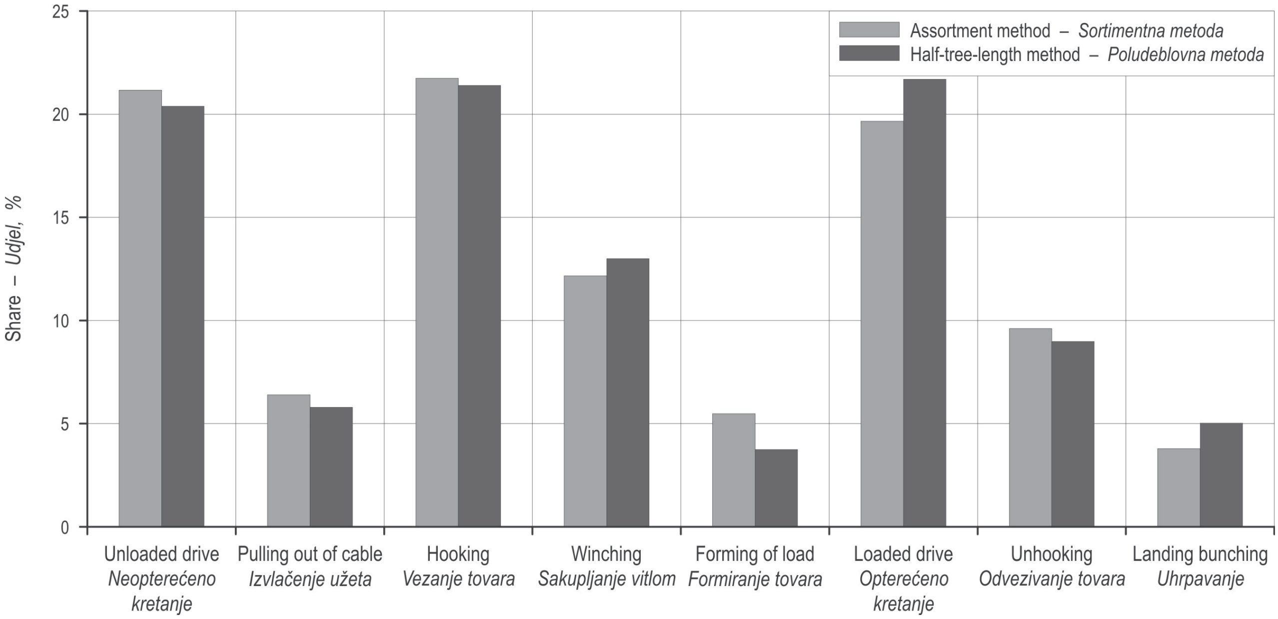

Fig. 2 Relative share of work operations in productive work time
Slika 2. *Relativni udio radnih operacija u proizvodnom radnom vremenu*

Table 4 Structure of delays
Tablica 4. *Struktura dodatnih vremena*

Delays *Dodatno vrijeme*	Assortment method *Sortimentna metoda*		Half-tree-length method *Poludeblovna metoda*	
	min	%	min	%
Preparatory-final time *Pripremno-završno vrijeme*	173.40	28	119.30	29
Technical delay *Tehnički prekidi rada*	66.93	13	59.37	17
Organizational delay *Organizacijski prekidi rada*	117.14	24	74.87	21
Personal delay *Osobni prekidi rada*	137.00	35	104.00	33
Total delays *Ukupno prekidi rada*	494.47	100	305.54	100

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 radnoga 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-

Table 5 Time dependence analysis – assortment method
Tablica 5. *Analiza ovisnosti vremena – sortimentna metoda*

Work operation *Radni zahvat*	N	Independent variable *Nezavisna varijabla*	Model *Model*	*F*-test	*R*	*p*	Standard error Standardna pogreška
Unloaded drive *Neopterećeno kretanje*	65	x_1 – distance, m x_1 – *udaljenost*, m	$y_1 = -0.189+0.0212x_1$	134.62	0.82	0.000	1.449
Pulling out of cable *Izvlačenje užeta*	58	x_2 – distance, m x_2 – *udaljenost*, m	$y_2 = 0.3208+0.047x_2$	17.17	0.48	0.000	0.728
Hooking *Vezanje tovara*	65	x_3 – load volume, m^3 x_3 – *obujam tovara*, m^3	$y_3 = 1.2243+1.0536x_3$	32.65	0.58	0.000	2.057
Winching *Skupljanje vitlom*	59	x_4 – distance, m x_4 – *udaljenost*, m	$y_4 = 1.5973+0.0546x_4$	10.38	0.38	0.002	1.294
Forming of load *Formiranje tovara*	42	x_5 – load volume, m^3 x_5 – *obujam tovara*, m^3	$y_5 = 0.5799+0.3672x_5$	6.15	0.36	0.017	1.431
Loaded drive *Opterećeno kretanje*	65	x_6 – distance, m x_6 – *udaljenost*, m x_7 – load volume, m^3 x_7 – *obujam tovara*, m^3	$y_6 = -0.1162+0.0171x_6+0.1469x_7$	146.69	0.90	0.000 0.026	0.851
Unhooking *Odvezivanje tovara*	61	x_8 – load volume, m^3 x_8 – *obujam tovara*, m^3	$y_7 = 1.4811+0.2462x_8$	2.83	0.39	0.008	0.906
Landing bunching *Uhrpavanje*	60	x_9 – load volume, m^3 x_9 – *obujam tovara*, m^3	$y_8 = 0.4632+0.1357x_9$	14.36	0.44	0.000	0.465

tion (Table 6). Strong correlation was established in dependence of landing bunching on load volume, $R = 0.60$ and in dependence of winching on winching distance ($R = 0.64$). Medium correlation was established in dependence of pulling out of the cable on pulling distance ($R = 0.49$). 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 unhooking on load volume ($R = 0.38$) and hooking of load on load volume ($R = 0.37$). Forming of load showed no significant dependence on any examined influencing factors. The significance level of all correlations is $p \leq 0.05$.

4.4 Productivity and costs – *Proizvodnost i troškovi*

Productivity was calculated so that the time required for each work operation (y_1, y_2,...y_8) was calculated by regression equation for cases where significant dependence on influencing factors was established, or using the average values for given distance and load volume if there was no dependence. The sum of work operation times was multiplied with 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 umber 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 m^3 (A1) against 0.33 m^3 (A2) and 0.57 m^3 (B1) against 0.75 m^3 (B2). The difference is more noticeable in sample plots with larger average log pieces. Consequently, 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 load is 22% (B1 against A1) and 25% (B2 against A2) bigger in half tree length method if all other conditions are the same. The average length of the logs in assortment method was 5.38 m and 5.30 m, and 8.97 m and 9.19 m in half-tree-length method. The average length of logs is 40% and 42% larger in half-tree-length method. These results are comparable with the findings of Horvat et al. (2007) who established that 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
Tablica 6. *Analiza ovisnosti vremena – poludeblovna metoda*

Work operation *Radni zahvat*	*N*	Independent variable *Nezavisna varijabla*	Model *Model*	*F*-test	*R*	*p*	Standard error *Standardna pogreška*
Unloaded drive *Neopterećeno kretanje*	39	x_1 – distance, m x_1 – *udaljenost*, m	$y_1 = 0.4808 + 0.0169x_1$	119.14	0.87	0.000	0.869
Pulling out of cable *Izvlačenje užeta*	39	x_2 – distance, m x_2 – *udaljenost*, m	$y_2 = 0.8146 + 0.0246x_2$	11.77	0.49	0.001	0.522
Hooking *Vezanje tovara*	36	x_3 – load volume, m^3 x_3 – *obujam tovara*, m^3	$y_3 = 3.6482 + 0.4596x_3$	5.54	0.37	0.024	1.801
Winching *Skupljanje vitlom*	39	x_4 – distance, m x_4 – *udaljenost*, m	$y_4 = 0.9294 + 0.0918x_4$	26.29	0.64	0.000	1.305
Forming of load *Formiranje tovara*	19	–	y_5 = average per cycle y_5 = *prosjek po turnusu*	–	–	–	–
Loaded drive *Opterećeno kretanje*	39	x_6 – distance, m x_6 – *udaljenost*, m x_7 – load volume, m^3 x_7 – *obujam tovara*, m^3	$y_6 = 0.3261 + 0.0157x_6 + 0.1487x_7$	74.08	0.90	0.000 0.002	0.683
Unhooking *Odvezivanje tovara*	30	x_8 – load volume, m^3 x_8 – *obujam tovara*, m^3	$y_7 = 1.4544 + 0.1417x_8$	4.78	0.38	0.037	0.613
Landing bunching *Uhrpavanje*	38	x_9 – load volume, m^3 x_9 – *obujam tovara*, m^3	$y_8 = 0.5178 + 0.1556x_9$	20.69	0.60	0.000	0.404

Table 7 Productivity and costs for skidding distance of 250 m
Tablica 7. *Proizvodnost i troškovi za udaljenost privlačenja 250 m*

Sample plot *Pokusna ploha*	A1	B1	A2	B2
Method *Metoda*	Assortment *Sortimentna*		Half-tree-length *Poludeblovna*	
Load volume, m^3 *Obujam tovara*, m^3	2.80	4.98	3.56	6.62
Cycle time, min *Vrijeme turnusa*, min	29.80	35.61	31.72	35.63
Standard time, min/m^3 *Norma vremena*, min/m^3	10.64	7.15	8.91	5.38
Productivity, m^3/day *Učinak*, m^3/dan	42.29	62.93	50.50	83.64
Costs, €/m^3 *Troškovi*, €/m^3	7.65	5.14	6.41	3.86

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.

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Sažetak

Usporedba dviju metoda privlačenja drva u bukovim brdsko-planinskim šumama

Istraživanje različitih metoda privlačenja obavljeno je u sjeverozapadnom dijelu Republike Srpske u BiH na području općine Ribnik. Uspoređivane su dvije metode privlačenja, sortimentna metoda i poludeblovna metoda. Istraživanje je obavljeno na 4 pokusne plohe u 2 odsjeka u bukovim šumama. Pokusne su se površine razlikovale po metodi rada i srednjim promjerom posječenih stabala.

Cilj je istraživanja bio usporedba proizvodnosti i ekonomičnost sortimentne metode koja je trenutačno dominanatna u šumarstvu Republike Srpske i poludeblovne metode koja je modificirana deblovna metoda. Privlačenje je obavljeno šumskim traktorom LKT 81T u zimskim uvjetima gotovo bez snijega. Pri istraživanju je primijenjen studij rada i vremena.

Rezultati su pokazali da je broj komada u tovaru vrlo sličan kod obje metode i na svim pokusnim plohama: 9,94 (A1), 9,0 (B1), 11,09 (A2) i 9,57 (B2). Zapravo je broj komada ovisio jedino o broju omči za vezanje tovara traktora.

Prosječni je obujam tovara kod sortimetne metode iznosio 2,80 m^3 i 4,98 m^3, a 3,56 m^3 i 6,62 m^3 kod poludeblovne metode. Duljine su kod sortimentne metode varirale od 3,83 do 7,66 m, a kod poludeblovne od 6,12 do 14,14 m. Udio je dodatnih vremena iznosio 30,18 % kod sortimentne metode i 31,15 % kod poludeblovne. Relativni udio trajanja radnih zahvata sličan je kod obje metode.

Za ispitivanje utjecaja pojedinih čimbenika na radni proces primijenjene su različite statističke metode. Višestruka linearna regresija pokazala je da trajanje radnih zahvata ovisi uglavnom o udaljenosti i obujmu tovara kod obje metode. Opterećeno kretanje skidera ovisi o udaljenosti i obujmu tovara. Jačina je korelacijske veze najveća kod ovisnosti trajanja neopterećenoga kretanja skidera o udaljenosti privlačenja i opterećenoga kretanja skidera o udaljenosti privlačenja, ali i o obujmu tovara vučenoga drva kod obje metode rada.

Rezultati su pokazali da je proizvodnost veća, a troškovi manji kod poludeblovne metode. Za udaljenost privlačenja od 250 m, za slične stanišne uvjete proizvodnost je 42,29 m^3/dan za sortimentu metodu (A1) i 50,50 m^3/dan za poludeblovnu metodu (A2), odnosno 62,93 m^3/dan (B1) i 83,64 m^3/dan (B2). Troškovi su 17 % (A2 prema A1) i 40 % (B2 prema B1) niži kod poludeblovne metode. Razlika je u troškovima veća što je prosječni obujam komada u tovaru veći.

Iako su mnoga istraživanja i prije pokazala da je privlačenje dugoga drva (poludeblovna metoda) proizvodnije od privlačenja kratkoga drva (sortimentna metoda), poludeblovna metoda još uvijek nije šire prihvaćena u šumarstvu BiH. Neki od razloga su zakonske prirode, a neki su posljedica nedovoljne otvorenosti sastojina mrežom *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 vodit 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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