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EVALUATION OF WINCH PERFORMANCE IN ROUND WOOD HARVESTING

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Abstract: *The time consumed in winching operations, as well as the resulted productivities are related to many process variables including those referring to the used equipments. Following a time study done on 159 winching replications for a farm tractor equipped with a Schlang & Reicart winch, in a fir-beech mixed stand where selective cuttings were applied, there has been found that only the winching distance proved to be a significant independent variable for modelling purposes. For a mean log volume of 2,284 m^3 and a mean winching distance of 23,02 m, the time study yielded a net production rate of 92.43 m^3h^{-1}. Considered on individual work elements, the mechanical winching was responsible for the greatest share of time consumption in a winching work cycle. The results reported by this paper may be useful for time consumption and productivity estimation under similar work conditions.*

Key words: *winching, farm tractor, time, equations, productivity.*

1. Introduction

Timber harvesting activity is done in order to extract from the forested areas the required wood for different processing industries as well as for the end user consumers [15]. Being a highly technical activity, timber harvesting includes a significant concentration of labor force, machines and capital [15].

In Romania, the most used timber harvesting equipments are the skidders, which, along with the farm tractors adapted for forest operations, represent more than 95% of the used machines in skidding operations [18].

In general, timber skidding presupposes three groups of operations: winching, on-trail skidding and landing operations [15] [17], [22]. Depending on the specific work conditions, winching may take more or less time within the overall skidding operations [14], [17], [19], [22], [23]. The mentioned work conditions refer, mainly, to the harvesting process variables [1], [22] such as operating distances, slope, direction, as well as to the technical characteristics of the used equipments. The presence of many process variables, which come in a great number of combinations, as well as the rate at which the technological progress advances, represent the main reasons for which work measurement studies are required. Therefore, the work measurement studies are done in order to observe the behavior

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of new equipment in certain given conditions or to assess the behavior of the same equipment in new, unstudied conditions [20]. In Romania for instance, experimental or observational studies targeting the modeling of inputs, outputs and process related variables in timber harvesting are quite scattered, being concretized in some studies such as those developed and reported by Duță and Borz, [13] Borz and Ciobanu [6] or the older normative dealing with forest operations time and production rates [23]. But, the use of rates developed for old-concept timber harvesting equipments [23] cannot provide in the future the required elements for a sustainable development of the timber harvesting activity, which presupposes, amongst others, the determination of costs and productivities [3], [9], organization and optimization [4], [5], [12], [16] as well as implementations in computer programming applications [7], [10], especially since new state-of-the art harvesting technologies were introduced on the Romanian market [11].

Being an important part of the skidding operations, winching has been addressed by several authors, whose studies involved different types of machines. When dealing with separate models for winching, some of the studies [2], [14], [22] found out that the most significant independent variable explaining the time consumption was the winching distance. However, other studies revealed also that the number of winched logs represents a significant independent variable when trying to express the time consumption involved by winching operations [14], [19]. The process variables come almost in endless combinations when one tries to realize an observational study [1], while emphasizing the effect of some of them is, sometimes, impossible. This study tries to test if supplementary process variables may be considered in expressing the time consumption in winching operations, for a winch type which, has not been studied until now, and which was mounted on a Romanian farm tractor. The study assumed that the time consumed during cable releasing is affected by the winching distance and winching slope whereas the time consumed during mechanical winching is affected by winching distance, winching slope, length of the logs and volume of each winched log. For an overall winching repetition, it was assumed that the time consumption is a function of all the mentioned independent variables, under circumstances of a significance threshold which has been chosen in advance for all the studied independent variables.

According to the mentioned assumptions, the study objectives were to: (i) test the formulated hypotheses using statistical procedures, (ii) elaborate time consumption models for different work elements and for the overall winching operation, (iii) extract the descriptive statistics regarding the share of different time consumption categories within the overall time consumption, and (iv) calculate a mean productivity of winching operations for the studied conditions.

2. Material and Methods

2.1. Study Site

This study has been done in three phases, involving a preliminary office phase, a field phase and a final office phase. The field study was conducted in compartment no. 9 belonging to the Management Unit no. 10 which is administrated by Braşov Forest District. The mentioned forest compartment is located near the town of Predeal. In November 2012, this forest compartment was scheduled for harvesting and it was operated with selective cuttings. Harvesting operations were done by means of a chainsaw and a farm tractor equipped for forest operations. Operational equipment of the tractor included a double-drum Schlang&Reicart winch. As a harvesting method, a combination between tree-length (TL) and cut-to-length (CTL) was used during field observations, depending on the volume of each harvested tree. During the field study, a total volume of 368.18 m^3 was harvested, representing about 44% of the volume to be harvested. Also, only fir trees were harvested during the field phase of the study. Additional descriptive statistics of the forest compartment taken into study are provided in Table 1.

Table 1

Descriptive statistics of studied forest compartment

Specification	Value
Mean terrain inclination [%]	29
Area [ha]	16.0
Mean age [years]	145
Volume to be harvested [m^3]	824
Fir	774
Beech	50
Harvesting intensity [$m^3 ha^{-1}$]	51.5
Harvesting intensity [trees ha^{-1}]	11.19
Mean volume of the tree to be harvested [$m^3 tree^{-1}$]	4.60
Fir	4.78
Beech	2.94

2.2. Equipment Description and Work Organization

Skidding operations were performed by a farm tractor – UTB 703 DTC (made 2002) – equipped with a diesel engine (4700 cc) which develops 81 HP and a double drum, (2 x 11 tons) Schlang & Reicart winch which was used for winching operations. The drum capacity was of 70 meters of cable in conditions in which the cable diameter was of 14 mm. Work organization included tree felling and processing (delimbing and crosscutting), skidding and landing operations. Tree felling was performed by a single worker by the means of a chainsaw, whereas skidding operations involved a two-man crew. The tractor driver was responsible only for mechanical winching, whereas the other worker dealt with cable releasing and pulling as well as with manual hooking of the logs. On-trail skidding was performed only by the worker who was responsible for the mechanized phases of the skidding. Landing operations included log piling, which was done by using the same tractor.

2.3. Field Measurements

Due to the fact that this study was rather an observational one, no pilot studies were conducted in order to calculate the required statistics for establishing the needed number of statistical repetitions. However, a number of 159 repetitions were recorded in the field. Due to specific tree distribution within the felling area, only fir trees were harvested and skidded during the field observations.

A winching work element (E_{WW}) was divided in the following subsequent work elements: maneuvering and parking (e_{mp}), cable releasing and pulling (e_{crp}), log hooking (e_{lh}) and mechanical winching (e_{mw}).

Only time consumption and volume of the logs were measured as inputs in the process. The delay-free elemental time consumptions were those corresponding to the identified work elements: time for maneuvering and parking (t_{mp}), time for cable releasing and pulling (t_{crp}), time for log hooking (t_{lh}) and time for mechanical winching (t_{mw}). A complete delay-free time consumption for a winching repetition (T_W) was considered to be the sum of the above mentioned elemental time consumptions.

Time consumption was measured using the continuous timing method; time consumption for each individual work element was computed through the difference during the office phase of the study. As process variables, the following were measured or calculated for each winching repetition: winching distance (W_{Dis}), winching slope (W_{Sl}), winching direction (W_{Dir}), log length (L_{Len}) and log volume (L_{Vol}). Winching distance was measured using a logger's tape at one meter accuracy, the winching slope was measured using an inclinometer at 5% accuracy, the winching direction (uphill/downhill) was visually assessed whereas the log length was measured using another logger's tape. Volume of each log was computed in the office based on the diameters measured at the ends of the logs and the log lengths (or diameters measured on intermediary lengths of the logs, depending on the log length). For this purpose, there were used the traditional calculus relations.

2.4. Data Processing and Analysis

All the recorded data was transferred into MS Excel worksheets. Statistical procedures for data analysis were done using the methodology described by Acuna et al. [1]. Thus, a sequence of steps aiming at the calculation of descriptive statistics, checking for outliers, testing for normality and data modeling were performed. Data modeling was performed by means of backward stepwise regression technique [21]. Firstly, a maximal model was elaborated for the following work elements: cable releasing and pulling, mechanical winching and overall winching operation. This meant including all the possible variables based on logical assumptions. Modeling procedure included the significance analysis for each model ($p<0.001$) and each independent variable ($p<0.05$) at each performed step, followed by the step-by-step exclusion of those variables which presented no significance at the $p<0.05$ threshold.

Time consumption distribution on elements was calculated using the cumulated recorded times for each element as well as the total delay-free time. Therefore, shares for each work element were calculated as percents of the total delay-free time. The net production rate for the studied conditions was calculated as the ratio between the mean delay-free time and the mean realized production, and was applied to a repetition added to the winch.

Statistical analysis involved by this study was performed using the MS Excel and Statistica 8 Data Analysis Software [24].

3. Results and Discussion

3.1. Descriptive Statistics of Operational Variables and Time Consumption Inputs in Process

Specific operational variables (Table 1) were those which contributed to different time consumptions on work elements (Table 2). Similar to other studies, like that of Behjou [2], mechanical winching accounted for the greatest share within a delay-free winching repetition (Table 2), but, by comparison, it took more time in this study which could be correlated with different operational conditions of this study. However, some other studies reported that this work element accounted for the greatest share of time consumption in winching operation [14]. In a study done on a Clark Ranger skidder, Behjou [2] found out that, on average, the time consumed for cable releasing and pulling was about 29 seconds. In this study, the time consumed for that work element was, on average, of about 35 seconds which could be explained by a greater mean winching distance in this study. The time consumed for tractor maneuvering and parking (establishing) was about the same as that reported by Behjou [2]. By comparison, log hooking (Table 2) took more time in this study because it was applied to considerably greater diameters of the logs when compared with the time reported by a similar study [2]. Also, the time consumption for a winching repetition was considerable greater (about 1.35 times greater) in this study compared with the similar studies [2] done for a Clark Ranger skidder. The mean winching distance in this study was about 23 m (Table 1) while in the study done by Behjou [2], it was of about 17 m.

3.2. Time Consumption Models and Winching Productivity

Following the application of backward stepwise regression procedures, three time consumption models were set up for cable releasing and pulling work element, mechanical winching work element and for an overall winching repetition. The final models, as resulted from regression analysis, are presented in Table 4.

Not all the assumptions made at the very beginning of the paper proved to be true after the statistical analysis. For instance, cable releasing and pulling time (t_{crp}) variation was best explained by the winching distance (W_{Dis}), which was true also in the case of mechanical winching and the overall winching operation. Therefore, log length (L_{Len}), log volume (L_{Vol}) and winching slope (W_{Sl}) failed to prove themselves as being relevant process variables in explaining the time consumption.

Winching direction (W_{Dir}) was included in the maximal models for each work element as a nominal scale variable, but it failed to be significant in explaining the variation of the consumed time. Therefore it was excluded during the regression analysis.

If compared with other studies, the obtained models indicate the fact that only the winching distance could be considered as a relevant independent process variable in explaining the time consumed in different work elements as well as for an overall winching repetition.

Descriptive statistics of the operational variables Table 2

Variable	Descriptive statistics			
	Minimum	**Maximum**	**Mean**	**Standard deviation**
L_{Len} [m]	4.20	23.00	12.41	±2.430
L_{Vol} [m^3]	0.231	7.869	2.284	±1.291
W_{Dis} [m]	5.00	50.00	23.02	±11.200
W_{Sl} [%]	5.00	30.00	19.62	±4.550

Descriptive statistics of the time consumption inputs Table 3

Variable	Descriptive statistics			
	Minimum	**Maximum**	**Mean**	**Standard deviation**
t_{mp} [s]	0.00	164.00	12.41	±28.390
t_{crp} [s]	8.00	180.00	34.79	±25.250
t_{lh} [s]	5.00	36.00	23.02	±4.800
t_{mw} [s]	6.00	320.00	41.12	±36.830
T_{MW} [s]	28.00	600.00	111.34	±72.68

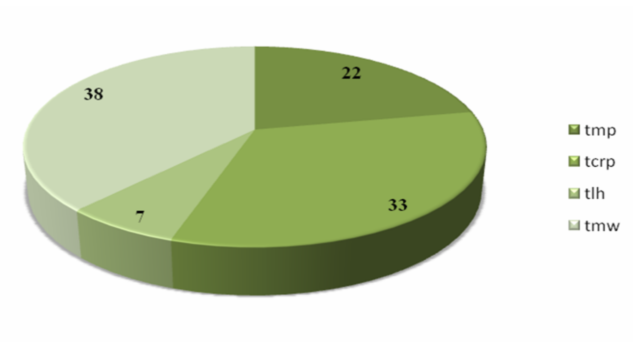

Fig. 1. *Delay-free time consumption distribution on work elements*

However, it should be pointed out that this study had an observational character, and different work conditions may generate completely different results.

Table 4

Time estimation models for the main work elements of winching operation

Time element	Model parameters			
	R^2	Sig.	Coef.	Descriptor
t_{crp} [s]	0.620	< 0.001	-6.08	Intercept
			1.78	W_{Dis}
t_{mw} [s]	0.501	< 0.001	-12.45	Intercept
			2.33	W_{Dis}
T_W [s]	0.416	< 0.001	10.77	Intercept
			4.18	W_{Dis}

A mean volume per winched log of 2.284 m^3 (Table 2), as well as a mean delay-free winching time of 111.4 seconds (Table 3), yielded for this study conditions (Table 2) a mean net production rate of 92.43 m^3h^{-1}. However, this applies only for winching operations, being considerable greater than that provisioned by the currently used normative for the same conditions [23]. If compared with the results provided by other studies [2], by transforming the needed data, a winching repetition was almost as productive as a winching repetition in this study (in this study the production rate was about 1.05 times greater). This could be explained mostly as an effect of a more reduced mean slope in this study, as well as a greater volume per a winched log (Table 2). Maybe one supplementary reason which generated this situation was the operational speed for those work elements involving cable movement, because the cable releasing and pulling as well as mechanical winching speeds were considerably high in this study (1.51 ms^{-1} respectively 1.79 ms^{-1}).

4. Conclusions

Despite the fact that the time consumption for winching operations may be calculated only by using the winching distance, as demonstrated by this study, this aspect should be used very carefully, and only in the conditions provided as operational variables by this study (minimum and maximum values). The main differences in what concerns the results of this study if compared with those provided by other studies are those related to the relevance of different independent variables such as winching slope, winching direction, volume of the log and the log length. Most of them may be significant or not, depending also on other workplace variables which are more difficult to measure, in conjunction with the number of repetitions taken into study [21]. The results of this study should not be regarded as final, but as the results of an observational study, which could be improved or extended, depending on the amount of field recorded data as well as by the variation of operational variables. However, in the absence of studies done for the same conditions and the same used forest equipment, the results of this study may be helpful in organizing the harvesting activity, as well as for elaborate experimental designs for other studies for the same equipment and conditions.

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