Skidder with single-drum or double-drum winch in mountainous areas – A case study from selective forests of Croatia

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Abstract:
In selected forests of Croatia, because of the stand and extraction factors, we are generally compelled to use skidders for the primary transport of wood. Most of the skidders used in Croatian forestry are equipped with a double-drum winch. Of the 45 Timberjack 240C skidders 30 are equipped with a double-drum, and 15 with a single-drum winch. Between 0.25 mil. m3 and 0.30 mil. m3 of round-wood is annually skidded with these machines, mainly in hilly and mountainous regions. This study was set up to determine the difference in productivity between single-drum equipped skidders and double-drum equipped skidders. By applying time and motion study methods half-length skidding work in selective cut was recorded. The differences between the speeds, fixed times consumptions and load volume were analysed by a T-test. Daily outputs based on the eight-hour work time were calculated. It was found that the skidder equipped with a single-drum winch achieved from 11% to 9% lower projected daily output at distances from 100 m to 800 m than the skidder equipped with a double-drum winch.

Keywords: timber skidding, productivity, Timberjack 240C

1 Introduction

Around 5.5 mil. m^3 of various wood assortments is annually produced in forests of Croatia. Of that amount 88% in produced in state forests. Felling and processing is mainly performed by chain-saws. About two-thirds of the wood produced is skidded by skidders and by adapted agricultural tractors. The remaining third is almost entirely forwarded by forwarders and tractor assemblies. Cable-yarding is only occasionally used, on steep slopes and unopened areas.

Almost half of the total production, about 2 mil. m^3, is hauled by the mechanization of "Croatian Forests" Ltd. Zagreb, a company that manages state forests. With their heavy skidders (mass greater than 5t) about 0.9 mil. m^3 is annually skidded, mainly in hilly and mountainous regions. Of their 183 heavy skidders 45 are type Timberjack 240C, 30 with double-drum winch and 15 with single-drum winch (Krpan and Zečić, 2001a). These skidders, haul between 0.25 mil. m^3 and 0.30 mil. m^3 per year.

1.1 Research goal

The aim of this research was to determine productivity differences in single-drum equipped and double-drum equipped Timberjack 240C half-length skidding by analysing the load volume and time consumptions for different work elements.

2 Material and Methods

The study was conducted in selective felling site, on area of 54.47 ha at an altitude of 630 m to 785 m and slope from 0 ° to 25 °. Before harvesting, there were 374 trees per hectare and growing stock was 378 m^3/ha. The growing stock was compound of silver fir trees with 68.83%, beech with 22.65%, spruce with 8.20%, while the remaining 0.41% was made of other hard broad-leaved trees. A total of 1689 trees (31 trees/ha) and 4005 m^3 of gross wood volume (73.53 m^3/ha) was marked for felling. Brest height diameter of the average marked tree was 51 cm for conifers and 44 cm for broad-leaves. Gross volume of the average marked tree was 1.38 m^3.

Half-length harvesting method was used. Work was performed by two groups of workers. Each group consisted of two cutters at the felling site, one tractor driver, one choker-man and one cutter at the landing site. Skidding was done by two Timberjack 240C skidders. One skidder was equipped with a standard Timberjack's single-drum T40 winch (nominal pulling force 125 kN) and the other one was equipped with a double-drum Konrad Adler HY16 winch (nominal pulling force 2 x 80 kN). According to the shape index (length 5860 mm, width 2590 mm, height 2911 mm) Timberjack 240C is classified as medium heavy and heavy tractor, and according to the engine power (75 kW) and mass (8409 kg) it belongs to the family of heavy tractors (Krpan and Zečić, 2001b).

Skidding work was investigated by time and motion study (Zečić et al. 2004). During the study, 99 single-drum winch skidder skidding cycles and 103 double-drum winch skidder skidding cycles were recorded. Skidding cycle work elements were precisely divided by fixed points. Time consumptions of individual work elements, as well as the delay times, were recorded using snap-back chronometry method. In this way time consumptions for unloaded tractor on skid road travel, felling site work (positioning, line pulling, choking, winching, load manoeuvring, mounting), loaded tractor on skid road travel (and travel winching), loaded tractor on landing travel and landing work (unchoking, bunching, skidder turning, mounting) were recorded. Along with time consumption, skidding distances, line pulling/winching distances and skidded load date were recorded. The analysis of recorded delays provided allowance time (Zečić, 1999).

Results of field studies were analyzed in software package STATISTICA 7. A T-test was used to analyze differences of mean values per cycle of travel speeds, of consumptions of fixed times at the felling site and at the landing and of the sizes of the load between the single-drum winch skidder and the double-drum winch skidder. In accordance with the T-test results recorded data was in further processing treated as one or two separate groups. Travel time consumptions dependence on skidding distance and line pulling and winching time consumptions dependence on line pulling/winching distance was explored by regression analysis. Times of all the other work elements ware calculated as the average time consumptions.

By dividing the total time consumption for projected skidding cycle with an average load volume standard time was calculated. Daily output was expressed for the eight-hour work time.

3 Results

In total 4231.61 min of single-drum winch skidder time consumption, and 4067.68 min double-drum winch skidder time consumption was recorded. Of that, 2709.60 min of effective time for single-drum winch skidder and 2619.15 min of effective time for double-drum winch skidder. Allowance time was 976.21 min for single-drum winch skidder, and 859.36 min for double-drum winch skidder. Unique allowance time factor is 1.35.

Load volumes skidded with single-drum winch skidder (SDS) and double-drum winch skidder (DDS) are shown in Figure 1. Results of the T-test ($p = 0.074478$) indicate that there is no significant difference between the load volume skidded with single-drum winch skidder and the load volume skidded with a double-drum winch skidder. Therefore, the load volumes were, in subsequent processing, regarded as a unique data set ($\bar{x} = 5.866$; min = 1.007; max = 9.877; Std. Dev. = 1.724087).

T-test analysis of travel speeds showed that only for the unloaded skidder on the skid road travel there was no significant difference between the two skidders, while for all other travel work elements significant difference was found (Table 1). In accordance with the T-test results regression analysis of skid road travel time to skidding distance was conducted (Fig. 2, 3 and 4). For calculating the landing travel time consumption in the projected skidding cycle for average distance of 40 m pertaining mean speed values were used.

For fixed times, T-test results indicate that there were no significant differences in time consumptions per turn between the two skidders only for the work elements skid road loaded travel winching, positioning and skidder turning (Table 1). For listed work elements unique data set means were calculated; 1.29 min/cycle for skid road loaded travel winching, 0.65 min/ cycle for positioning and 0.49 min/ cycle for skidder turning. For all other work elements, which were treated as a fixed time per cycle, mean values of separate data sets (Table 1) were used in following calculations.

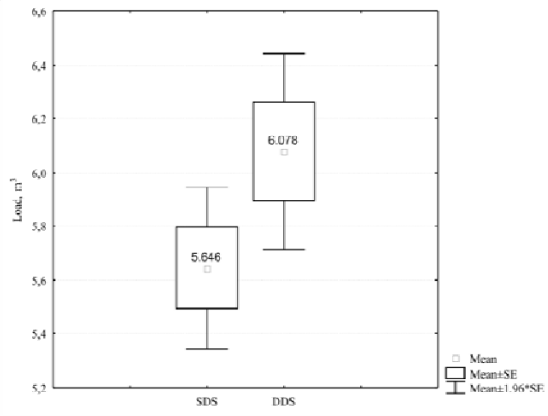

Figure 1: Box & Whisker Plot for skidder's load volume

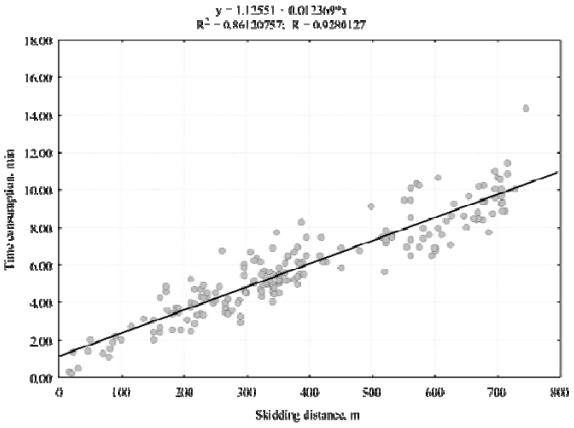

Figure 2: Skid road travel time consumptions - unloaded

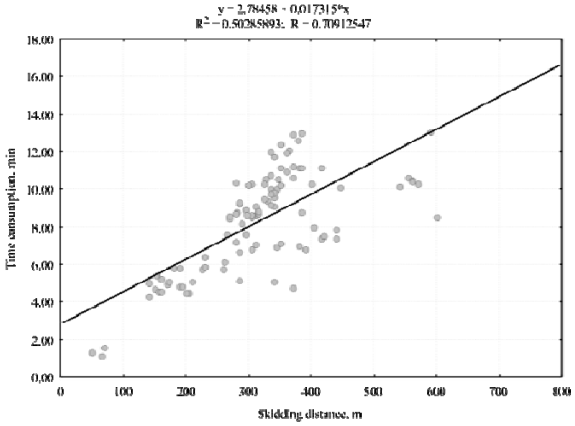

Figure 3: Skid road travel time consumptions - SDS loaded

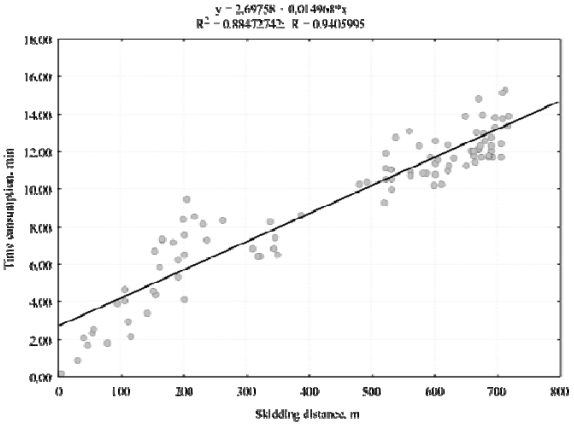

Figure 4: Skid road travel time consumptions - DDS loaded

Time consumptions of line pulling and winching to line pulling/winching distance dependence was investigated by regression analysis as shown in Figures 5, 6, 7 and 8. Winching with the single-drum winch was done on an average distance of 23 m, whereas winching with the double-drum winch was done on an average distance of 15 m. To calculate the time consumption for line pulling and winching in the projected skidding cycle the corresponding regression equations and the average distances of line

pulling/winching were used. Since the recorded data pairs (distance-time), in the case of double-drum winch, were regarded as single data set regardless of the drum they were recorded on, it is necessary to multiply the time consumptions calculated using the equations on Figures 6 and 8 by 2.

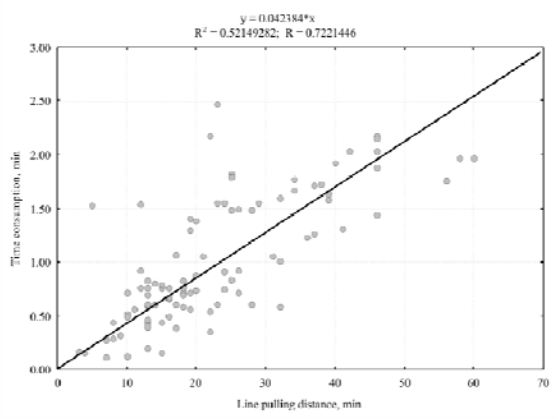

Figure 5: Line pulling time consumptions - SDS

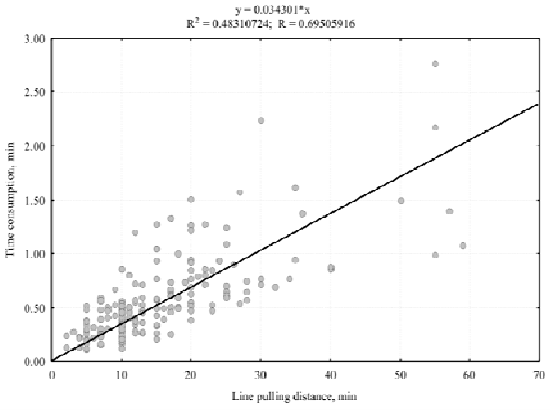

Figure 6: Line pulling time consumptions - DDS

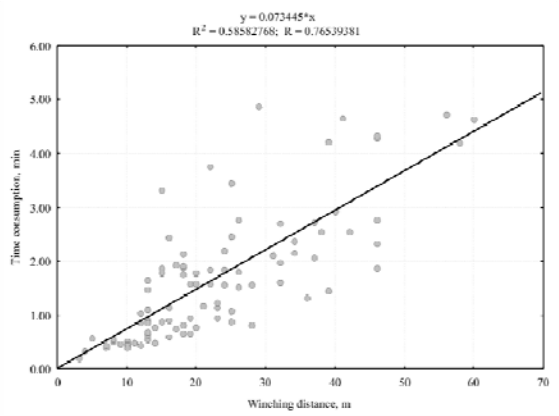

Figure 7: Winching time consumptions - SDS

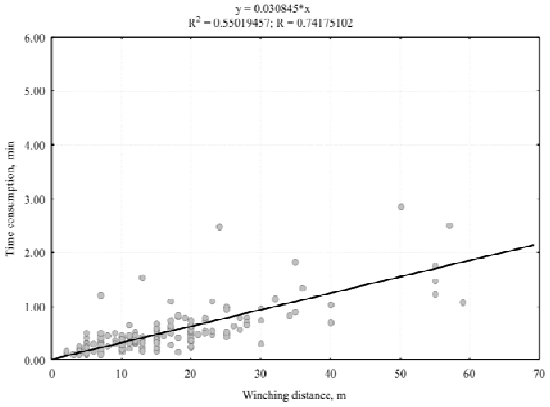

Figure 8: Winching time consumptions - DDS

The effective time consumptions by groups of work elements, the total time consumption and the standard time for skidding distances on the strip road from 100 m to 800 m of skidder equipped with single-drum winch (SDS) and of skidder equipped with double-drum winch (DDS) are shown in Table 2. The skidder equipped with single-drum winch achieved 11% to 9% lower daily output at skidding distance 100 m to 800 m compared to skidder equipped with double-drum winch (Figure 9).

Table 1: T-test results (bolded values indicate significant difference, p < 0.05)

Data group	Mean		t-value	df	p	Valid N		Std.Dev.		F-ratio Variances	P Variances
	SDS	DDS				SDS	DDS	SDS	DDS		
Travel unloaded landing site [km/h]	**4.677598**	**4.149093**	**2.161766**	**177**	**0.031979**	77	**102**	**2.055564**	**1.190139**	**2.983094**	**0.000000**
Travel unloaded skid road [km/h]	3.796094	3.899731	-0.937696	196	0.349555	99	99	0.676105	0.867297	1.645534	0.014425
Travel loaded skid road [km/h]	**2.359133**	**2.673224**	**-3.29105**	**194**	**0.001186**	**99**	**97**	**0.615309**	**0.717869**	**1.361145**	**0.130315**
Travel loaded landing site [km/h]	**3.136228**	**2.482093**	**4.327235**	**196**	**0.000024**	**96**	**102**	**1.175278**	**0.945439**	**1.545305**	**0.031861**
Skid road loaded travel winching [min]	1.283402	1.294369	-0.049416	198	0.960637	97	103	1.348934	1.750278	1.683575	0.010443
Positioning [min]	0.610928	0.676214	-0.701027	198	0.484109	97	103	0.721068	0.593022	1.478468	0.052483
Choking [min]	**2.569175**	**1.685437**	**5.402827**	**198**	**0.000000**	**97**	**103**	**1.374642**	**0.903320**	**2.315771**	**0.000037**
Load manoeuvring [min]	**0.341753**	**0.580971**	**-2.90346**	**198**	**0.004109**	**97**	**103**	**0.238026**	**0.777779**	**10.67737**	**0.000000**
Felling site mounting [min]	**0.00**	**0.106602**	**-6.49401**	**198**	**0.000000**	**97**	**103**	**0.00**	**0.161649**	**0.00**	**1.000000**
Unchoking [min]	**0.731546**	**0.636796**	**2.065880**	**198**	**0.040142**	**97**	**103**	**0.391669**	**0.244136**	**2.573805**	**0.000004**
Bunching [min]	**3.311649**	**2.410777**	**2.025791**	**198**	**0.044128**	**97**	**103**	**3.061241**	**3.218243**	**1.105204**	**0.621467**
Skidder turning [min]	0.497113	0.474563	0.389192	198	0.697552	97	103	0.506347	0.290253	3.043296	0.000000
Landing site mounting [min]	**0.068557**	**0.117184**	**-2.14816**	**198**	**0.032915**	**97**	**103**	**0.143120**	**0.174392**	**1.484749**	**0.051383**

Table 2: Effective time consumptions per work element groups, allowance time, cycle time and standard time vs. average skidding distance

Skidder	Average skidding distance	Travel time – skid road		Travel time – landing		Felling site work time	Landing work time	Effective time	Allowance time 34.45%	Cycle Time	Standard time
		Unloaded	Loaded	Loaded	Unloaded						
	m	min									min/m^3
SDS	100	2.36	5.81	0.77	0.51	6.22	4.60	20.26	6.98	27.24	4.64
	200	3.60	7.54	0.77	0.51	6.22	4.60	23.23	8.00	31.23	5.32
	300	4.84	9.27	0.77	0.51	6.22	4.60	26.20	9.02	35.22	6.00
	400	6.07	11.00	0.77	0.51	6.22	4.60	29.17	10.05	39.22	6.68
	500	7.31	12.73	0.77	0.51	6.22	4.60	32.14	11.07	43.21	7.37
	600	8.55	14.46	0.77	0.51	6.22	4.60	35.10	12.09	47.20	8.05
	700	9.78	16.19	0.77	0.51	6.22	4.60	38.07	13.11	51.19	8.73
	800	11.02	17.93	0.77	0.51	6.22	4.60	41.04	14.14	55.18	9.41
DDS	100	2.36	5.48	0.97	0.58	4.97	3.65	18.01	6.20	24.22	4.13
	200	3.60	6.98	0.97	0.58	4.97	3.65	20.75	7.15	27.89	4.75
	300	4.84	8.48	0.97	0.58	4.97	3.65	23.48	8.09	31.57	5.38
	400	6.07	9.97	0.97	0.58	4.97	3.65	26.21	9.03	35.24	6.01
	500	7.31	11.47	0.97	0.58	4.97	3.65	28.95	9.97	38.92	6.63
	600	8.55	12.97	0.97	0.58	4.97	3.65	31.68	10.91	42.60	7.26
	700	9.78	14.46	0.97	0.58	4.97	3.65	34.42	11.85	46.27	7.89
	800	11.02	15.96	0.97	0.58	4.97	3.65	37.15	12.80	49.95	8.51

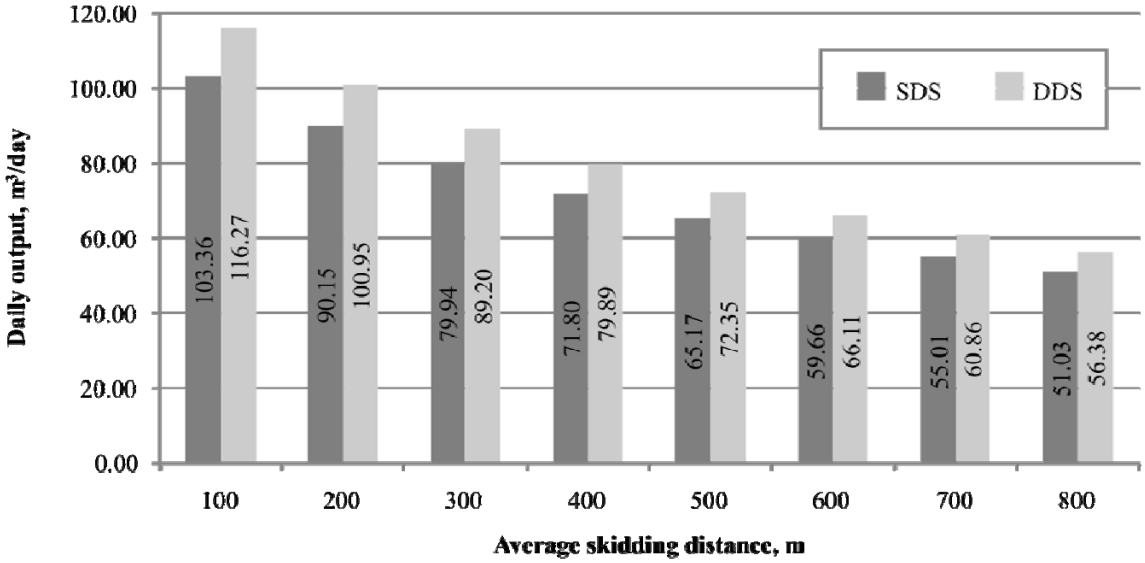

Figure 9: Daily output vs. average skidding distance

4 Discussion

Differences in single-drum winch skidder's productivity and double-drum winch skidder's productivity lie in a lower time consumption for work at the felling site and work at the landing of the double-drum winch skidder and in higher skid trail loaded travel speed of the double-drum winch skidder. Lover time consumption for the work at the felling site is a consequence of lover time consumption for line pulling, choking and winching, while the lover time consumption for the work at the landing is a consequence of lover time consumption for unchoking and bunching. Differences in speeds, if impact of human factor is disregarded, may lie in the characteristics of the load and condition of the skid roads, which was not further investigated. As differences in the load volume between the two investigated skidders were not statistically significant, their impact on the projected productivity isn't visible. Otherwise, the difference between productivity would be even higher in favour of the skidder with a double-drum winch.

Zečić et al. (2004) investigated the productivity of skidder Timberjack 240C equipped with a double-drum winch in conditions of regeneration cut. They determined that it achieved outputs from 100.54 m^3/day at skidding distance of 100 m to 57.75 m^3/day at skidding distance of 700 m. The impact of selection felling stand factors to the productivity of the same skidder was researched by Sabo and Poršinsky (2005). The productivity determined in this research ranged from 16.9 m^3/h at a skidding distance of 50 m to 9.9 m^3/h at a skidding distance of 400 m, with a lower share of allowance time (20.5%). For the same skidder Zečić et al. (2010) investigated the influence of skid trail slope in selective cut to the average load volume and productivity. They determined the cycle time from 26.82 min at a skidding distance of 100 m to 57.62 min at a skidding distance of 800 m. In tree-length skidding in the felling site of Euro-American poplar the same skidder achieved an average load of 8.63 m^3, resulting in a projected daily output from 129.52 m^3/day at a skidding distance of 100 m to 84.01 m^3/day at a skidding distance of 800 m (Zečić et al., 2011).

In selective forests of Croatia we are generally compelled to use skidders for the primary transport of wood, because of the stand and extraction factors. Based on this study and review of previous research conducted in the Croatian forests it can be concluded that the investigated skidder, in both winch versions, is a highly productive means of work which due to its size and construction, with obligatory professional planning and supervision of work, can effectively perform the tasks of wood hauling in our conditions.

When procuring new skidding machines, the key role in the selection of single or double-drum variant will be, beside the difference in productivity, the difference in the purchase price and the expected lifetime in which the more expensive (double-drum) version can on a long-term be the more profitable one.

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