Effects of Working Time and the Volume and Weight of Timber on Productivity of Log Loader Caterpillar Type 966 F and WL 980 C

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Abstract

Timber harvesting involves a series of activities to move timber from harvesting sites to the processing sites. The activities could be divided into four main components: felling, skidding, hauling and stockpiling. Loading at the landing site and unloading of cargo at the log yard are some of the major activities in timber harvesting. The overall activity is influenced by various factors such as timber volume and weight as well as working time. However, there has been lack of empirical information about what factors influenced by the productivity of timber harvesting in tropical forest in eastern Indonesia. Thus, the aim of this study was to determine the effect of timber volume and weight as well as the working time and their interaction on the productivity of Log Loader Caterpillar 966 F Type and WL 980 C which are the most commonly used equipments in tropical timber harvesting in Indonesia. The multiple linear regression analysis showed that on the loading productivity, the volume and weight of timber, the working time and interaction among them showed positive coefficient regression but others showed negative coefficient regression; while on the unloading productivity, volume, the working time, interaction between volume and weight of timber, and interaction between weight of timber and working time showed positive coefficient regression but others showed negative coefficient regression; and on loading and unloading productivity of cargo per round trip hauling, volume and weight of timber showed positive coefficient regression, but their interaction shows negative coefficient regression. Thus, these factors were taken into account in predicting the magnitude of tool productivity.

Keywords: volume and weight of timber, working time, productivity.

Introduction

Indonesian forest coverage is reasonably large. Unfortunately, the rapid rate of deforestation has made Indonesia as one of the countries which has massive forest destruction. Margano in Vidal (2014) mentioned that primary forest losses about 6.02 million hectares between 2000 and 2012, increased by around 47,600 hectares a year over this time. Previously, it was estimated that forest loss have included the clearing of pulp plantations and oil palm estates, the real loss of primary forest has until now been obscured. In the same report, it was mentioned that in 2012, it was about 840,000 hectares of primary forest lost in Indonesia.

Tropical forest management requires a unique silvicultural system that can grow and harvest timber with minimum destruction. Indonesian Selective Logging (TPTI) is a silvicultural system which was designed for the management of forests in Indonesia since Indonesia's natural forest stands are typically of uneven aged while forest structure could be maintained by natural regeneration (Tomatala 2011).

One of the activities specified in TPTI is timber harvesting. According to Conway (1978) in Kewilaa (2012) and Jiati (2011), timber harvesting is a series of activities that aim to move the timber from the forest to the processing places. This activity is divided into four main components: (1) Felling, includes felling trees and bucking them into several pieces if necessary before skidding; (2) Skidding is to move the timber from the logging site to the edge of the road transport or landing; (3) Hauling is to transport timber from landing to the log yard or to processing place; (4) Stockpiling is the effort to keep the wood in order to maintain its condition before it gets used or sold (Jiati 2011, Kewilaa 2012).

The used of mechanical power in harvesting activities shows progress with advances in technology, where the felling, skidding, loading and unloading gradually become more mechanical as technology develops (Kewilaa 1978). One of the activities in the harvesting is loading and unloading of cargo where the activity is carried out before and after hauling, raising timbers on trailer at the landing and down them after trailer arrives in log yard. This activity could be done by mechanical tools such as crawler tractors, wheel tractors and excavators (Yanto 2009).

Sastrodimedjo (1977) in Yuniawati and Suhartana (2010) distinguished the loading and unloading equipments in two types, i.e. mobile power, such as wheel loaders and excavator, and stationary power, such as track loader.

Factors affecting the productivity of loading and unloading activities of the equipments are the same as the factors affecting skidding such as timber volume, climate, size and properties of wood (FAO 1974 in Jiati 2011). The working time is also a component in determining tool productivity (Kewilaa 2012). The time needed by someone to finish a job under normal conditions to produce a unit of output is called standard time (Barnes 1968; Marvin 1970).

Based on the background of the above problem, the author aimed to search the effect of working time and the volume and weight of timber on productivity of log loader Caterpillar 966 F Type and WL 980 C in IUPHHK PD. Panca

Karya, Leku Village, District Waesama, South Buru Regency.

Materials and Methods

Study Area

This study was held in March 2013, at IUPHHK PD. Panca Karya, Leku Village, Waesama District, South Buru Regency. Anonymous (2015) stated that by the end of 2013, Maluku had 13 units of IUPHHK-HA (Business License Timber Forest Product Utilization in Natural Forest (IUPHHKHA), scattered in five districts: Buru, South Buru, Middle Maluku, Aru Islands, and the District of MTB (Western Southeast Maluku). PD. Panca Karya is one of IUPHHK-HA in South Buru. This company held concession in the year of 2013, extended with 63,440 hectares, with a target of cut of 52,062.25 m^3 and realization of 13,471.06 m^3 or 25.87%.

Material and Equipment

Materials used in this study were 51 pieces of logs at landing while the equipment used included meter roll (20m), scale stick, stop watch, ruler, calculator, and writing equipment and tools of loading and unloading of cargo, i.e. Log Loader 966 F type and WL 980 C.

Research Procedures

The data collected included:

1. The length of log, measured by meter roll (m)
2. Diameter, measured by a scale stick (cm).
   Average diameter of log was calculated by the formula:

$$D = \frac{db + de}{2} \quad (1)$$

$$Db = \frac{d1 + d2}{2} \quad (2)$$

$$De = \frac{d3 + d4}{2} \quad (3)$$

Where:

D = Average diameter (cm)
Db = Diameter of the base (cm)
De = Diameter of the end (cm)
$d1$ = Short distance of base diameter (cm)
$d2$ = Long distance of base diameter (cm)
$d3$ = Short distance of end diameter (cm)
$d4$ = Long distance of end diameter (cm)

3. Log volume
   Log volume was calculated using the formula of Brereton Metric, according to the Method of Measurement of jungle round wood in Indonesia (Anonymous 2009):

$$V = \frac{0{,}7854 \times D^2 \times P}{10000} \ (m^3) \quad (4)$$

Where:

V = Volume (m^3)
D = Average diameter (cm)
P = Length (m)

4. Weight of timber, calculated using formula by Bodiq and Jayne, (1982).

$$Density = \frac{Weight}{Volume} g\ cm^{-2} \text{; or} \quad (5)$$

Weight = Volume x density (in g or kg) (6)

The sample size was 10 cm x 10 cm x 3 cm.

5. Log loader operator working time is measured with a stop watch in a total time of:
   a. Log loader running time to empty the timber load (second)
   b. Time of lifting logs (second)
   c. Time goes by charge (second)
   d. Time of lowering and smoothing log onto the trailer (second)
   e. Unloading time (second)
6. Productivity of log loader was calculated based on the volume of timber transported per working time according to the formula proposed by Kewilaa (2012) as follows:

$$P = \frac{V}{T} m^3 hr^{-1} \quad (7)$$

Where:

P = Productivity of log loader (m^3/hr)
V = Log volume (m^3)
T = Working time (hr)

Data Analysis

All the observed data in the loading and unloading activities and loading and unloading time per round trip hauling were tabulated. Statistical analysis used was multiple linear regression and data processing using a computer with the software Minitab 17 to get the models as the best predictor on tool productivity.

Multiple linear regression models for loading and unloading of cargo according to Steel and Torrie (1981) was:

$$Y = b_0 + b_1x_1 + b_2x_2 + \ldots\ldots + b_7x_7 \quad (8)$$

Where :

Y = Productivity
b_0 = Constant
b_i = Regression coefficient ($i = 1,2,3,4,5,6,7$)
x_1 = Log volume
x_2 = Weight of timber
x_3 = Working time
x_4 = Interaction x_1x_2

x_5 = Interaction x_1x_3

x_6 = Interaction x_2x_3

x_7 = Interaction $x_1x_2x_3$,

and multiple linear regression model for loading and unloading time per round trip hauling was:

$$Y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 \quad (9)$$

Where:

Y = Productivity
b_0 = Constant
b_i = Regression coefficient (i = 1, 2, 3)
x_1 = Log volume
x_2 = Working time
x_3 = interaction x_1x_2

Results and Discussion

Statistical Analysis on the Effect of Volume and Weight of Timber Productivity and Working Time

Based on the results of analysis of variance, the volume and weight of timber, the working time as well as all interactions gave high significant effect on productivity for the loading and unloading activities while timber volume, working time and their interactions gave high significant effect on the productivity of the loading and unloading of cargo per round trip hauling. This is reflected in Table 1, Table 2 and Table 3 as follows.

Table 1. ANOVA of the effect of timber volume and weight, loading time and interaction on tool productivity

Source of Variance	Df	SS	MS	F –Value	P-Value
Regression	7	5536.69	790.956	86.74	0.000
X1	1	736.80	736.802	80.80	0.000
X2	1	3.32	3.320	0.36	0.549
X3	1	6.15	6.150	0.67	0.416
X1X2	1	98.69	98.690	10.82	0.002
X1X3	1	254.40	254.400	27.90	0.000
X2X3	1	0.62	0.620	0.07	0.796
X1X2X3	1	105.33	105.330	11.55	0.001
Error	43	392.10	9.119		
Total	50	5928.79			

Regression analysis for loading productivity: Y versus X1, X2, X3, X1X2, X1X3, X2X3, X1X2X3

The regression equation was

Y = - 9.75 + 16.85 X1 + 0.00054 X2 + 19.6 X3 - 0.01081 X1X2 – 40.54 X1X3 - 0.00038 X2X3 + 0.003114 X1X2X3,
R-Sq = 93.39%

Table 2. ANOVA of the effect of volume and weight of the wood, unloading time and their Interaction on tool productivity

Source of Variance	Df	SS	MS	F -Value	P-Value
Regression	7	18170.9	2595.85	371.58	0.000
X1	1	310.1	310.10	44.39	0.000
X2	1	15.6	15.60	2.23	0.143
X3	1	0.5	0.50	0.08	0.78
X1X2	1	1.9	1.90	0.27	0.606
X1X3	1	126.3	126.30	18.08	0.000
X2X3	1	18.2	18.20	2.60	0.114
X1X2X3	1	1.8	1.80	0.26	0.615
Error	43	300.4	6.99		
Total	50	18471.3			

Regression analysis for unloading productivity: Y versus X1, X2, X3, X1X2, X1X3, X2X3, X1X2X3

The regression equation was

Y = -2.5 +24.59 X1 - 0.00516 X2 + 37 X3 + 0.000406 X1X2 - 1426 X1X3 + 0.475 X2X3- 0.0034 X1X2X3,
R-Sq = 98.37%

Table 3. ANOVA of the effect of volume, cargo loading and unloading time per round trip hauling as well as their interaction on tool productivity

Source of Variance	Df	SS	MS	F-Value	P-Value
Regression	3	5680.88	1893.63	245.93	0.000
X1	1	168.40	168.40	21.87	0.002
X2	1	0.09	0.09	0.01	0.917
X1X2	1	38.21	38.21	4.96	0.061
Error	7	53.90	7.70		
Total	10	5734.77			

Regression analysis for loading and unloading per round trip hauling: y versus x1, x2, x1x2
The regression equation was
$Y = - 11.8 + 8.42 x_1 + 28.2 x_2 - 16.76 x_1x_2$; R-Sq = 99.06%

Statistical analysis showed that:

1. On loading activity
   - Coefficient regression b_1, b_2, b_3 , and b_7 were positive. This means that the value of the random modifiers X_1 (timber volume), X_2 (timber weight), X_3 (working time) , and interaction among $X_1X_2X_3$ tend to occur together with the great value of the random variable Y (tool productivity).
   - Coefficient regression b_4, b_5 and b_6, were negative. This means that the value of the random modifiers X_1X_2, and X_1X_3 and X_2X_3 tend to occur together with the small value of the random variable Y (tool productivity).
2. On unloading activity
   - Coefficient regression b_1, b_3, b_4, and b_6 were positive. This means that the value of the random modifiers X_1 (volume), X_3 (working time), X_1X_2 (interaction between timber volume and weight), X_2X_3 (interaction between weight of timber and working time) tend to occur together with the great value of the random variable Y (tool productivity).
   - Coefficient regression b_2, b_5 and b_7 are negative, this means that the value of the random modifiers X_2 (weight of timber), X_1X_3 (interaction between volume of timber and working time) and $X_1X_2X_3$ (interaction among volume and weight of timber and working time) tend to occur together with the small value of the random variable Y (tool productivity).
3. On loading and unloading activity of cargo per round trip hauling
   - Coefficient regression b_1 and b_2 were positive. This means that the great value of the random modifiers X_1 (timber volume) and X_2 (weight of timber) tend to occur together with the great value of the random variable Y (tool productivity).
   - Coefficient regression b_3 is negative. This means that the value of the random modifiers X_1X_2 (interaction between volume and weight of timber) tends to occur together with the small value of the random variable Y (tool productivity).

Effect of Wood Volume and Weight on Tool Productivity

The data show that the number of logs measured were 51 pieces with average volume of 4.32 m^3 per piece (Appendix 1, Appendix 2, and Appendix 3) and 33.57 m3 per round trip hauling (Appendix 4). Multiple linear regression analysis results show that the volume of timber appears in the model with the regression coefficient b_1 = 16.85 for loading activities, and the unloading activities b_1 = 24.59 as well as the activities of loading and unloading of cargo per trip transport round b_1 = 8.42. Results of this analysis indicated that the greater the volume of timber that is loaded or unloaded, the greater tool productivity. This result is in accordance with the opinion of Sukadaryati and Dulsalam (2003) who stated that the tool productivity depends on the volume of timber removed where productivity could be improved by increasing the volume of timber removed.

On the other hand, weight of timber (X_2) appeared in the model for loading activities where the coefficient regression b_2 = 0.00054. This means that the greater weight of timber, the greater tool productivity. But for unloading activity b_2 = -0.00516 which means that the greater value of weight of timber causes the smaller value of productivity since the greater weight of the wood takes a longer working time per unit of production which in turn has an impact on productivity. This result is in accordance with the opinion of Brown (1958) in Sukardayati and Sukanda (2006) who stated that the size and weight of the wood is one of the factors to consider in harvesting timber crops.

Effect of Working Time on Tool Productivity

Observational data indicated that the average log volume was 4.32 m^3 per stem (Appendix 1, Appendix 2 and Appendix 3) with loading time of 0.22 hours or 13.2 minutes/stem (Appendix 2) and unloading time of 0.11 hours or 6.6 minute per stem (Appendix 3). Data on the Appendix 2 and Appendix 3 show that the load time per stem is larger than unloading time.

Multiple linear regression analysis results showed that the factor of working time appears in models for cargo loading activities with regression coefficient b_3 = 19.6, and unloading activity with regression coefficient b_3 = 37, and for loading and unloading per round trip hauling where the coefficient regression b_2 = 28. This means that working time is directly proportional to productivity which is reflected in the regression coefficients. This means that the greater the cargo loading and unloading time and loading and unloading time per round trip hauling will cause greater tool productivity.

This result is in accordance with the opinion of Sukadaryati *et al*. (2002) who argued that in addition to the volume of wood, working time also affect the size of productivity. Tool productivity depends on the time required to remove the wood where productivity can be improved by minimizing the time that was not effective (Sukadaryati and Dulsalam 2003).

Effect of Interaction Among the Timber Volume and Weight as well as Working Time on Tool Productivity

Multiple linear regression analysis results revealed that not all interaction factors that appear in the model is inversely proportional to productivity. It is shown by its coefficient regression. If the coefficient is positive means that the greater value of interaction causes the greater value of tool productivity, but if it is negative, means that the greater the value of the interactions causes the smaller tool productivity.

It could be concluded that base on analysis of variance, the volume and weight of the wood, working time and all interactions gave high significant effect on the productivity of the log loader. However, multiple linear regression analysis revealed that the volume of wood and weight, working time and their interaction (X_1X_2, X_1X_3, X_2X_3 and $X_1X_2X_3$) is significant in determining the amount of productivity in loading cargo activity, with the value of the coefficient of determination was 93.39%, and on the unloading with the value of the coefficient of determination is 98.37%.

Effect of Wood Volume and Loading and Unloading Time per Round Trip Hauling on Productivity

Data in Appendix 4 reveals that the average charge per trip is 33.57 m^3 timbers, and loading and unloading cargo load time is 0.25 hours or 15 minutes, with the average productivity is 135.84 m^3 per hour. Results of analysis of variance showed that the volume of timber, working time and their interactions gave high significant effect on the productivity of the loading and unloading of cargo per round trip. Multiple linear regression analysis results revealed that coefficients regression b_1 and b_2 were positive and b_3 was negative with determination coefficient R^2= 99.06%. This means that the greater the volume of timber and working time on loaded and unloaded per round trip would cause greater tool productivity, but the greater the value of the interaction between them would cause lesser tool productivity. Data in Appendix 4 shows the difference between the average productivity of data per round trip with the results predicted by the model was 0.012 m^3 hr^{-1}.

Based on the statistical analysis results presented above, it could be concluded that the multiple linear regression models generated could be used to predict the level of tool productivity shown by the coefficient of determination while inaccuracy is due to the influence of the error rate of other factors.

Productivity of Log Loader

To determine the productivity achieved by a log loader operator, a formula proposed by Kewilaa (2012) was used, where the data list on the Appendix 1, Appendix 2, Appendix 3 and Appendix 4 are summarized in Table below:

Table 4. Productivity log loader

Activity	Total pcs or Round trip	Average volume/ Pcs or round trip (m^3)	Time (Hr/ Pcs or round trip)	Productivity (m^3/Hr)	Y predict by full multiple regression	Differ
Loading	51 pcs	4.32	0.220	22.250	22.229	0.040
Unloading	51 pcs	4.32	0.110	44.270	44.180	0.086
Round trip Hauling	11 trip	33.57	0.252	135.838	135.825	0.012

Data in the table above shows that the tool productivity for loading activity is smaller than the tool productivity of unloading of about 50.26%. This means that the activity of loading requires twice the number of unloading tools so that unloading cargo equipment will not be idle. The data in the table above correspond to the data on the Appendix 1, Appendix 2, Appendix 3 and Appendix 4. Data on Table 4 shows that the difference in the average tool productivity on the activity of loading and unloading activity and loading and unloading of cargo per round trip hauling with Y predicted by multiple linear regression was close to zero.

Conclusion and Suggestion

Conclusion

The volume and weight of the wood, working time and their interactions gave high significant effect on productivity of log loader.

Statistical analysis showed the multiple linear regression models: Y = - 9.75 + 16.85 X1 + 0.00054 X2 + 19.6 X3 - 0.01081 X1X2 – 40.54 X1X3 - 0.00038 X2X3 + 0.003114 X1X2X3, for loading activity with R-Sq = 93.39%; Y = -2.5 +24.59 X1 - 0.00516 X2 + 37 X3 + 0.000406 X1X2 - 1426 X1X3 + 0.475 X2X3 - 0.0034 X1X2X3, for unloading cargo activity with R-Sq = 98.37%; $Y = -11.8 + 8.42 x_1 + 28.2 x_2 - 16.76 x_1 x_2$; for activities of loading and unloading of cargo per round trip hauling with R-Sq = 99.06%. It means that the models can be used to predict the productivity of Log Loader 966 F type and WL 980 C because the difference between the average tool productivity on the activity of loading and unloading activity and loading and unloading of cargo per round trip hauling and Y predicted by model was close to zero.

Suggestions

Tool productivity of loading activity was 50% smaller than the tool productivity of unloading activity, meaning that the number of tools of loading the cargo in the company should have doubled the unloading tools so that tool for unloading activities would not be idle.

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