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Income and costs of forest cutting in wood logging in a forestry management area

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ABSTRACT: The productivity and costs of logging in the Amazon rainforest were evaluated during the performance of the cutting forest operations with the chainsaw. The study was conducted in the forest management, upland forest, located in the south of Pará state, Brazil. To determine the income, individual volumes of the exploited trees were obtained and the time of each element of the operational cycle of the forest cutting. The production cost was calculated between the operational costs, fixed and variables by the worked hours. A correlation analysis was performed to verify the influence of physical and mechanical wood properties during the falling of trees. The forest cutting operational cycle lasted an average of 31.5 min per processed tree. Preliminary operations consumed the most time with 45.4% of the total time, with an average time of 14.3 min per tree. The operational efficiency of the cutting was 75% and the average productivity of 20.15 m^3 he^{-1}, with a cost of per effectively worked hour of US$ 19.36. The production cost was US$ 1.18 m^{-3}. The technological properties of the wood did not explain statistically the differences found at the time of falling.

Keywords: rainforest, Amazon, chainsaw.

Rendimento e custos do corte florestal na exploração madeireira em área de manejo florestal

RESUMO: Avaliou-se a produtividade e os custos da exploração de madeira na floresta Amazônica, durante a realização das operações do corte florestal com a motosserra. O estudo foi conduzido em área de manejo florestal, floresta de terra firme, localizada no sul do Estado do Pará. Para a determinação do rendimento foram obtidos os volumes individuais das árvores exploradas e os tempos dos respectivos elementos do ciclo operacional do corte florestal. O custo de produção foi calculado pela razão entre os custos operacionais, fixos e variáveis, pelas horas efetivas trabalhadas. Foi realizada uma análise de correlação para a verificação da influência de propriedades físicas e mecânicas da madeira no tempo de derrubada das árvores. O ciclo operacional do corte florestal durou em média 31,5 min por árvore processada. As operações preliminares consumiram o maior tempo com 45,4% do tempo total, sendo o tempo médio por árvore de 14,3 min. A eficiência operacional do corte foi de 75% e a produtividade média de 20,15 m^3 he^{-1}, com custo por hora efetiva trabalhada de US$ 19,36. O custo de produção foi de US$ 1,18 m^{-3}. As propriedades tecnológicas da madeira não explicaram estatisticamente as diferenças encontradas nos tempos de derrubada das árvores.

Palavras-chave: floresta tropical, Amazônia, motosserra.

1. INTRODUCTION

The world production of logs and lumber from tropical forests remained stable between 2007 and 2010, with 138.4 and 43.2 million cubic meters, respectively, data from 2010. The tropical wood production in Brazil reached 25 million m^3 (ITTO, 2015). The logging of native forests in Brazil occurs mainly in the Legal Amazon, carried out largely from not sustainable wood according to Amaral and Pinto (2012).

The sustainable forest management is constituted as a conservation technique of the areas promoting the use of wood in a planned way and forest maintenance (PINHO et al., 2009). The poorly planned logging may cause negative impacts such as environmental degradation, waste, and injuries to workers and commitment to the management regime. Therefore, the treatments in the forest and future stock should be considered (SESSIONS, 2007). Côrrea et al. (2015) highlighted the potential of non-timber forest products, such as *copal*, *Brazil nuts*, *andiroba*, *piquiá*, *jatobá,* and *amapá*, after logging.

Boltz et al. (2003) pointed out the Reduced Impact Logging (RIL) practices as planning and implementation of operational techniques to reduce the damage to the forest, wood waste and the costs of extraction and increase the productivity of operations. The logging techniques aimed at reducing damage to soil and remaining tree stock (MACPHERSON et al., 2011; EDWARS et al., 2012; GUITET et al., 2012.)

The technical and economic evaluations are essential in the planning of lumbering. There are numerous reports of studies of planted forests in different situations and working conditions in the area, aiming to identify bottlenecks in production or identify details that can be improved in daily activities (LOPES et al, 2008; SILVA et al., 2010; SIMÕES et al.; 2010); it is emphasized that the studies in areas of tropical forest under a forest management regime are still incipient.

The study of time and motion is routinely used in technical analysis of operations and system (LOPES et al., 2013; SILVA et al., 2010; SANTOS et al., 2008). The application already in use in other production sectors, this methodology was defined by Barnes (1977) as the systematic study of work systems which aims to develop and standardize the system and the preferred method, with lower cost, determining the time taken for a qualified and properly trained person, working in a normal rhythm, performing a specific task or operation, and guiding the worker training in the preferred method.

The cutting of trees is the first operation of the forestry enterprise to obtain the raw material wood. In the cutting analysis, it should be considered minimizing costs, optimizing incomes and reducing environmental impacts. Pereira et al. (2012) also highlighted the importance of completing the cut in the technical recommendations aimed at reducing the risk of accidents in the operation.

The objective of this study was to determine the productivity and cost of production in the forest cutting operations, with the use of chainsaws in forest management in the Amazon Region, to contribute to the generation of production indicators.

2. MATERIAL AND METHODS

2.1. Study area

The study was conducted in the municipality of Breu Branco, south of Pará state, Brazil (Figure 1). In Köppen classification, the weather is Am kind, with annual rainfall exceeding 2,000 mm. The relative humidity is on average 80%, and the average monthly temperature is between 25-26 °C. The soils of the region are Dystrophic Yellow Latosol, medium and clayey

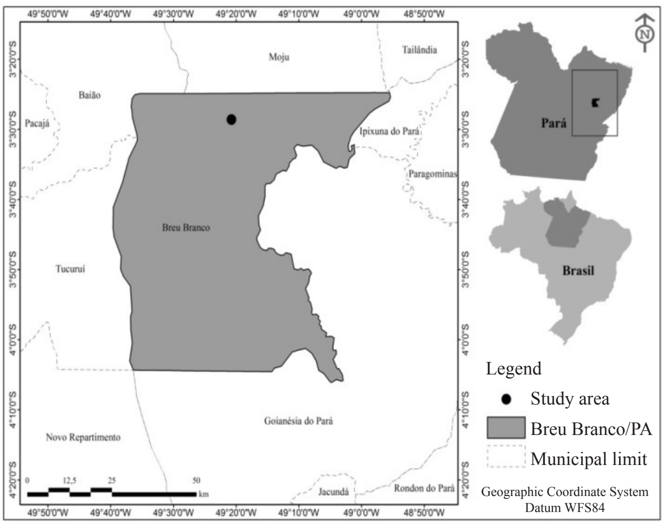

Figure 1. Location of the study area.
Figura 1. Localização da área de estudo.

texture, and 5% slope relief. Of the total of 8,000 ha of Dense Ombrophilous Rainforest, 3,920 ha (49%) were under forest management regime.

2.2. Commercial species and exploitation system

Based on the market, the important commercial species in the study area were: *maçaranduba* (*Manilkara huberi* (Ducke) Standl.) *maparajuba* (*Manilkara paraensis* (Huber) Standl.) *red angelim* (*Dinizia excelsa* Ducke), *ipê* (*Tabebuia serratifolia* (Vahl Nichols), *piquiá* (*Caryocar villosum* (Aubl.), *jatobá* (*Hymenea courbaril* L.) *timborana* (*Pseudopiptadenia suaveolens* (Miq.) Brenan) and *faveiras* (*Parkia* spp).

The adopted logging system was the long logs, with the falling operations, cross cuts in woods and log, being carried out with Husqvarna chainsaws Model 288 XP, and the extraction of logs for forestry tractor *skidder* dragger. The logs were taken to the stockyard as a *skidder* and were processed according to the specifications demanded by the sawmill. The cutting teamwork had a chainsaw operator and a helper for the tree location in the supply at the opening of the escape routes, cleaning the area, wedge use, and measurement of logs.

2.3. Data collection and sampling sufficiency

Data were collected in three work units (250 x 250 m) and the ideal number of established samples was based on the error accuracy of 10 and 95% of confidence, according to Eq. 1.

$$n = \frac{t^2 \times cv^2}{EL^2} \qquad (1)$$

where: n = number of sampling intensity; t = Student's t value obtained according to the level of probability and the freedom degrees (n-1); cv = coefficient of variation, in %; EL = preset error limit, in%.

2.4. Technical analysis and operational costs

For technical analysis, there was the time taken for each operating cycle of the element, checking breaks during the cutting operation. The continuous-time method was adopted for marking, and the operations were divided into the following elements:

a) Preliminary operations: time spent on tree location, verification of quality for cutting (hollow test), cleaning the area, lianas cutting, cleaning the undergrowth around the tree and opening of escape routes;

b) Falling: time spent since the turning on the chainsaw, followed by the tree slaughter, until the moment when the tree completed its fall – hitting the ground;

c) Cross-cuts: time spent by the chainsaw operator to remove the canopy, considering the including minimum diameter the shaft of 10 cm.

d) Plotting: time spent for tree log, measured from the displacement of the chainsaw operator to the finalization of a log. There were one or two logs taken, 7.0 m long, depending on the commercial tree height; and

e) Interruptions: all times were recorded when the chainsaw operator was not performing the activities described above, as well as a description of the cause of each interruption, aiming to classify them into operational difficulties (problems with sword and use of directional wedge), technical or mechanical (supply, chain sharpening, and other maintenance) and operational (meal and rest).

Based on the obtained times and the volume of each sampled tree, calculated according to Eq. 2, adjusted to the area of study by Leite and Rezende (2010), the technical productivity parameters (Eq. 3) and operational efficiency were determined (Eq. 4).

$$V = -10.554 + 0.24d \qquad (2)$$

where: V = volume of each sampled tree, in m^3; d = average diameter of the stump, in cm.

$$P = \frac{\sum_{i=1}^{n} V_i}{he} \qquad (3)$$

where: P = operating productivity, in $m^3\ he^{-1}$; V_i = volume of each sampled obtained tree by inventory in m^3; he = effective working time, in h.

$$OE = \frac{he}{(he + hp)} \times 100 \qquad (4)$$

where: OE = operational efficiency, in %; he = effective working time in h; hp = interruption time in h.

Fixed costs, variables, and administration were calculated to determine the total operating costs (SANTOS et al., 2013; FERNANDES et al., 2013, PEREIRA et al., 2013). Fixed costs involved depreciation, interest and insurance, and the variables involved fuel, lubricating oil, maintenance and repairs, PPE, personal transport and operating personnel remuneration. Both components of the operating costs were calculated and expressed in dollars per effective working hour (US$ h^{-1}). The production cost (US$ m^{-3}) was determined by the ratio of total operating costs (US$ h^{-1}) and the productivity obtained in the cutting operation with chainsaws ($m^3\ h^{-1}$).

For the calculation of operating costs, the following data provided by the company responsible for forestry were used: (a) acquisition of the chainsaw (US$ 1,000); (b) resale value (US$ 100); (c) interest rate and insurance (16% per year); (d) estimated useful life (2 years); (e) working hours (10 h day^{-1}, a total of 1624 year $hours^{-1}$); (f) fuel (US$ 1.1 per liter and consumption of 0.86 l h^{-1}); (g) lubricating oil (US$ 1.25 per liter and consumption of 0.38 l h^{-1}); (h) PPE (US$ 0.28 h^{-1}); (i) auxiliary materials - sword, chain and files (US$ 0.32 h^{-1}); (j) operating labor (operator wage of US$ 650 per month, social charges of 65.5% of the salary, and social expenses of US$ 204 per month); (k) operating personnel transport (US$ 0.54 per hour); (l) management cost (9% of the total fixed and variable costs); and interest rate of 12% per year.

2.5. Data analysis

For the analysis of the cutting operation income, the values of diameter at breast height (DBH) of felled trees were considered. The centers of the diametric classes and their frequencies and productivities were calculated.

There was also the influence of the physical and mechanical properties of wood, basic density, and *Janka* hardness, in the time taken for the falling of trees. The data available in IBDF (1988) were adopted as values of these properties for each species. Regarding *Janka* hardness property, they considered the values for the saturated condition and perpendicular direction, and the green condition since the trees have high moisture content at the time of the cut and in the perpendicular direction to the fiber, direction where the chainsaw sword enters the trunk of the tree. In this evaluation, the correlation according to Pearson (1896) was used with linear correlation values in the correlation matrix.

3. RESULTS AND DISCUSSION

According to the data presented in Figure 2, the operating cycle element with longer time was the step defined as preliminary operations, which corresponded to 45.4% of the total time, and this percentage is related to the mean time of 14.3 min $tree^{-1}$. For the other steps, the percentages and their average times were: (a) falling with 28.5% (8.97 min $tree^{-1}$); (b) log with 9.1% (2.9 min $tree^{-1}$); (c) cross-cut with 6.5% (2.05 min $tree^{-1}$); and (d) interruptions with 10.5% (3.28 min $tree^{-1}$). Thus, because the overall set of data, the cutting operation lasted an average of 31.5 min per processed tree.

The time spent on the preliminary operations was more influenced by the delay in the location of trees within the work units. It was observed that the operator optimized this time when trees were felled next to each other. For this step, the highest average time value has been found, about other cycle elements and also the greater dispersion of data, which showed greater variation in time due to the location of the tree, lianas cutting and preparation of escape routes (Figure 2).

The falling time was influenced by some factors, such as slope, wind direction and intensity, the undergrowth intensity, individual tree volume, tree falling direction and the ability of the operator.

The log times were most influenced by the length of trees than the increase in diameter. The time spent in the trees crosscuts was the lowest operating cycle due to the small diameter of the commercial height considered by the company.

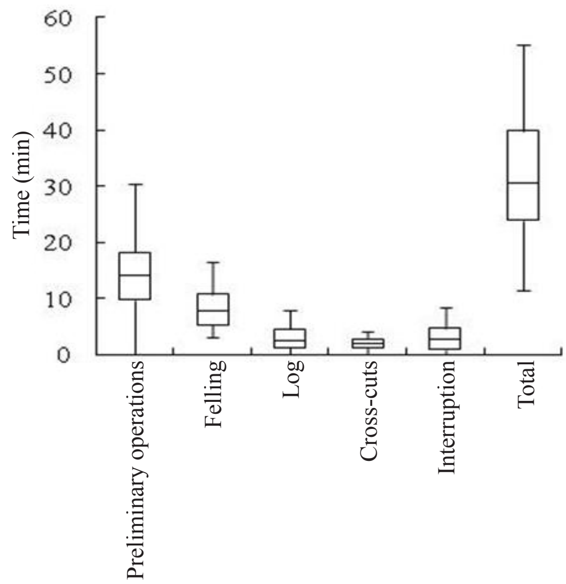

Figure 2. Time, in min, of the forest cutting operations.
Figura 2. Tempo, em min, das operações do corte florestal.

Among the observed interruptions, inherent in the forest cutting work cycle, there are: (a) the removal of undergrowth and lianas in places close to the trees; (b) the sword hooking in the falling, which occurred when the sword of the chainsaw was stuck during the operation; and (c) sword hooking in the log where the sword was stuck in the tree trunk when the operator performed this operation.

In the case of different types of tropical forests in the Brazilian Amazon, several studies about logging in a historical series has revealed an average time for forest cutting operation of 14.0±4.3 min (UHL et al., 1991). In a study of tropical forests of Cameroon, Africa, the cutting operating cycle showed time of 13.2 min using specific falling techniques (JONKERS, 1999).

The operational efficiency obtained of forestry sectional cutting was 75% and the average income of 20.1 m^3 h^{-1}, considering a total volume of 414.75 m^3 extracted. In Indonesia's forests, using codes of exploitative practices (FAO, 2015), the use of wedge for the falling generated productivity of 18 m^3 h^{-1} (ELIAS, 1998), and in Malaysia, the cutting cycles had an average time 32 of min (TAY et al., 2002).

Table 1 shows the cutting of forest productivity values due to the DBH. The tree diameter size influenced the time spent for the falling, and it was observed that the largest number of trees was concentrated in the first two classes of DBH (64 and 74 cm), with a trend towards higher productivity.

Regarding the physical and mechanical properties of wood, there was a low correlation between the dependent variable, falling time, and the independent variables, basic density, and *Janka* hardness, for these last two variables a high correlation was noticed (Table 2).

The species with the highest basic density values were *Astronium lecointei* Ducke (0.79 g cm^{-3}), *Enterolobium schomburgkii* Benth (0.84 g cm^{-3}), *Hymenaea* L. (0.76 g cm^{-3}), *Manilkara huberi* (Ducke) Standl. (0.87 g cm^{-3}), *Manilkara paraensis* (Huber) Standl. (0.87 g cm^{-3}), *Pseudopiptadenia psilostachya* (DC.) G. P. Lewis and M. P. Lima (0.76 g cm^{-3}), *Vantanea guianensis* Aubl (0.86 g cm^{-3}). Among these species, *Pseudopiptadenia psilostachya* (DC.) G. P. Lewis and M. P. Lima, *Astronium lecointei* Ducke and *Manilkara huberi* (Ducke) Standl are among those who contributed the highest percentage of cutting operating time, indicating that tougher species requiring more time in this operation. Although it is among the species that have the greatest amount of basic density, it was found that *Vantanea guianensis* Aubl had low influence on the falling time.

Table 1. Productivity (P) in m^3 h^{-1}, on different diameter classes for the forestry cutting operation.
Tabela 1. Produtividade (P), em m^3 he^{-1}, em diferentes classes diamétricas para a operação de corte florestal.

CD (cm)	CC (cm)	V (m^3)	OF	He (hs)	P (m^3 he^{-1})
59 - 69	64	59.1	11	4.04	14.61
69 - 79	74	148.6	23	10.34	14.37
79 - 89	84	51.49	6	3.47	14.86
89 - 99	94	61.99	7	3.65	16.98
99 - 109	104	56.34	4	2.21	25.44
109 -119	114	12.41	1	0.39	31.69
119 - 129	124	12.41	1	0.85	14.56
129 - 139	134	12.41	1	0.43	28.68
Total	-	414.75	54	25.40	-

CD = DAP class; CC = DAP class center; V = volume; OF = observed frequency of trees; He = spent effective hours; P = productivity.

Table 2. Correlation analysis between the tree falling time and the technological characteristics of the wood, in the diameter class of 69-79 cm.
Tabela 2. Análise da correlação entre o tempo de derrubada da árvore e as propriedades tecnológicas de sua madeira, na classe diamétrica de 69-79 cm.

Variables	BD (g cm^{-3})	JH (Kgf)	OT (seg)
BD (g cm^{-3})	1		
JH (Kgf)	0.891	1	
OT (seg)	0.322	0.497	1

BD = basic density; JH = *janka* hardness; OT = overthrow time.

Exceptions regarding the expected behavior for the falling time were also observed for low-density species. The *Parkia nitida* Miq. Species, second lowest basic density (0.42 g cm^{-3}), was the species that most contributed to the operating time. The species *Parkia pendula* (Willd.) Benth. ex Walp. had the third lowest basic density (0.50 g cm^{-3}), responsible for the second highest percentage of operating time. These findings point to other relevant factors such as cutting diameter, direction of the fibers and the presence of buttresses, which together with the density contributed to the discrepancy of the falling time.

The species with higher *Janka* hardness values were *Manilkara paraensis* (Huber) Standl. (1118 kgf), *Manilkara huberi* (Ducke) Standl. (1118 kgf), *Vantanea guianensis* Aubl (1043 kgf), *Enterolobium schomburgkii* Benth. (986 kgf), *Hymenaea courbaril* L. (965 kgf), *Crysophyllum* sp. (914 kgf), *Astronium lecointei* Ducke (906 kgf) and *Pseudopiptadenia psilostachya* (DC.) G. P. Lewis and M. P. Lima (835 kgf). Among the hardest species *Manilkara huberi* (Ducke) Standl, *Pseudopiptadenia psilostachya* (DC.) G. P. Lewis and M. P. Lima (835 kgf) and *Astronium lecointei* Ducke (906 kgf) contributed with the highest percentages (>10%) in the falling time.

Thus, the physical and mechanical variables were not enough to explain the different recorded productivities. A study performed by Jacovine et al. (2005), evaluating the operational quality in five subsystems showed that the quality of the process in forest harvesting is related to an effective control system, investments, and operators training.

Considering the interest rate of 12% per year and the operating efficiency of 75%, the cost/time effectively worked of US$ 19.36 was reached, considering the practice exchange of US$ 1.00 equivalent to R$ 4.00.

Figure 3 shows the percentages obtained for each of the elements of the operating costs. It was noted that the fixed costs accounted for 2.53% and variables to approximately 89.21% of total costs; the administration cost was approximately 8.25% of total costs.

Among the variable costs, spending on labor, equivalent to 69.1% represented the highest percentage. The obtained production cost was US$ 1.18 m^{-3}. The low production cost was obtained due to the high operational productivity, consequently achieved, due to the high individual volumes of trees.

Homes et al. (2004) found a value of 18.65m^3 he^{-1} for falling and delineate operations, in a study conducted in a tropical forest located in Ulianópolis/Pará, Brazil, with the production cost of US$ 0.62 m^{-3}. Explanations for the differences found by the authors and the current study may be associated with times making method, the activities performed by cutting teams, forest structure, explored species, among other factors.

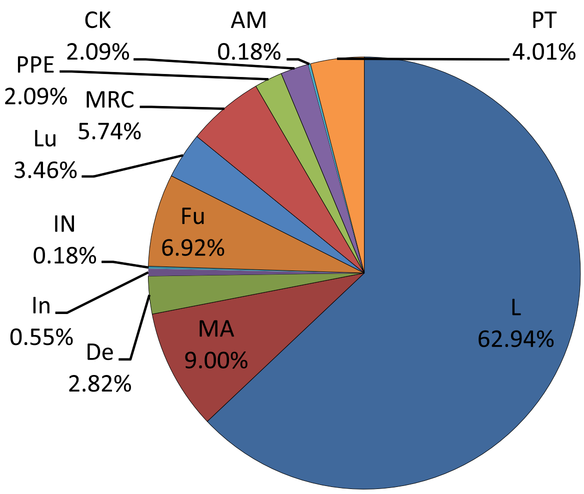

Figure 3. Distribution of the components of the operating costs of forest cutting. L (labor); MA (management cost); De (depreciation); In (interest); IN (insurance); Fu (fuel); Lu (lubricants); MRC (maintenance and repair costs); PPE (personal protective equipment); CK (cutting kit); AM (auxiliary materials); and PT (personnel transport).
Figura 3. Distribuição dos componentes do custo operacional do corte florestal. L (mão de obra); MA (custo de administração); De (depreciação); In (juros); IN (seguros); Fu (combustível); Lu (lubrificantes); MRC (custos de manutenção e reparos); PPE (equipamentos de proteção individual); CK (conjunto de corte); AM (materiais auxiliares); e PT (transporte de pessoal).

4. CONCLUSIONS

Preliminary operations were the most demanded in time spent for forest cutting, especially related to the location of trees. The operating efficiency of forest cut was 75%, reaching an average productivity of 20.15 $m^3 h^{-1}$ at a cost per effectively worked hour of US$ 19.36, and production cost of US$ 1.18 m^{-3}.

5. REFERENCES

AMARAL, P.; PINTO, A. Manejo florestal como base para produção e conservação florestal na Amazônia. In: CASES, M.O. (Org.). **Gestão de Unidades de Conservação: Compartilhando uma experiência de capacitação**. Brasília: WWF, 2012. p. 265-278.

BARNES, R. M. **Estudo de movimentos e de tempos: Projeto e medida do trabalho**. São Paulo: Edgar Blücher, 1977. 635p.

BOLTZ, F.; HOLMES, T. P.; CARTES, D. R. Economic and environmental impacts of conventional and reduced impact logging in Tropical South America: a comparative review. **Forest Policy and Economics**, Amsterdam, v. 5, n. 1, p. 69-81, 2003. http://dx.doi.org/10.1016/S1389-9341(01)00075-2

CORREA, V. V.; GAMA, J. R. V.; RIBEIRO, R. B. da S.; ALVES, A. F.; VIEIRA, D. dos S.; XIMENES, L. C. Estrutura e uso potencial de espécies arbóreas em floresta manejada, Santarém-Pará. **Cerne**, Lavras, v. 21, n. 2, p. 293-300, 2015.

EDWARS, D. P.; WOODCOCK, P.; EDWARDS, F. A.; LARSEN, T. H.; HSU, W. W.; BENEDICK, S.; WILCOVE, D. S. Reduced-impact logging and biodiversity conservation: a case study from Borneo. **Ecological Applications**, Washington, v. 22, n. 2, p. 561-571, 2012. http://dx.doi.org/10.1890/11-1362.1

ELIAS. **Reduced impact timber harvesting in the tropical natural forest in Indonesia.** Forest Harvesting Case Study. Rome: FAO, 1998. 48p.

FERNANDES, H. C.; BURLA, E. R.; LEITE, E. da S.; MINETTE, L. J. Avaliação técnica e econômica de um "Harvester" em diferentes condições de terreno e produtividade da floresta. **Scientia forestalis**, Piracicaba, v. 41, n. 97, p. 145-151, 2013.

FOOD AND AGRICULTURE ORGANIZATION (FAO). **FAO model code of Forest harvesting practice.** Disponível em: <http://www.fao.org/docrep/v6530e/v6530e00.HTM/>. Acesso em mar. 2015.

GUITET, S.; PINTHON, S.; BRUMAUX, O.; JUBELIN, G.; GOND, V. Impacts of logging on the canopy and the consequences for forest management in French Guiana. **Forest Ecology and Management,** Amsterdam, v. 277, n. 1, p. 124-131, 2012. http://dx.doi.org/10.1016/j.foreco.2012.04.011

INSTITUTO BRASILEIRO DE DESENVOLVIMENTO FLORESTAL (IBDF). **Madeiras da Amazônia, características e utilização, Estação Experimental de Curuá-Una.** Brasília: IBDF/LPF, vol. 2, 1988. 236p.

INTERNATIONAL TROPICAL TIMBER ORGANIZATION (ITTO). **Annual Report 2013.** Yokorama: ITTO, 2013. Disponível em: <http://www.itto.int/annual_review_output/>. Acesso em abr. 2015.

JACOVINE, L. A. G.; MACHADO, C. C.; SOUZA, A. P. de; LEITE, H. G.; MINETTI, L. J. Avaliação da qualidade operacional em cinco subsistemas de colheita florestal. **Revista Árvore,** Viçosa, v. 29, n. 3, p. 391-400, 2005.

JONKERS, W. B. J. **Logging damage and efficiency: a study on the feasibility of reduced impact logging in Cameroon.** The Tropenbos-Cameroon Programme, Kribi (Cameroon). Final Report, p. 57, 1999.

LEITE, F. S.; REZENDE, A. V. Estimativa do volume de madeira partindo do diâmetro da cepa em uma área explorada de floresta amazônica de terra firme. **Ciência Florestal,** Santa Maria, v. 20, n. 1, p. 69-79, 2010.

LOPES, E. S.; FERNANDES, H. C.; SANTOS, N. T.; RINALDI, P. C. N. Avaliação técnica e econômica de uma garra traçadora operando em diferentes produtividades. **Scientia Forestalis**, Piracicaba, v. 36, n. 79, p. 215-222, 2008.

MACPHERSON, A. J.; CARTER, D. R.; SCHULZE, M. D.; VIDAL, E.; LENTINI, M. W. The sustainability of timber production from Eastern Amazonian forests. **Land Use Policy**, Amsterdam, v. 29, n. 2, p. 339-350, 2011. http://dx.doi.org/10.1016/j.landusepol.2011.07.004

PEREIRA, R. S.; GUIMARÃES, P. B. R.; MENEZZI, C. H. S. D.; VALE, A. T. do; ROBERT, R. C. G. Avaliação da segurança e ocorrência de defeitos na operação de corte semimecanizado de florestas de eucalipto. **Revista Árvore**, Viçosa, v. 36, n. 3, p. 511-518, 2012.

PEREIRA, R. S.; SILVESTRE, R.; NAPPO, M. E.; MIGUEL, É. P.; EMMERT, F. Qualidade da colheita e atributos físicos do solo: implicações no planejamento da reforma de povoamentos florestais. **Engenharia na Agricultura,** Viçosa, v. 21, n. 3, p. 223-233, 2013. http://dx.doi.org/10.13083/1414-3984.v21n03a01

SANTOS, P. H. A.; SOUZA, A. P. de; MARZANO, F. L. da C.; MINETTE, L. J. Produtividade e custos de extração de madeira de eucalipto com Clambunk Skidder. **Revista Árvore,** Viçosa, v. 37, n. 3, p. 511-518, 2013.

PEARSON, K. **Mathematical Contributions to the Theory of** Evolution. III. Regression, Heredity and Panmixia. Philosophical Transactions of the Royal Society of London, 187, p. 253-318, 1896. http://dx.doi.org/10.1098/rsta.1896.0007

PINHO, G. S. C.; FIEDLER, N. C.; GUIMARÃES, P. P.; SILVA, G. F.; SANTOS, J. dos. Análise de custos e rendimentos de diferentes métodos de corte de cipós para produção de madeira na floresta nacional do Tapajós. **Acta Amazonica,** Manaus, v. 39, n. 3, p. 555-560, 2009. http://dx.doi.org/10.1590/S0044-59672009000300010

SESSIONS, J. **Harvesting Operations in the Tropics.** [S.l.]: Spring-Verlag, 2007.

SILVA, E. N.; MACHADO, C. C.; MINETTE, L. J.; SOUZA, A. P. de; FERNANDES, H. C.; SILVA, M. L. da; JACOVINE, L. A. Avaliação técnica e econômica do corte mecanizado de *Pinus* sp. com harvester. **Revista Árvore**, Viçosa, v. 34, n. 4, p. 745-753, 2010.

SIMÕES, D.; IAMONTI, I. C.; FENNER, P. T. Avaliação técnica e econômica do corte de eucalipto com feller buncher em diferentes condições operacionais. **Ciência Florestal**, Santa Maria, v. 20, n. 4, p. 649-656, 2010.

TAY, J. et al. Financial assessment of reduced impact logging techniques in Sabah, Malaysia. Asia Pacific Forestry Commission, International Conference, **Proceedings…**, Kuching, Malaysia, 2002.

UHL. C.; VERÍSSIMO, A.; MATTOS, M. M.; BRANDINO, Z.; VIEIRA, I. C. G. Social, economic, and ecological consequences of selective logging in an Amazon frontier: the case of Tailândia. **Forest Ecology and Management**, Amsterdam, v. 46, n. 3-4, p. 243-273, 1991. http://dx.doi.org/10.1016/0378-1127(91)90235-N