



## Technical analysis of extraction operation performed by a forwarder with traction aid winch in an *Eucalyptus* spp. plantation

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**ABSTRACT:** The progress of mechanization in forest harvesting is one of the factors that contributed to boost the competitiveness indices of the economic activity of forest production in Brazil. However, the use of mechanized harvesting systems in areas with steep slopes is still a technological challenge to forest companies, in particular in extraction operations. This study aimed to evaluate technically the forest extraction in mountainous terrains using a Forwarder with traction aid winch (TAW). Data were collected from an unprecedented operational test, performed in areas of *Eucalyptus* spp. in São Paulo state, Brazil. The various productivities of the Forwarder were evaluated in different extraction distances (ED), slopes, and with the use or not of the TAW. The results show that the Forwarder was efficient, and performed the extraction within acceptable limits of productivity. However, using the TAW on an increased slope led to a decrease in its productivity. It was concluded that the use of TAW and the increase in the slope decrease the productivity of the Forwarder, due to the fact that it takes more time to carry out the operational cycle elements on slopes above 25.1° where the loading was the operational cycle element that spent more time on any slope.

**Keywords:** forest harvesting, slope, extraction distance, productivity.

Enálise técnica da operação de extração realizada por um *forwarder*  
com guincho de tração auxiliar em um povoamento de *Eucalyptus* spp.

**RESUMO:** O progresso da mecanização na colheita florestal é um dos fatores que contribuíram para alavancar os índices de competitividade da atividade econômica da produção florestal no Brasil. Entretanto o uso de sistemas de colheita mecanizados em áreas de declividade acentuada ainda é um desafio para o empreendimento florestal, em específico nas operações de extração florestal. Este trabalho objetivou avaliar tecnicamente a extração florestal em terreno montanhoso com o uso do *forwarder* com Guincho de Tração Auxiliar (GTA). Os dados foram coletados em um teste inédito realizado em áreas de povoamento de *Eucalyptus* spp. no Estado de São Paulo, Brasil. Diferentes produtividades do *forwarder* foram avaliadas em tratamentos com diferentes distâncias de extração, declividades e com o uso ou não do GTA. Os resultados mostraram que o *forwarder* foi eficiente apresentando um desempenho aceitável dentro dos limites de produtividade. Foi concluído que o uso do GTA e o aumento da declividade diminuem a produtividade do *forwarder* pelo fato de que demora-se mais para realizar os elementos do ciclo operacional em declividades acima de 25,1°, sendo o carregamento o elemento que mais gastou tempo nos tratamentos.

**Palavras-chave:** colheita florestal, declividade, distância de extração, produtividade.

### 1. INTRODUCTION

The timber harvesting consists on the cutting and extraction operations. In the cut-to-length system, the felling, delimiting, bucking, and stacking are performed in the stands before the extraction; while in the full-tree system only felling occurs in stands and usually the delimiting, bucking and stacking are performed on the forest road. In a summary, Uusitalo

(2010) identifies the following extraction systems: drag or manual loading, animal drag, drag with crawled bulldozer, mechanized with skidder, forwarder, tractor with a dragger winch, aerial cables, and helicopters. The high diversity of extraction methods shows the importance of this operation in the harvesting chain because in some cases: topography, soil characteristics, extraction distances and other factors can turn some methods impractical. The full mechanization of extraction

in steep terrains occurs normally with the use of TAW, which give possibility to the machine work until 37° of steep. The performance of extraction operations are very influenced by the topography, distance of extraction, operator's experience, log dimensions, load machinery capacity and soil properties (LOPES et al., 2016a; CARMO et al., 2015; LEITE et al., 2014; OLIVEIRA et al., 2009). Parallel to the influence variables in extraction operations, the use or not of TAW is important to understand the influence of their use on the operations in steep terrains.

In Brazil, there are extraction methods such as extraction by animals, manual, mechanized with a dragger winch, and by aerial cables. The last three methods are frequently used in steep terrains extractions. In general, the timber extraction methods used in Brazil can cause considerable environmental damages and have high operating costs due to a lower performance, therefore they need to be reviewed before being put into operation. (FIEDLER, 2012).

Bantel (2010), while studying the timber extraction types in mountainous terrain, presented six different types: (1) manual extraction; (2) with the aid of animals; (3) mechanized with skidders in slope levels from 17° to 22°; (4) using winches attached to tractors and winched agricultural tractor; (5) besides the yarder; and (6) the use of helicopters and balloons that can perform extractions in terrains up to 45° slope.

The extraction in slopes areas above 25° have been a technical and operational challenge to the engineering sector of forest companies (STUDIER; BINKLEY, 1974). Many technologies have been developed in order to perform those operations safely, meet the ergonomic requirements, and adequate the costs to the competitiveness of the market, oriented to the raw material production to supply the forest-based industries.

According to Leite et al. (2012), the use of a crane can be an alternative to the timber extraction on lands with unfavorable and rugged topography, in wood movement facilitation, reducing the soil impacts, and in enabling the lifting of wood until the roadside.

Uusitalo (2010), who indicates that the shovel logging ensures that the machinery will work in clearcuttings, presents another use of machinery on steep terrains and they may work together with chainsaws and Feller Bunchers. A c a r ; Unver (2013) presented a study with the guttering system used in Turkey to timber extraction with an average slope of 17°, and average extraction distances of 140 meters, where productivities of 70 m<sup>3</sup> h<sup>-1</sup> and 43 m<sup>3</sup> h<sup>-1</sup> were observed.

The utilization of harvesting methods where a large number of workers are required within the stand has been questioned. Fiedler et al. (2012) indicated that besides it needs a large amount of workforce, the displacement of workers in hilly areas, the high physical stress in the activity, the danger of accidents, and the low thermal comfort index, result in problems such as physical and metabolic overload of workers.

The fact of being faced as the only alternatives for extraction in steep terrains does not eliminate, in the use of dragger winches and aerial cables, the labor utilization when lashing the logs on the cables. It can be very disadvantageous from the viewpoint of work safety engineering and ergonomics, with the risk of accidents and injuries by high physical exertion.

Another key factor that often disadvantages the dragger winches and aerial cables use is linked to the fact that trees often arrive wrecked, when yarded to the roadside or to the stand

edge. It happens due to the contact of the logs with felled trees stumps and other obstacles (rocks, holes, etc.) located in the dragging line, thereby reducing the utilization and decreasing the logs quality.

In order to classify a site about its terrain and slope range, it is necessary to group them by intervals, according to Embrapa (1999) methodology, in which it proposes a classification for slope analysis (Table 1).

As a technological advancement in the use of cutting and extraction machinery on steep terrains, like the harvester and the forwarder, it is possible to mention the coupling of the auxiliary traction system with a winch, which takes the TAW acronym (auxiliary traction winch). The first machine using an TAW was developed in Switzerland, by Herzog Forsttechnik, in 2008 (WEGMANN, 2009). The system filled a gap in the forest mechanization on steep areas, enabling the extraction with forwarder, causing minimal damage to the soil, in areas where the use of other systems would result in higher costs (THEES et al., 2011).

According to Biernath (2012), currently almost all machinery manufacturers offer the TAW, and it can be coupled to harvester and forwarder.

In a study about the combination of a 911 X3M harvester and a forwarder with TAW, the Thuringian Ministry for Agriculture, Forestry, Environment and Nature Conservation (2011) indicates to a better performance, that this system should operate in conditions of natural forest, with trees with average diameter at breast height (DBH) around 25 cm, and slopes from 19.2° to 26.5°.

The purpose of this study was to evaluate technically the forest extraction in mountainous terrains using a Forwarder 860.4 with TAW in areas with *Eucalyptus* spp. plantations, in mountainous and craggy terrain in Southeastern Brazil, contributing to decision makers in extraction planning with the use or not of the winch

Table 1. Slope limits for land evaluation.

Tabela 1. Limites de inclinação para avaliação da terra.

Terrain	Slope classes	
	Slope range (%)	Slope (degrees)
Flat / Nearly level	0 to 3	0 to 1.7
Gently sloping	3 to 8	1.7 to 4.6
Moderately sloping	8 to 20	4.6 to 11.3
Strongly sloping	20 to 45	11.3 to 24.2
Mountainous/ Steep	45 to 75	24.2 to 36.9
Craggy / Very steep	Above 75	Above 36.9

Source: Adapted from EMBRAPA (1999)

## 2. MATERIAL AND METHODS

### 2.1. Study area

The Study was carried out in an area of a forest company located in São Paulo State with hybrid clone of *Eucalyptus grandis* Hill ex-Maiden and *Eucalyptus urophylla* ST Blake forests of first cut. The study area was located at 22° 59' 21.66" S and 45° 06' 32.06" W, at an average altitude of 640 meters above sea level. The weather type of the region is humid subtropical climate (Köppen) with a mean temperature in the hottest month of 19.9 °C and an average annual rainfall of 1350 mm. The predominant soil type of the region is Cambisol Haplic Tb Typical distrophic, A moderate with clayey texture

with stoniness due to remnant quartz in the soil, albeit randomly and discontinuously distributed in a surface with less presence of stones with topography varying from flat to mountainous (Embrapa 1999). Accordingly, the plantations were located on slopes between 7° to 38°. The Eucalyptus stands were homogenous originating from seed, with seven years and 6 months old and 3 x 2 m tree spacing. The plantation was harvested under clear-cut operation and the harvested trees had a mean volume of 0.14 m<sup>3</sup>, being processed to logs of 6.0 m debarked for paper production.

## 2.2. Forwarder

The Forwarder assessed in this study was manufactured by Komatsu Forest, 860.4 model with 8x8 traction, coupled with aid traction winch system and total weight of 16 t. The machine had 529 hours of use when it started operating in the area. The wheelset system was tires, implemented with semi-tracks, 8x8 traction, and 74 AWI diesel engine of 197 hp. According to data provided by the company, the volumetric loading capacity of the machine was of 15 m<sup>3</sup> or 14t (KOMATSU, 2017). The technical specifications of the machine recommend a maximum load capacity of 14 t. The extent of the crane is of 7.8 m. The machine had a cargo box with variable area, from 3.30 m<sup>2</sup> to 4.50 m<sup>2</sup>, and claw of 0.28 m<sup>2</sup>. To replace the cable winch extraction area demand established by the company, the forwarder operated on slope terrains about 27° to 37°. The system of control and information of the machine was the MaxiForwarder.

The winch had a traction force of 72 kN and approximate weight of 880 kg, with a steel cable of 14 mm diameter, 400 m in length. It can be operated up to a maximum speed of 3.5 km h<sup>-1</sup>. The traction winch, as shown in the Figure 1a, is manufactured by Ritter, under the SPW 246 model, consisting of a synchronized transmission to the machine transmission, which is used in situations where the mobility with the traction of the machine itself is not possible. The aid winch is exclusively used as aid traction of the machine in very steep terrains, low adherence conditions or low soil resistance to traction. The work method for forwarding is to establish a well-rooted anchor tree or stump at the border of the forest road where logging is being done. The winch cable is attached to the anchor tree or stump with a webbed sling. The forwarder then moves down the slope to an appointed load area, and begins loading, backing up the hill with the winch providing pull to stabilize the forwarder (Figure 1b).

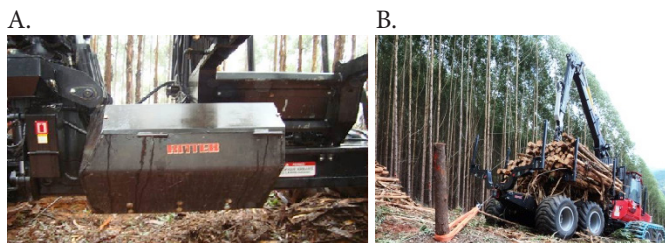


Figure 1. Traction aid winch Ritter spw 246 (1a), tied on an anchor stump (1b).

Figura 1. Treinador de ajuda de tração Ritter spw 246 (1a), amarrado em um coto de âncora (1b).

## 2.3. Time and motion study

The method of continuous time determined by Barnes (1977), which the time counting is continuous, without pausing the chronometer, was used for the time and motion study for the

Forwarder. This method was used due to the longer duration of the machine movements and its operational cycle characteristics. The elements that compose the operational cycle for the Forwarder are:

- (1) Empty displacement: displacement of the machine with empty cargo box.
- (2) Loading: the movement of the crane to remove the wood pile, the action of carrying the cargo box, and ending with the machine moving.
- (3) Displacement between bundles: displacement between bundles of piles for loading until the positioning for a new loading, ending with the start of the crane movement.
- (4) Full displacement: displacement of the machine with full load, towards the yard's edge.
- (5) Adjustment of wood piles: building of a support with use of residues, in order to prevent the logs from rolling downhill.
- (6) Unloading: after positioning and complete stoppage of the machine in the yard, the start of the movement of the crane, removing the logs from the cargo box, until the complete emptying of the cargo box.
- (7) Cable attachment: stopping time, releasing, installing and attachment of the winch on the anchor stump, ending with the return of the displacement of the machine (when necessary the winch use).
- (8) Cable removal: stopping action, releasing, uninstalling and roll it back up and back to the movement of the machine (when the winch was used).
- (9) Displacement between plantation lines for harvesting: the displacement of the machine towards its next plantation line of extraction, after the pre-accomplished loading, ending with the displacement of the machine for loading in the next plantation line for harvesting.
- (10) Interruptions: diverse operational factors or not, such as stop for food, hydration, corrective maintenance, preventive maintenance, machine fueling, rain, personal needs, among others.

Every trip was characterized as a cycle, estimating the production for each cycle based on the maximum volume carried by the Forwarder. The data were gauged along with the Production Form filled up daily by the Forwarder operator. The assessment of the yarded wood per day, done by the supervisors of the harvesting, was based on measurements of piled wood in the yards along the roadside, where the Forwarder used to operate.

In order to obtain a minimum number of observations with a desired confidence level, it was collected the "n" with 26 observations with an acceptable sampling error from 5 to 95 % probability of confidence. It was used the equation described by several authors (FIEDLER et al., 2008; OLIVEIRA JR. et al., 2009; SIMÕES et al, 2010a; SIMÕES et al., 2010b; SIMÕES et al., 2014).

## 2.4. Operation performance: productivity and efficiency

The productivity represented the timber volume in cubic meters yarded from the stand until the yard or the roadside per hour of effective work (m<sup>3</sup> PMH<sub>0</sub><sup>-1</sup>). The data of the harvesting supervisors should be identical to those presented by the Forwarder operator, in order to use the maximum loading value, which ranged from 12 m<sup>3</sup> to 15 m<sup>3</sup>. Values referring to 12 m<sup>3</sup> were used in slopes above 32°, representing 80 % of the maximum load yarded by the Forwarder, which corresponded



to 15 m<sup>3</sup>. These values were defined based on estimates made by the company based on the data of individual average volume from forest inventory and measurement of piles. The test was always performed using extreme situation, i.e., using the maximum load to be carried. The Equation 1 below was used to calculate productivity.

$$Pr = \frac{mlv}{Et} \quad (1)$$

where: Pr - production of the Forwarder (m<sup>3</sup> PMH<sub>0</sub><sup>-1</sup>); mlv - Maximum load volume, in m<sup>3</sup>, with 15 m<sup>3</sup> for slopes up to 32°, and 12 m<sup>3</sup> for slopes above 32°; and Et - Effective work time (productive machine hours).

It was calculated machine availability (MA) (Equation 2); machine utilization (MU) (Equation 3) and utilization Rate (UR) (Equation 4). The equations used to calculate these parameters are shown under:

$$MA = \frac{SMH - MT}{SMH} \times 100 \quad (2)$$

$$MU = \frac{(PMH - int)}{PMH} \times 100 \quad (3)$$

$$UR = MU \times MA \quad (4)$$

where: UR - utilization rate (%); MU - machine utilization (%); MA - mechanical availability (%); PMH - productive machine hours (hours); int - interruptions (hours); SMH - scheduled machine hours; and MT - maintenance time (hours).

## 2.5. Influence factors for forwarder operation

The factors of influence used by Lopes et al. (2016b) in the forwarding were the same that composed the treatments of this study: extraction distance, slope, and winch use. This factors were analyzed as discrete variables under five treatments: slope class, extraction distance class, and whether use or not of traction winch, as shown in Table 2.

## 2.6. Extraction distance average

The extraction distance (ED) class was estimated by the operator, who had extensive experience in working with machinery in forestry, and twelve years in the Forwarder operation. The same machine operator was used, and the extraction distance (ED) considered was the one covered by the Forwarder from the roadside to the point within the stand, where the cargo box began to be filled out, being stratified into

three levels: ED ≤ 100 m; 100 < ED ≤ 200 m; e ED > 200 m. For reasons of work safety determined by the company, it was not possible to measure the extraction distance by other methods. That is why it was used distance as a discrete variable in classes with intervals of 100 meters (Table 2).

## 2.7. Declivity

The study was conducted to assess the declivity influence and the individual and the combined influence of the extraction distance (Forwarder) on productivity and performance of the machine analyzed herein. For this, all other variables like work shift, soil type, forest, climate, location, and operator were considered homogenous.

## 2.8. Traction winch using

A peculiarity related to the Forwarder, however, had to be compared to the technical performance and working time: the use or the not use of the auxiliary traction winch. When the Forwarder had to perform extractions in places that required the anchoring of the cable along with an anchor tree on the edge of the stand, data related to these activities were collected and they were compared to situations that the same Forwarder did not have to use the winch.

## 2.9. Data analysis

The data were analyzed using the statistical program SPSS version 12.0 licensed for the University where the data were analyzed, where were generated graphics of boxplot type, in order to compare the different treatments used for the Forwarder on the dependent variables. The Bartlett's test was used to check the homogeneity of variances and the averages of productivity were compared by Tukey test at 5 % significance level. In addition were provided the P-values to infer about differences or not in the averages founded.

To evaluate the influence of the slope under the elements of the operational cycle performed by the Forwarder, it was carried out the calculation of the linear correlation matrix. This matrix correlation reports the magnitude and direction of the associations between the variables, with the values within the range of -1 until 1. As the correlation matrix is dimensionless, it cancels the effect of different scales, what facilitates the interpretation of results. The correlations between variables were obtained by following Equation 5:

$$r = \frac{C(X, Y)}{S_y \cdot S_x} \quad (5)$$

where: r - Pearson's linear correlation coefficient; C - covariance; and S - variance.

Table 2. Treatments used in the study with the forwarder and discrete variables regarding to slope class, extraction distance class, and winch use.

Tabela 2. Tratamentos utilizados no estudo com o encaminhador e variáveis discretas em relação à classe de inclinação, classe de distância de extração e uso de guincho.

Treatment	Nº of sampled plots	Slope	ED* (m)	Operation / winch use
1	4	0° to 25°	0 – 100	No winch
2	4	0° to 25°	100.1 – 200	No winch
3	5	0° to 25°	0 – 100	With winch
4	7	Steeper than 25.1 °	100.1 – 200	With winch
5	6	Steeper than 25.1°	Above 200.1	With winch

\* ED = Extraction distance

3. RESULTS

The various elements of the operational cycle performed by the Forwarder in the different treatments are presented in the Figure 2.

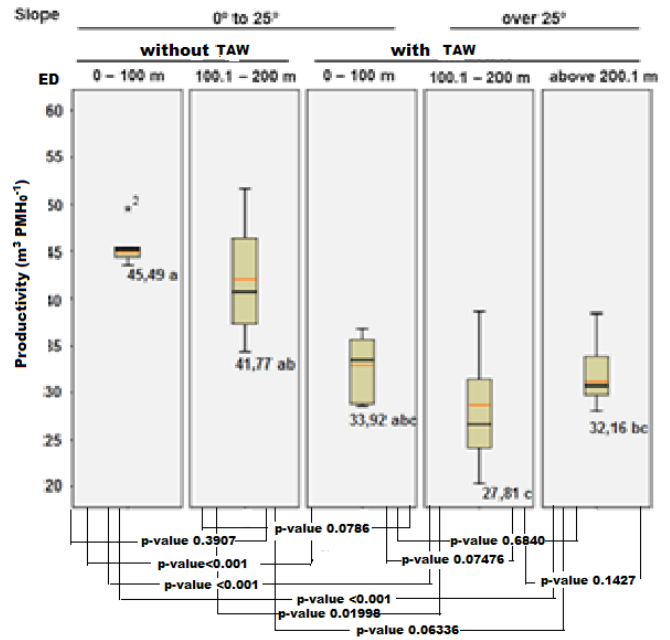
It is observed that in the different treatments for the Forwarder it was not noted a similar behavior in regard to the time spend for each operation analyzed. However the data shows that in cases where the use of the winch was necessary, the time spent in cable attachment and cable removing was responsible for the lower averages in productivity. Another important aspect is about the treatments with the use of winch and in slopes above 25.1°, where the operations of displacement with the machine loaded took the longest time to be performed. This is due to the fact that the winch must not be used as a support for the machine at the anchor tree, but as an auxiliary implement in the traction of the machine.

For all treatments, the loading was the operational cycle element that took longer, followed by the loaded displacement. The empty displacement and the unloading spent less time than the loading and loaded displacement, and they were the following elements of the operational cycle that took less time spent. In descending order, regarding the time spent to perform the operations, it is possible to determine the following sequence: loading, loaded displacement, empty displacement, and unloading.

3.1. Productivity

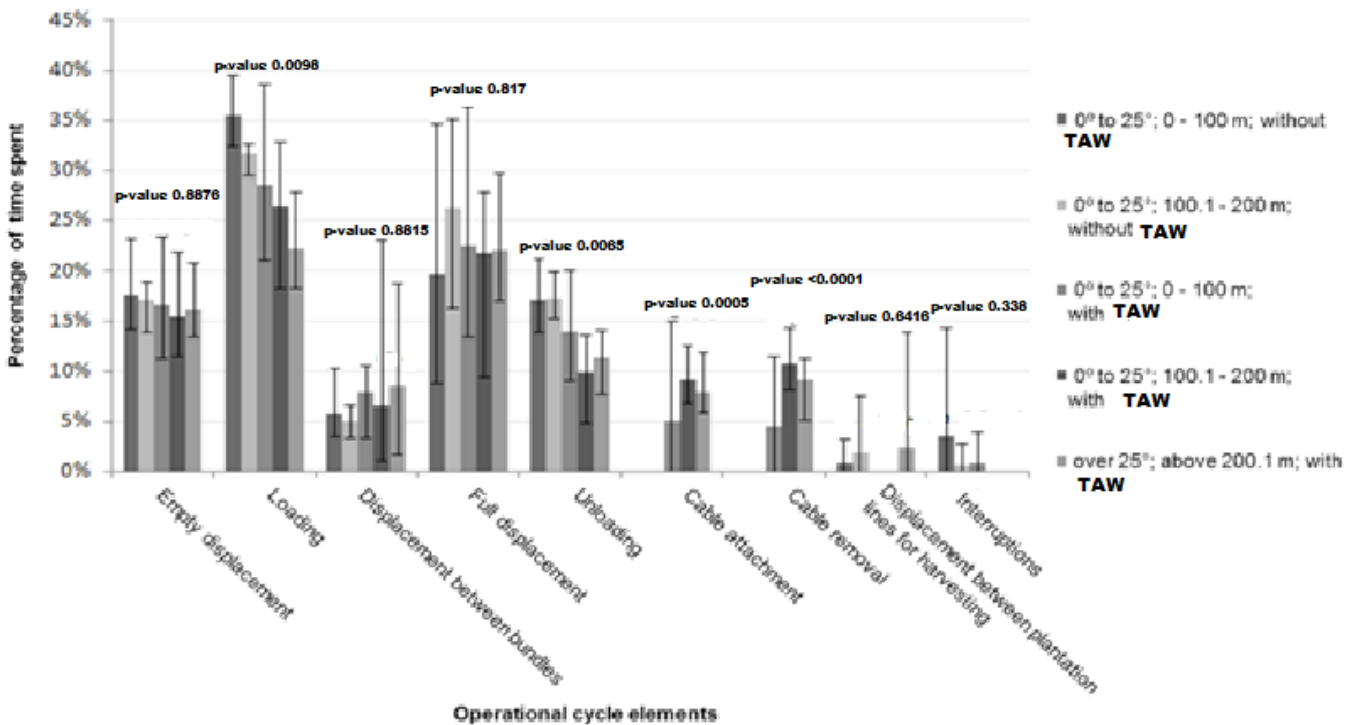
Figure 3 shows the average productivity, maximum and minimum values, results of first quartile, median and third quartile, among the five treatments studied on the assessment of the Forwarder.

The average productivity including all treatments was 36.02 m<sup>3</sup> PMH<sub>0</sub><sup>-1</sup>. The results shows that among the productivities



Note 1: averages followed by the same lower case letter do not differ significantly by the Tukey test at 5 % significance level.  
 Note 2: P-values under 0.05 infer to difference between the average productivity values.  
 Note 3: the orange marks represent the averages.  
 Figure 3. Productivity (m<sup>3</sup> PMH<sub>0</sub><sup>-1</sup>) and average productivity for the forwarder in different treatments.  
 Figura 3. Produtividade (m<sup>3</sup> PMH<sub>0</sub><sup>-1</sup>) e produtividade média para o encaminhador em diferentes tratamentos.

of treatment 3 with 5 and 1 with 2 are the values with more similarity, corresponding to 68.40% and 39.07%, respectively. In slope conditions from 0° to 25° without the use of winch, the Forwarder productivity decreases as the average distance of extraction increases. Bacher-Winterhalter (2004) concluded



Note: P-values under 0.05 infer to difference between the average percentage of time spent values  
 Figure 2. Distribution of time spent by the elements of the operational cycle of the forwarder in the five different treatments.  
 Figura 2. Distribuição do tempo gasto pelos elementos do ciclo operacional do encaminhador nos cinco tratamentos diferentes.

in his study performed in lands of slope from 0° to 22° that, although the extraction with Forwarder in selective thinning regimes in Germany have reached productivities from 17 to 27 m<sup>3</sup> PMH<sub>0</sub><sup>-1</sup>, these values were influenced by different factors and they had a high dispersion. Comparing treatments wherein into the distance of extraction varies, like in the treatments 4 and 5, where the slope class (above 25.1°) and the winch use remained constant, another behavior can be observed, since the increase the distance of extraction induces to higher productivity. Thus showing that the treatment had the lowest performance in regards to productivity when: the auxiliary traction winch was used, the slopes were above 25.1°, and the average distance of extraction ranged from 100.1 to 200 meters.

It is found that among the treatments 1 and 3, wherein the only variable that differed was the use of the winch in the treatment 3, it is seen that in slope of 0° to 25° and within the distance of extraction from 0 to 100 meters, the use of winch made the operation 29 % less productive. This was also observed when comparing the treatments 2 and 4, where there were two variables differing: the slope and the use of winch (treatment 4). The difference in productivity in this comparison was 33 % lower than in the treatment with higher slope classes and using the winch. The abovementioned analysis can also be observed with the correlation analysis presented in Table 3.

Table 3. Correlation of the variables productivity versus slope and extraction distance.

Tabela 3. Correlação das variáveis produtividade versus inclinação e distância de extração.

Treatment	Correlation	
	Slope	ED (Extraction Distance)
1	-0,85	-0,02
2	0,03	0,88
3	-0,45	-0,33
4	-0,71	-0,03
5	-0,75	0,56

### 3.2. Operational efficiency and mechanical availability during the tests period

Comparing the machine utilization attained by the Forwarder (Table 4) with other studies as the one directed by Oliveira et al. (2009) wherein they calculated a machine utilization of 70 % for a Forwarder 6x6, the difference was about 15 %. It is due to the fact that the Forwarder in the study was new and it was in tests period, along with a Harvester that was also in tests period.

The low machine utilization presented by the Forwarder showed that, as it was not an operation performed with prior planning or fleet dimensioning, and due to the difference and lack of production balancing among cutting and extraction operations, the Forwarder had often to wait the completion of a harvesting in a plantation line or to stand by the Harvester. Then the extraction would be performed, always obeying the distance limits of safety between the machines.

Table 4. Percentage of machine utilization, machine availability, utilization rate, and fuel consumption.

Tabela 4. Percentagem da utilização da máquina, disponibilidade da máquina, taxa de utilização e consumo de combustível.

Machine utilization	Machine availability (%)	Utilization rate	Fuel consumption (L.PMH <sub>0</sub> <sup>-1</sup> )
60,7	93,6	56,8	14,8

### 3.3. Activities during the machine downtime

In the Figure 4 below it is possible to visualize the distribution of occurrences that determined the total time that the Forwarder 860.4 was stopped in the tests period.

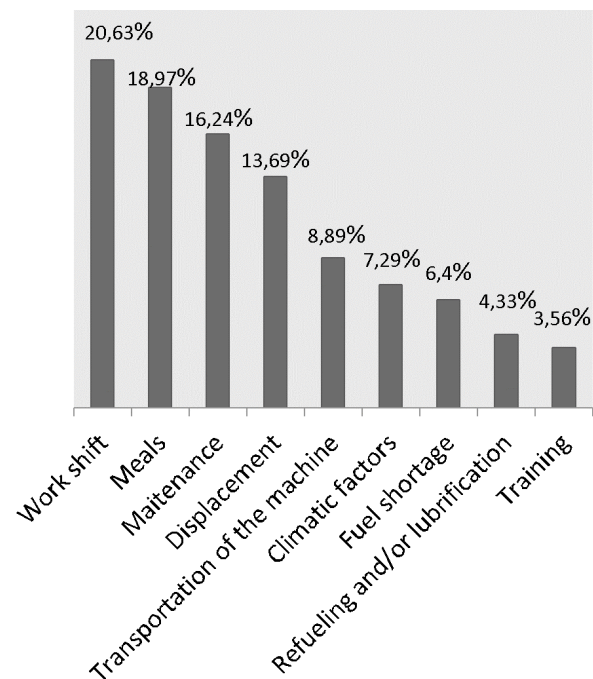


Figure 4. Distribution of occurrences, in percentage of the total time that the forwarder 860.4 was stopped during the tests period.

Figure 4. Distribution of occurrences, in percentage of the total time that the forwarder 860.4 was stopped during the tests period.

## 4. DISCUSSIONS

The presented results showed conform to Cavalli et al. (2009), who concluded that long displacement distances during the loading and the extraction, associated with an increased slope in the terrain, are variables that contribute to the decrease of the Forwarder productivity with traction aid cable winch.

Seixas (2008) stated that the speed is not an essential feature for the Forwarder, since most of the time is used in loading and unloading, with its efficiency based on the ability to overcome many adverse situations in the field. Santos and Machado (1995) concluded that, analyzing the Forwarder operation, the loading time was the element that consumed most in the operational cycle time. The machine productivity increased as the volume per tree increases and as the extraction distance decreases.

In the majority of the operational cycle elements on slopes above 25.1°, the minimum values were greater than in the treatment with declivity up to 25°; the same occurring for maximum values. Such amplitude may be a result of a greater care and precaution when performing such operations, due to the machine stability. The lower productivity is also justified by the fact that from 32° slope, the Forwarder would have an allowed load volume of 12 m<sup>3</sup>; 3 m<sup>3</sup> less than in slopes up to 32°

Lopes et al. (2016b) founded productivities of 13.6 m<sup>3</sup> PMH<sub>0</sub><sup>-1</sup> in classes of slope of 0° to 20° and in slope of 21° to 30° an average productivity of 9.4 m<sup>3</sup> PMH<sub>0</sub><sup>-1</sup> using the winch in both slope classes in forwarding classes until 200 m. The



results obtained by Lopes et al. (2016b) were lower than the productivities obtained in this study because the difference of silvicultural treatments in the two studies: one was collected in thinning operations of *Pinus taeda* plantations and the other in clear-cut operations.

The greatest correlations regarding the slope variable among the observed treatments relating to productivity were in the treatments 1, 4, and 5, where they were negative. It shows an inverse relation with productivity, i.e., the productivity decreases as the slope increases. This correlation is stronger in slopes of 0° to 25° with average distances of extraction between 0 and 100 meters, without using the winch. Productivity also tends to decrease when the slopes are above 25° with the use of the winch in extraction distances above 100 meters. Without using the winch and in slopes up to 25°, with extraction distances from 100 to 200 meters, it is observed that the average extraction distance presents the highest correlation with productivity, in a way that increasing the ED increases productivity.

The Forwarder in the work shift had the largest number of stoppage hours, representing 20 % of the total stopping time, followed by 19 % with meals and 16 % with maintenance. The values showed to be well distributed, with maintenance below 20 % of the stopping time. The percentage found by Oliveira et al. (2009) on a study on Pine extraction was of 35.4 % for maintenance. The low percentage for maintenance in the total stopping time of the machine infers in an assessment that such result was obtained due to the low number of hours of machine utilization.

## 5. CONCLUSION

The use of TAW showed possibilities of use with efficiency in clear-cut operations but it is expected a decrease of productivity due the additional operational cycle elements: attachment and removal of cable.

The use of TAW is adequate to areas with steep slopes beginning in the border of the forest road, therefore extracting timber in the whole stand with TAW, avoiding its frequently attachment and removal of the cable.

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