Works of the Faculty of Forestry
University of Sarajevo
No. 2, 2018 (17-32)

UDK 630*36:631.372]:65.015(497.6)

PRODUCTIVITY OF THE ECOTRAC 120V SKIDDER FOR TIMBER SKIDDING IN THE AREA OF *MU „IGMAN "*

Produktivnost skidera Ecotrac 120V pri privlačenju drveta na području PJ „Igman"

Jelena Knežević[1], Safet Gurda[1], Jusuf Musić[1], Velid Halilović[1], Aldin Vranović[1]

Abstract

This paper presents the research results of the skidding productivity for the Ecotrac 120V skidder in mountainous areas of MU „Igman" in Bosnia and Herzegovina. Time and work study were performed. Multiple regression analysis was used for determination of work operations time consumption depending on influencing factors. The following influencing factors were recorded: the condition of the tractor road (surface), the skidding distance, the winching distance, number of pieces in the load, the volume of the load and the slope of the tractor road. The share of productive time in the total work time is 58.47%. The average value of the influencing factors was established: unloaded travel distance 585.26 m, loaded travel distance 490.49 m, winching distance 16.83 m, number of pieces in the load 5.95, the volume of the load 5.17 m^3 and the volume of the piece in the load 1.02 m^3. The half-tree length method was used. Standard time for skidding and daily skidding productivity were expressed depending on the skidding distance, while average values were used for other influencing factors. The standard time for skidding was 6.57 min/m^3 at a skidding distance of 100 m, i.e. 17.60 min/m^3 at a skidding distance of 1,500 m. The daily skidding productivity ranges from 73.07 m^3/day at a skidding distance of 100 m to 27.28 m^3/day at a skidding distance of 1,500 m. Comparison of the daily skidding productivity with the results of other researches showed that the Ecotrac 120V skidder in this particular case realizes approximately the same skidding productivity under similar working conditions.

Key words: *timber skidding, Ecotrac 120V, skidding productivity, time and work study.*

INTRODUCTION - *Uvod*

The forest areas of Bosnia and Herzegovina are primarily located in hilly and mountainous regions. The orographic terrain structure causes a complicated and expensive timber transport in all phases (MIHAĆ, 1977). Timber skidding represents the

[1] University of Sarajevo, Faculty of Forestry, Zagrebačka 20, 71000 Sarajevo, Bosnia and Herzegovina

key phase of forest harvesting from the aspect of labor cost as well as damaging the stands and forest soil (KULUŠIĆ, 1990).

Timber skidding represents the transport of cut wood in different production degrees (from the finalized wood assortment to the whole tree) from the stump to the closest road or, in rare cases, to the production or distribution facility (KULUŠIĆ, 1990). The most common timber transport type is skidding, respectively hauling by tractors, and in Bosnia and Herzegovina it is almost exclusively skidding by tractors on the ground (SOKOLOVIĆ and MUSIĆ 2009).

The most common means of work in Bosnia and Herzegovina are a chainsaw in the felling and processing phase and a cable skidder in the skidding phase. Animals, cableways and other means of work are used to a lesser extent, far lesser than it is demanded by the terrain and stand conditions.

The research of means of work for skidding phase in the Federation of Bosnia and Herzegovina showed that timber skidding is carried out by 195 tractors, out of which 85% are skidders (HALILOVIĆ et al. 2015). Different Timberjack and LKT types are the most common among the skidders. In recent years there has been interest by forest enterprises in acquiring the Ecotrac skidders produced by the Croatian manufacturer Hittner and their employment in the timber skidding phase.

The research of skidding productivity in the area of Bosnia and Herzegovina began in the 1970s (MIHAĆ, 1977; KULUŠIĆ and MIODRAGOVIĆ 1979; JOVANOVIĆ, 1980; ŠIPAD - IRC 1989; JOVANOVIĆ, 1990; JAKUPOVIĆ, 2003; HALILOVIĆ, 2012; MARČETA, 2015) and included different skidder types (IMT 533, IMT 558, IMT 560, IMT 561, IMT 567, IMT 577, IMT 586, Belt GV 70, Tree Farmer C4 D, Tree Farmer C5 D, LKT 80, LKT 81, LKT 81T, LKT 120, Timberjack 208 D, Timberjack 209 D, Timberjack 225, Timberjack 350A).

More recent research in the forest harvesting in our country offer an overview of LKT 81T skidding productivity. Daily skidding productivity of the above-mentioned skidder ranges from 42.29 m^3/day for a load volume of 2.80 m^3 and cut to length method to 83.64 m^3/day for a load volume of 6.62 m^3 and the half-tree length method. The above showed skidding productivities have been determined for skidding distance of 250 m (MARČETA, 2015).

BORZ, (2015) offered a general overview of Romanian and international research on wood skidding. Net skidding productivity (without delays) is in a range between 1.26 m^3/h and 22.93 m^3/h, averaging 7.89 m^3/h.

Skidding productivity of the Ecotrac 120V skidder depending on the most important influencing factors has not been the subject of research in Bosnia and Herzegovina. The productivity and morphological features of the skidder in the area of Croatia were presented in the works by ZEČIĆ, (2006), HORVAT et al. (2007) and ZEČIĆ et al. (2008).

ZEČIĆ, (2006) was researching the skidding productivity of the Ecotrac 120V in two working areas, hilly (Koprivnica) and mountainous (Senj) conditions, i.e. in preparatory and selective felling. The daily skidding productivity for the first area was

determined in a range from 62.22 m^3/day at a skidding distance of 50 m to 35.74 m^3/day at a skidding distance of 500 m, and on the other area, from 50.53 m^3/day at a skidding distance of 50 m to 35.54 m^3/day at a skidding distance of 500 m.

According to the research by ZEČIĆ et al. (2008), the daily skidding productivity of the Ecotrac 120V skidder is 44.08 m^3 for regeneration felling in hilly and lowland areas in Croatia. The skidder productivity is presented for the average skidding distance of 300 m on skid roads and 50 m on the roadside landing, average load volume of 2.78 m^3 and average volume of the piece in the load of 0.35 m^3.

ZEČIĆ and VUSIĆ (2009) offered an overview of skidding productivity for the Ecotrac 120V skidder created for the purposes of the enterprise „Hrvatske šume" d.o.o. The skidding productivity was determined for timber skidding without chokerman.

AKAY et al. (2004) distinguish the timber skidding distance as a factor with the most important influence on the total transport cycle time during timber skidding using forest skidders. A longer skidding distance increases the transportation time. The slope of the skid road influences the total transport cycle time in a manner that on steep skid roads, the moving speed is lower which increases the duration of the cycle. The load weight also influences the decrease in moving speed, especially on steep roads during uphill timber skidding.

MATERIAL AND METHODS - *Materijal i metode*

The research was conducted in the area managed by *Forest enterprise „Sarajevo šume "d.o.o. Sarajevo*, in forest compartment 151, management unit „Igman". The area of compartment is 56,96 ha. A total of 1.818,59 m^3 net wood was marked for felling, 69% broadleaves and 31% conifers. Timber skidding was conducted by the Ecotrac 120V skidder. This is a four-wheeled (4x4) vehicle which, together with the operator, weights 7,257 kg, 59% of which is at the front and 41% on the rear axle. It comes with a Diesel engine (Deutz D914-L06) of a nominal power of 86 kW. It is equipped with a double-drum winch of 80 kN nominal tractive force. The winch cable is 14 mm in diameter and 70 m long in each drum. The winch is driven hydraulically, and the steering is electro-hydraulical. The rear anchoring blade is used for receiving, protecting and anchoring purposes and it can be lifted or lowered using two hydraulic cylinders. The Ecotrac 120 V skidder is characterized by a small width considering its length, due to the need of moving on built skid roads of a total width of 2.5 m. The unfavourable increase of the skidder length does not impact its mobility due to the centrally installed articulated joint. Due to the increased engine power relative to skidder mass, it is possible to increase travelling speed and provided the wheel thrust force required for overcoming the tractive and rolling resistance, by which work efficiency would also be increased and particularly so on sloped terrain (HORVAT et al. 2007).
Time and work study were performed. The duration of certain categories of work time was determined using the „snap-back chronometry method" which is often used in research of skidding productivity (KULUŠIĆ and MIODRAGOVIĆ 1979; JOVANOVIĆ,

1980; SABO and PORŠINSKY 2005; ZEČIĆ, 2006; ZEČIĆ and VUSIĆ 2009; ZEČIĆ et al. 2011; HALILOVIĆ, 2012; VUSIĆ et al. 2013; MARČETA, 2015).

The total work time is divided to productive time and delay times. The following work operations are part of productive time: unloaded travel, positioning of the skidder, pulling out the winch cable, hooking the load, winching, forming the total load, driving for collecting the load, loaded travel, winching during the loaded travel, unhooking the load and decking. Delay times are divided into allowance time, avoidable delays and delays due to recording. Allowance time encompasses preparatory-final time and unavoidable delay times (KULUŠIĆ and MIODRAGOVIĆ 1979). The following allowance time categories have been specified: preparatory-final time, organizational delays, technical delays, meal time, delays due to rest and personal needs of workers, delays due to load and other unavoidable delays. During the implementation of the time and work study avoidable delays which represent subjectively motivated delays without justified need were also recorded. A special category within the work delay times were delays due to unfavorable weather conditions which include delays caused by rain or snow. Avoidable delays, delays due to recording and delays due to unfavorable weather conditions were not considered while calculating standard time for skidding and daily skidding productivity.

The duration of work time categories was recorded using the *Hanhart* stopwatch which measures time in minutes and hundredths of a minute ($min \cdot 10^{-2}$; 1/100 min). This is the most common technique in conducting work studies (MAGAGNOTTI and SPINELLI 2012). The following influencing factors were recorded: the condition of the tractor road (surface), skidding distance, winching distance, number of pieces in the load, the volume of the load and the slope of the tractor road.

Skidding distance was measured using a measuring tape, and the winching distance using the *Haglöf Vertex* instrument. The recording showed that the skidding distance is not a unique value for unloaded and loaded travel due to load formation on a several places along the tractor road. Therefore, the unloaded travel distance was determined separately from the loaded travel distance. The volume of the load was determined by measuring the diameter and length of certain pieces using caliper and measuring tape. The measurements were conducted in accordance with the JUS D.BO. 022 standard from 1984. The average slope of the tractor road was calculated as the weighted arithmetic mean of measured lengths of uniform slope segments with the related measured slope, according to the methodology used by ZEČIĆ and VUSIĆ (2009). The tractor road slope is presented in percentage (%). The inclination mark (-/+) was determined in the direction of loaded travel. The mark „-" signifies downhill timber skidding and the mark „+" signifies uphill timber skidding. Slope measurement was conducted using the *Haglöf Vertex III* instrument. The statistical program *STATGRAPHICS Centurion XVII* was used for data processing and result interpretation.

RESULTS - *Rezultati*

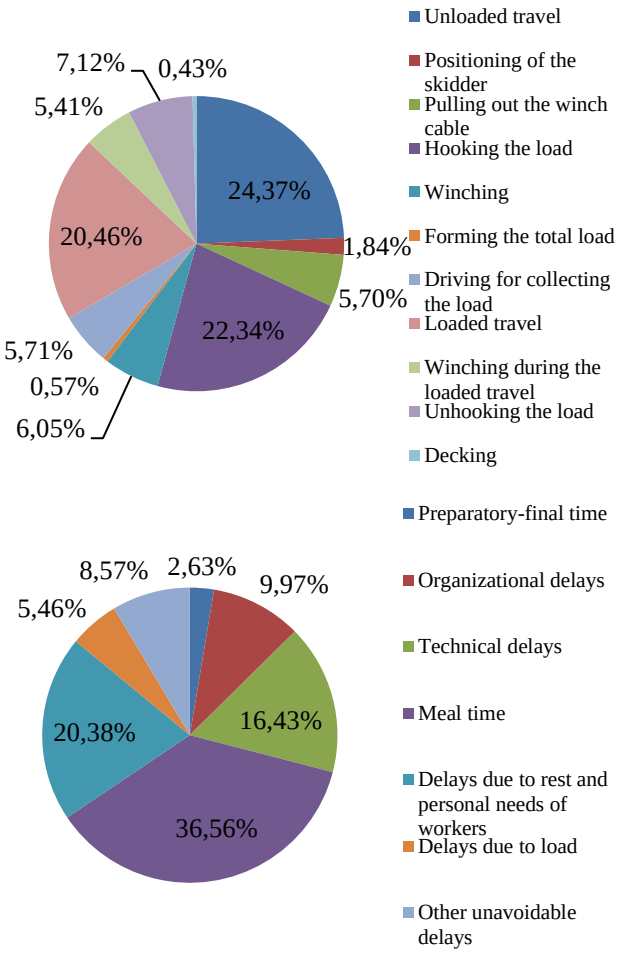
The recording of skidding productivity was conducted during the winter work season. There was no snowfall during the recording. The average air temperature determined at the nearest meteorological station „Bjelašnica" was 0.3ºC. The work organization 1+1 was applied, skidder operator and chokerman. This work organization means that the operator only operates the skidder and winch, while the chokerman performs the tasks of pulling out the winch cable, hooking the load and unhooking the load. Forty-three cycles were recorded. A total of 222.36 m^3 timber was skidded, 54% broadleaves (beech), and 46% conifer (fir and spruce). The half-tree length method was applied.

Work time analysis - *Analiza radnog vremena*

The structure of total work time is presented in Table 1, and the structures of productive and allowance time are shown in Graph 1 and 2.

Table 1. Structure of total work time
Tabela 1. Struktura ukupnog radnog vremena

Work time category	Total duration of the work time category (min)	Percentage share in the total work time (%)
Productive time	1,539.53	58.47
Allowance time	597.13	22.68
Avoidable delays	143.99	5.46
Delays due to unfavorable weather conditions	346.27	13.15
Delays due to recording	6.29	0.24
Total work time	2,633.21	100.00
Volume of skidded timber (m^3)	222.36	
Productive time per unit (min/m^3)	6.92	
Total time per unit (min/m^3)	11.84	
Average daily productivity (m^3/day)	31.77	

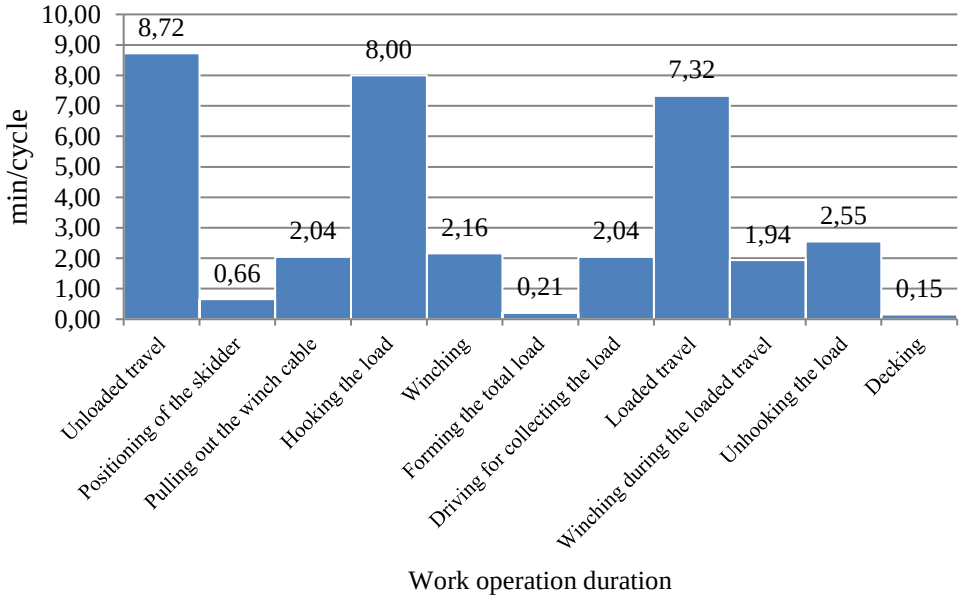


Graph 1. Productive time structure
Grafikon 1. Struktura operativnog vremena

Graph 2. Allowance time structure
Grafikon 2. Struktura dodatnog vremena

The share of productive time in total work time is 58.47%, and the share of allowance time is 22.68%. The largest share in productive time has the unloaded travel (24.37%), and the smallest decking (0.43%). In the category of allowance time, the most common are delays due meal time (36.56%), and the smallest share has preparatory-final time (2.63%).

The analysis of work operations within the cycle (Graph 3) showed that the longest average duration has unloaded travel (8.72 min/cycle). The shortest duration has decking (0.15 min/cycle).



Graph 3. Average duration of work operations
Grafikon 3. Prosječno trajanje radnih operacija

Influencing factors analysis - *Analiza uticajnih faktora*

The data on the influencing factors is presented in Table 2. The surface of the tractor road is described as dry to moist during 95% of the cycles, i.e. wet during 5% of the cycles. The slope of the tractor road for certain cycles was in the range from -21.52% to 20.04%. The average slope of tractor roads, determined as the weighted arithmetic mean of certain cycles slopes and corresponding skidding distances of loaded travels, was -12.05%.

Table 2. Basic statistical indicators of recorded influencing factors
Tabela 2. Osnovni statistički pokazatelji snimljenih uticajnih faktora

Influencing factor	Unit of measure	Average value	Minimum value	Maximum value	Standard deviation
Unloaded travel skidding distance	m	585.26	27.00	1,791.00	532.38
Loaded travel skidding distance	m	490.49	17.00	1,526.00	486.60
Winching distance	m	16.83	5.00	36.50	7.48
No. of pieces in the load		5.95	1.00	11.00	2.45
Volume of the load	m^3	5.17	1.11	9.67	1.69
Average volume of piece in the load	m^3	1.02	0.28	2.91	0.52

Standard time for skidding and daily skidding productivity - ***Norme vremena i učinka traktora***

The influence of certain influencing factors on the standard time for skidding and daily skidding productivity was determined using the multiple regression analysis according to the following general equation (ČABARAVDIĆ, 2017):

$$\hat{Y}_e = \beta_0 + \beta_i x_{ie} + ... + e_e ; \text{ with:}$$

$\hat{Y}_e$ - estimate of the depending variable in the population (e = 1, ...n),
β_i - model parameters (i = 1, ...k),
x_{ie} - independent variables,
e_e - random mistake.

Stepwise regression was applied. This procedure encompasses choosing a model which contains only statistically relevant independent variables but does not exclude any useful variables. The *Backward Selection* option was used, which begins with the model with all variables included and then excludes one variable at a time until the model is reached in which all the remaining variables are statistically important. One selection criterion was the p-value of 0.05.

The results of the conducted regression analysis are presented in Table 3. The duration of unloaded travel was analyzed according to influencing factors of the skidding distance and the slope of the tractor road; the analysis of duration of loaded travel also included the load volume and number of pieces in the load. The duration of pulling out the winch cable and winching was analyzed depending on the following influencing factors: winching distance, number of pieces in the load and load volume, and the duration of hooking the load, forming the total load, unhooking the load and decking depending on the number of pieces in the load and the volume of the load. The selected regression model for certain work operations encompassed only the statistically significant independent variables. The duration of work operations: positioning of the skidder, driving for collecting the load and winching during the loaded travel is expressed as an average value of the recorded data. The statistical significance of analyzed independent variables on the duration of the work operation decking has not been confirmed, thus the average value of recorded data was used in calculating standard time for skidding and daily skidding productivity.

Table 3. Regression analysis results
Tabela 3. Rezultati regresione analize

Dependent variable	Independent variable(s)	Determination coefficient (R^2)	Standard Error of Estimation	Estimation importance level (p)	Regression model/ Average duration of the work operation (min/cycle)
T_{UT}	utsd	97.68	1.32	0.0000	$T_{UT}=0.3237+0.0159\cdot utsd$
T_{SP}	-	-	-	-	$T_{SP}=0.66$
T_{PW}	wd	31.09	0.94	0.0009	$T_{PW}=-0.5854+0.0778\cdot wd+0.2279\cdot np$
	np			0.0013	
T_H	np	49.96	2.33	0.0000	$T_H=0.9789+0.7298\cdot np+0.5514\cdot lv$
	lv			0.0192	
T_W	wd	25.70	0.98	0.0019	$T_W=-0.2034+0.0753\cdot wd+0.1921\cdot np$
	np			0.0080	
T_{FTL}	lv	15.43	0.42	0.0387	$T_{FTL}=-0.3349+0.1163\cdot lv$
T_{CL}	-	-	-	-	$T_{CL}=2.04$
T_{LT}	ltsd	95.28	1.47	0.0000	$T_{LT}=1.1170+0.0134\cdot ltsd$
T_{WD}	-	-	-	-	$T_{WD}=1.94$
T_{UH}	np	58.98	0.83	0.0000	$T_{UH}=0.1607+0.4012\cdot np$
T_D	np	-	-	-	$T_D=0.15$
	lv				

T_{UT} - time consumption for unloaded travel; T_{SP} - time consumption for skidder positioning; T_{PW} - time consumption for pulling out the winch cable; T_H - time consumption for the hooking the load; T_W - time consumption for the winching; T_{FTL} - time consumption for the forming the total load; T_{CL} - time consumption for the driving for collecting the load; T_{WD} - time consumption for the winching during the loaded travel; T_{LT} - time consumption for the loaded travel; T_{UH} - time consumption for the unhooking the load; T_D - time consumption for the decking; utsd - unloaded travel skidding distance (m); wd - winching distance (m); np - number of pieces in the load; lv - volume of the load (m^3); ltsd - loaded travel skidding distance (m).

The determined standard time for skidding and daily skidding productivity are presented in Table 4. The standard time for skidding was calculated by dividing the productive work time increased by the coefficient of allowance time with the average volume of the load, and the daily skidding productivity was calculated by dividing the eight-hour work day (480 min) with the standard time for skidding. The coefficient of allowance time is 1.39. The results are presented depending on the skidding distance, while for other influencing factors, average values have been used.

Table 4. Standard time for skidding and daily skidding productivity
Tabela 4. Norme vremena i učinka

Skidding distance (m)	Standard time for skidding (min/m^3)	Daily skidding productivity (m^3/day)	Daily skidding productivity decrease factor
100	6.57	73.07	1.00
200	7.36	65.24	0.89
300	8.14	58.93	0.81
400	8.93	53.74	0.74
500	9.72	49.38	0.68
600	10.51	45.68	0.63
700	11.30	42.49	0.58
800	12.08	39.72	0.55
900	12.87	37.29	0.51
1,000	13.66	35.14	0.48
1,100	14.45	33.23	0.46
1,200	15.23	31.51	0.43
1,300	16.02	29.96	0.41
1,400	16.81	28.55	0.39
1,500	17.60	27.28	0.37

The standard time for skidding is 6.57 min/m^3 at a skidding distance of 100 m, i.e. 17.60 min/m^3 at a skidding distance of 1,500 m. The daily skidding productivity ranges from 73.07 m^3/day at a skidding distance of 100 m to 27.28 m^3/day at a skidding distance of 1,500 m. The standard time for skidding is 9,65 min/m^3, daily skidding productivity 49,76 m^3/day at average skidding distance for loaded travel (490,49 m).

DISCUSSION - *Diskusija*

The determined percentage share of productive time in total work time (58.47%) has been compared to the results of other researches of the skidding productivity for the Ecotrac 120V skidder or other skidders under similar work conditions. ZEČIĆ, (2006) found the share of productive time in the total work time for timber skidding by the Ecotrac 120V skidder in hilly and mountainous conditions, i.e. the preparatory and selective felling in amount of 47.06%, i.e. 80.20%. MARČETA, (2015) determined a higher share of productive time in total time (76.25%) compared to the presented result in timber skidding by the LKT 81T skidder for the half-tree length method. SABO and PORŠINSKY (2005) state that the share of productive time in total work time is 67.50%, i.e. 68.16% in fir timber skidding using the forest Timberjack 240C cable skidder with a double-drum winch at two compartments with different levels of stoniness. ZEČIĆ et al. (2011) reached similar results (64.39%) for the same type of skidder (Timberjack 240C) with a double-drum winch while skidding timber in selection forests using the half-tree length method.

The determined productive time per product unit (6.92 min/m^3 and 11.84 min/m^3) is shorter regarding to the results reached by ZEČIĆ, (2006). This author determined the following values while skidding timber by the same skidder: 8.06 min/m^3 and 17.14 min/m^3 in hilly conditions, respectively 9.88 min/m^3 and 12.31 min/m^3 in mountainous work conditions. The determined daily skidding productivity (31.77 m^3/day) is similar to the result reached by the before-mentioned author for mountainous work conditions (31.88 m^3/RD).

The determined coefficient of allowance time (1.39) is somewhat larger comparing to the results determined by ZEČIĆ, (2006) who found the factors of allowance time 1.34 and 1.18 for same skidder and MARČETA, (2015) who determined coefficients of allowance time 1.30 and 1.31 while using the assortment, respectively half-tree length method during timber skidding by the LKT 81T skidder.

The structure of productive work time showed that unloaded travel has the largest share in productive work time (24.37%) and decking the smallest (0.43%). Loaded travel time has a smaller share in the productive work time (20.46%) comparing to unloaded travel. However, if we add the time of winching during the loaded travel to the loaded travel time, we reach a share of 25.87%. MARČETA, (2015) determined that the highest percentage share in productive work time has the loaded travel (22%), and the lowest forming of load (4%). ZEČIĆ, (2006) states that the largest share in productive work time has the work at the felling site (36.02%, i.e. 48.96%) on both sites, in hilly and mountainous work conditions. If we sum up all the work operations connected to the felling site, we reach that the percentage share of work at the felling site in the total work time for the conducted research is 34.66%. SABO and PORŠINSKY (2005) also confirmed that in the structure of productive work time, felling site work has the largest share on both sites of the research (44.60% and 46.40%).

In the category of allowance time, the most common are delays due to meal time (36.56%), while preparatory-final time has the lowest share (2.63%). ZEČIĆ, (2006) also ascertained that delays due to meal time has the largest share in allowance time (38.60% and 36.29%). The results of the same research show a significantly larger share of the preparatory-final time (35.10% and 21.28%) comparing to recorded data. MARČETA, (2015) states that personal delays have the largest share in allowance time (33%), and the technical delays the lowest share (17%) for half-tree length method.

Comparing the characteristics of the load with the results of other researches brings us to the conclusion that the presented results (Table 2) are very similar to the results reached by ZEČIĆ, (2006) for researching the skidding productivity of the Ecotrac 120V skidder in mountainous conditions (average load volume: 5.34 m^3; average number of pieces in the load: 5.70 and average volume of the pieces in the load: 0.93 m^3). A smaller average volume of the load and the pieces in the load was determined while operating the same skidder in hilly conditions compared to the presented results (Table 2). ZEČIĆ et al. (2008) found that average volume of the load for timber skidding by the Ecotrac 120V skidder in the regeneration fellings in hilly and lowland areas of Croatia is 2.78 m^3, and average volume of pieces in the load is 0.35 m^3 using the half-tree method. MARČETA, (2015) determined the average volume of the

load to be 3.56 m^3, average number of pieces in the load 11.09, average volume of the piece in the load 0.33 m^3, i.e. 6.62 m^3, 9.57, 0.75 m^3 for timber skidding by the LKT 81T forest skidder and the half-tree method in two sites.

Performing of the multiple regression analysis it was determined that the loaded travel skidding distance has an exclusive statistically significant influence on the loaded travel time consumption, while the influence of the volume of the load, number of pieces in the load and the slope of the tractor road is not statistically significant. The research by ZEČIĆ and MARENČE (2005) showed that the skidding distance and the slope of tractor road have a statistically significantt influence ($p<0.05$) on the work operation loaded travel for the Ecotrac V 1033 F skidder, while the influence of the volume of the load and the number of pieces in the load has not been statistically significant. In addition, JOVANOVIĆ, (1990) states that the skidding distance best characterizes the times of unloaded and loaded travel of the tractor. The performed regression analysis did not show statistically significant influence of the load volume and the number of the pieces in the load on the work operation of decking. In analyzing the results of published Romanian and international research in the area of timber skidding, BORZ, (2015) concluded that the time consumption per cycle depends on the skidding distance, winching distance and the number of pieces in the load, while the skidder productivity is likely to be affected also by the used practice such as the load volume, which can compensate for the long skidding distances in terms of productivity. The conducted research determined the statistically significant influence of the before-mentioned factors on the duration of individual work operations of the cycle.

The determination coefficient higher than 90% was determined for the dependence of time consumption of unloaded travel and loaded travel depending on the skidding distance of the unloaded, i.e. loaded travel.

The skidding productivity ranges from 73.07 m^3/day at a skidding distance of 100 m to 27.28 m^3/day at a skidding distance of 1,500 m. The presented results are calculated for average values of influencing factors: winching distance 16.83 m, number of pieces in the load 5.95, volume of the load 5.17 m^3 and the volume of the piece in the load 1.02 m^3. The average slope of tractor roads for loaded travel is -12.05%. ZEČIĆ, (2006) determined that the daily skidding productivity of the same skidder in timber skidding in similar stand and field conditions ranges from 50.53 m^3/day at a skidding distance of 50 m to 35.54 m^3/day at a skidding distance of 500 m. The average volume of the load in the presented research was 5.34 m^3, the average number of pieces in a load was 5.70 and the average volume of the pieces in the load was 0.93 m^3. The average slope of the tractor roads for loaded travel was -9%. In addition, the same method (half-tree length) was applied. The share of beech in the skidded timber was 84.30 %, and fir 15.70%. ZEČIĆ et al. (2008) state that the daily skidding productivity for the Ecotrac 120V skidder is 44.08 m^3/day at an average skidding distance of 300 m on skid trails and felling site and 50 m at the roadside landing. The results are presented for to the regeneration felling in hilly and lowlands areas in Croatia for the half-tree length

method, average load volume of 2.78 m^3 and average volume of the piece in the load of 0.35 m^3.

CONCLUSIONS - *Zaključci*

Timber skidding using cable skidders is the most common manner of timber transport in Bosnia and Herzegovina. In the last years, we have witnessed the modernization of means of work in the timber skidding phase which does not follow the determination of their objective productivity depending on the most influencing factors. The presented results contribute to establishing standard time for skidding and skidding productivity in the work of the Ecotrac 120V skidder for the area of Bosnia and Herzegovina. The comparison of determined work skidding productivity with results from other researches showed that the Ecotrac 120V skidder, in this particular case, realizes approximately the same skidding productivity under similar work conditions. Based on the conducted analysis, it can be concluded that there is the possibility of an enhanced productivity through better work organization and lowering the share of delays in the total work time.

REFERENCES - *Literatura*

AKAY, A.E., ERDAŞ, O., SESSIONS, J. (2004). Determining Productivity of Mechanized Harvesting Machines. *Journal of Applied Sciences*. 4(1): 100-105.

BORZ, S.A. (2015). A review of the Romanian and international practices in skidding operations. *XIV World Forestry Congress*. Durban, South Africa, 7-11 September 2015.

ČABARAVDIĆ, A. (2017). *Biometrika u šumarstvu i hortikulturi*. Sarajevo: Šumarski fakultet Univerziteta u Sarajevu.

GURDA S., JOVANOVIĆ, B., MUSIĆ, J., HALILOVIĆ, V. (2010). Tehnologije u šumarstvu, standardi šumskih drvnih sortimenata i šumska biomasa. Završni izvještaj studije. Sarajevo: Federalno Ministarstvo poljoprivrede, vodoprivrede i šumarstva.

HALILOVIĆ, V. (2012). Komparacija metoda dobivanja šumske biomase kao obnovljivog izvora energije iz hrastovih sastojina. Doktorska disertacija. Sarajevo: Univerzitet u Sarajevu, Šumarski fakultet.

HALILOVIĆ, V., GURDA, S., SOKOLOVIĆ, DŽ., MUSIĆ, J., BAJRIĆ, M. (2013). Analiza utroška vremena pri sječi i izradi stabala hrasta kitnjaka primjenom sortimentnog metoda rada. *Naše šume*. 30-31: 4-13.

HALILOVIĆ, V., MUSIĆ, J., GURDA, S., TOPALOVIĆ, J. (2015). Analysis of the means of forest harvesting in the Federation of Bosnia and Herzegovina. *Glasnik Šumarskog fakulteta Univerziteta u Beogradu*. Posebno izdanje (2015): 55-62.

HORVAT, D., ZEČIĆ, Ž., ŠUŠNJAR, M. (2007). Morfološke i proizvodne značajke traktora Ecotrac 120V. *Nova mehanizacija šumarstva*. 28, Posebno izdanje 1: 81-92.

IZVEDBENI PROJEKAT (2017). *Odjeljenje 151 PJ „Igman"*. Kantonalno javno preduzeće za gospodarenje državnim šumama „Sarajevo šume "d.o.o. Sarajevo.

JAKUPOVIĆ, DŽ. (2003). Istraživanje optimalne tehnologije sječe, izrade i transporta drveta iz prorednih sječa u kulturama bijelog bora. Magistarski rad. Sarajevo: Univerzitet u Sarajevu, Šumarski fakultet.

JOVANOVIĆ, B. (1980). Istraživanja utroška vremena za dvije tehnologije rada kod eksploatacije bukovih šuma u SR Bosni i Hercegovini. Magistarski rad. Zagreb: Sveučilište u Zagrebu, Šumarski Fakultet.

JOVANOVIĆ, B. (1990). Komparativno istraživanje tehničko-tehnoloških karakteristika traktora pri privlačenju drva. Doktorska disertacija. Zagreb: Sveučilište u Zagrebu, Šumarski fakultet.

JOVANOVIĆ, B., GURDA, S., MUSIĆ, J., BAJRIĆ, M., LOJO, A., VOJNIKOVIĆ, S. ČABARAVDIĆ, A. (2005). Šumska biomasa - potencijalni izvor obnovljive energije u Bosni i Hercegovini. Posebno izdanje, 19. Sarajevo: Univerzitet u Sarajevu, Šumarski fakultet.

KULUŠIĆ, B. (1990). Karakteristike šumskih terena kao indikatori izbora tehnologije privlačenja drveta. *Šumarski list*. 114(11-12): 463-473.

KULUŠIĆ, B., MIODRAGOVIĆ, D. (1979). Prilog istraživanju tehnološkog procesa sječe, izrade i privlačenja drveta pri iskorišćavanju borovih i hrastovih šuma u BiH. *Radovi Šumarskog fakulteta i Instituta za šumarstvo u Sarajevu*. 22(5-6): 3-93.

MAGAGNOTTI, N., SPINELLI, R. (EDS.) (2012). COST Action FP0902 – *Good Practice Guidelines for Biomass Production Studies*. Firence: CNR IVALSA.

MARČETA, D. (2015). Comparison of technologies of wood biomass utilization in beech stands. Doctoral dissertation. Ljubljana: University of Ljubljana, Biotechnical faculty.

MIHAĆ, B. (1977). Privlačenje, utovar i transport drveta. *Radovi Šumarskog fakulteta i Instituta za šumarstvo u Sarajevu*. 21(1-2): 3-63

SABO, A., PORŠINSKY, T. (2005). Skidding of fir roundwood by Timberjack 240C from selective forests of Gorski Kotar. *Croatian Journal of Forest Engineering*. 26(1): 13-27.

SOKOLOVIĆ, DŽ., MUSIĆ, J. (2009). Privlačenje drveta šumskim žičarama. *Naše šume*. 14-15: 33-41.

ŠIPAD - IRC (1989). Tehničke norme rada u iskorišćavanju šuma. Sarajevo: ŠIPAD - IRC, OOUR SILVA.

VUSIĆ, D., ŠUŠNJAR, M., MARCHI, E., SPINA, R., ZEČIĆ, Ž., PICCHIO, R. (2013). Skidding operations in thinning and shelterwood cut of mixed stands - Work productivity, energy inputs and emissions. *Ecological engineering*. 61: 216-223.

ZEČIĆ, Ž. (2006). Usporedba djelotvornosti traktora Ecotrac 120 V pri privlačenju drva u brdskim i gorskim uvjetima. *Glasnik za šumske pokuse*. Posebno izdanje br. 5: 557-571.

ZEČIĆ, Ž., MARENČE, J. (2005). Mathematical models for optimization of group work in harvesting operation. *Croatian Journal of Forest Engineering*. 26(1): 29-37.

ZEČIĆ, Ž., PENTEK, T., VUSIĆ, D., NEVEČEREL, H., STANKIĆ, I., LEPOGLAVEC, K., BOSNER, A. (2008). Exploitation and Productivity Characteristics of the new Croatian Skidders Ecotrac 55 V and Ecotrac 120 V. In: *Proceedings of „Formec" 41. International Syposium*. Schmallenberg, Germany, 2-5 June 2008.

ZEČIĆ, Ž., VUSIĆ, D. (2009). *Računalne norme privlačenja drva traktorima (RANOP)*. Zagreb: Šumarski fakultet Sveučilišta u Zagrebu.

ZEČIĆ, Ž., VUSIĆ, D., MILKOVIĆ, D., ZORIĆ, M. (2011). Skidder with single-drum or double drum winch in mountainous areas – A case study from selective forests of Croatia. In: *44th International Symposium on Forestry Mechanisation: „Pushing the Boundaries with Research and Innovation in Forest Engineering"*. Graz, Austria, 9-13 October 2011.

SAŽETAK

U radu su prikazani rezultati istraživanja efekata rada šumskog zglobnog traktora Ecotrac 120V, koji se sve više koristi za privlačenje drveta u bosanskohercegovačkim preduzećima šumarstva. Istraživanje je provedeno u šumskom odjeljenju 151 PJ „Igman", planinskog područja Igman. Primijenjen je studij rada i vremena. Trajanje radnog vremena je ustanovljeno primjenom povratnog metoda snimanja. Zavisnost vremena trajanja radnih operacija od uticajnih faktora je utvrđena uz primjenu višestruke regresione analize. Primijenjen je poludeblovni metod izrade drveta. Snimljeni su sljedeći uticajni faktori: stanje traktorskog puta (podloge), distanca privlačenja drveta traktorom, distanca primicanja drveta vitlom, broj komada u teretu, zapremina tereta i uzdužni nagib traktorskog puta. Udio operativnog vremena u ukupnom radnom vremenu iznosi 58,47%, a udio dodatnog vremena 22,68%. Najveći dio operativnog vremena otpada na radnu operaciju prazna vožnja (24,37%), a najmanji na radnu operaciju meglanje (0,43%). U kategoriji dodatnog vremena najzastupljeniji su prekidi zbog jela (36,56%), dok najmanji udio ima pripremno-završno vrijeme (2,63%). Analiza radnih operacija u okviru transportnog ciklusa je pokazala da najveće prosječno trajanje ima radna operacija prazna vožnja (8,72 min/tc). Najmanje prosječno trajanje ima radna operacija meglanje (0,15 min/tc). Utvrđena je prosječna vrijednost uticajnih faktora: distanca prazne vožnje 585,26 m, distanca pune vožnja 490,49 m, distanca primicanja 16,83 m, broj komada u teretu 5,95, zapremina tereta 5,17 m^3 i prosječna zapremina komada u teretu 1,02 m^3. Primjenom višestruke regresione analize

je utvrđeno da na vrijeme radnih operacije prazna vožnja i puna vožnja statistički značajan uticaj imaju distanca prazne vožnje i distanca pune vožnje. Vrijeme radnih operacija izvlačenje užeta vitla i primicanje vitlom zavisi od distance primicanja i broja komada u teretu. Vrijeme radne operacije vezivanje tereta zavisi od broja komada u teretu i zapremine tereta, vrijeme radne operacije formiranje ukupnog tereta od zapremine tereta a vrijeme radne operacije odvezivanje tereta od broja komada u teretu. Norme vremena i učinka su izražene u zavisnosti od distance privlačenja, dok su za druge uticajne faktore korištene prosječne vrijednosti. Utvrđena je norma vremena od 6,57 min/m^3 za distancu privlačenja drveta 100 m, odnosno 17,60 min/m^3 za distancu privlačenja 1.500 m. Dnevni učinak traktora se kreće u intervalu od 73,07 m^3/RD za distancu privlačenja 100 m do 27,28 m^3/RD za distancu privlačenja 1.500 m.

Corresponding author: Jelena Knežević; University of Sarajevo, Faculty of Forestry; Zagrebačka 20, 71000 Sarajevo, Bosnia and Herzegovina; e-mail address: j.knezevic@sfsa.unsa.ba