Lumber yield of Sucupira-Vermelha in central Amazon sawmill

Rendimento no desdobro de toras de Sucupira-Vermelha em serraria na Amazônia Central

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ABSTRACT

The sustainable use of forestry resources has an intrinsic relationship with log yield in sawmills, because the knowledge of this variable can optimize the processed wood production. Thus, the objective of this work was to determine the percentage yield in the sawing of Sucupira-Vermelha (*Andira parviflora* Ducke.) logs in different diameter classes and to adjust mathematical models to estimate processed wood. It was sampled 56 logs with diameters between 31 and 69 cm grouped into 4 diameter classes. Afterwards the sawing was performed obtaining various pieces of wood which were cubed to determine the yielding percentage. The increase in diameter classes provided an increase in sawn wood yield, which showed a significant difference only between the diameter class 1 and the others studied. Twelve mathematical models, 6 linear and 6 nonlinear, were evaluated. The models quality adjustment and selection was based on the highest adjusted determination coefficient (R^2_{adj}), lowest estimation standard error (S_{yx}) and variation coefficient (VC%) and, most homogeneous residues graphic distribution. The nonlinear models of single entry (diameter) and double entry (diameter and length) were the most accurate to estimate the sawn wood yield of Sucupira-Vermelha species.

Keywords: tropical wood, wood residues, mathematical models.

RESUMO

A utilização dos recursos florestais madeireiros de forma sustentável tem relação intrínseca com o rendimento de toras em serrarias, pois por meio do conhecimento desta variável pode-se otimizar a produção de madeira serrada. Assim, o objetivo deste trabalho foi determinar o rendimento no desdobro de toras da espécie Sucupira-Vermelha (*Andira parviflora* Ducke.) em diferentes classes diamétricas e ajustar modelos matemáticos para estimativa de madeira serrada. Foram amostradas 56 toras com diâmetros entre 31 e 69 cm agrupadas em 4 classes de diâmetro. Em seguida realizou-se o desdobro obtendo-se peças variadas de madeira as quais foram cubadas para determinação do rendimento. O aumento de classes diamétricas proporcionou um aumento de rendimento em madeira serrada, onde foi evidenciada uma diferença significativa somente entre a classe diamétrica 1 e às demais estudadas. Foram avaliados 12 modelos matemáticos, 6 lineares e 6 não-lineares. A qualidade do ajuste e seleção dos modelos foi baseada no maior coeficiente de determinação ajustado (R^2_{ajust}), menor erro padrão da estimativa (S_{yx}) e coeficiente de variação (CV%) e, distribuição gráfica dos resíduos mais homogênea. Os modelos não-lineares de simples entrada (diâmetro) e dupla entrada (diâmetro e comprimento) mostraram-se mais precisos para estimar o rendimento em madeira serrada da espécie Sucupira-Vermelha.

Palavras-chave: madeira tropical, resíduos de madeira, modelos matemáticos.

1 INTRODUCTION

Besides being a big producer, Brazil is also a big consumer of tropical Amazon woods. The activities related to logging in the Brazilian Amazon can be summarized as selective logging and, for the most part, still have obsolete technological levels in sawmills logging processes (Garcia *et al*. 2012). Due to the huge waste of forest resources from all production chain stages, from logging to industrial processing in sawmills, there is a greater impact on the forest. Thus, making the material harnessing an important object of study aiming at its optimization (Latorraca, 2004).

Among the strategies to produce sawn wood, is highlighted the yield that the sawmill has in the logs sawing, that is, the processing of the log in the conversion to sawn wood. The log is a material that, when processed to produce sawn wood, generates losses in the form of shanks, saw dust and pieces tips. This generates a waste of raw material in the form of byproduct that is estimated as a waste whose attempts to use it have not added due value to a material considered so noble (Garcia *et al.* 2012). The issue of the use of wood residues is a recurring theme in the scientific community, mainly due to the worldwide concern of the associative triad of high consumption of resources, high production of natural residues and their destination, which has been aggravating the emission of related pollutants. with global warming, since wood waste is primarily burned outdoor, with the aim of reducing its volume (Mendoza *et al.*, 2020).

The sawing logs processes performed in most sawmills in the Amazon present low yields, around 30% (Higuchi e Clement, 2006), due to the low technological level involved in the production process. Around 80% of tropical sawn wood volume does not reach this 30% yield, thus increasing the product final price and the volume of waste generated in form of saw dust and small pieces (Biasi e Rocha, 2007). Sustainability in the use of forest resources depends, among other factors, on the sawing logs yield, since the area forest logged has a negative correlation with the utilization level of the raw material (Danielli *et al*. 2016). Moreover, Iwakiri (1990) mentions that knowledge of the yield of a species in the sawmill is essential for forestry entrepreneurs to improve production planning, optimization and control.

In order to ensure the Amazonian logging industry sustainability, is clear the high demand for research that generates data that will serve as a basis for determining techniques aimed at maximizing the Amazonian species sawn wood yield.

Within this context, the study objective was to determine the yield percentage in lumbering Sucupira-Vermelha (*Andira parviflora* Ducke.), verify possible yield differences between diameter classes, verify the sawing logs byproducts generation percentage in the process and adjust mathematical models to estimate future yield in sawn wood.

2 MATERIAL AND METHODS

STUDY LOCAL

The study was conducted at Mil Madeiras Precious Ltda. sawmill, located in Itacoatiara county on AM-363 highway, km 1.5, east of Amazonas state, approximately 235 km from Manaus, where they practice sustainable forest management on its own land since 1996 and is certified on Forest Stewardship Council® (FSC®) and Forest Certification Certification Program (PEFC®) standards since 1997.

Logs collection and grouping

In the sawmill yard were aleatory selected 56 Sucupira-Vermelha logs from the 2016 harvest. These logs had their tips painted and enumerated according to their thin top diameter and were divided into 4 diameter classes with 14 logs in each class. The colors blue, green, yellow and red represented the diameter classes 1, 2, 3 and 4 respectively, the logs length section was standardized in 4.5 m (Table 1).

Table 1. Logs grouping in diameter classes with their respective average diameters, length and number of logs.

Diameter classes	Diameter range (cm)	Number of logs	Average diameter (cm)	Length (m)
1	30-39,9	14	37,0	4,5
2	40-49,9	14	46,6	4,5
3	50-59,9	14	54,3	4,5
4	60-69,9	14	65,4	4,5
TOTAL		56		

Logs volume

To obtain the diameter of each log and so determinate the volume was used a measuring tape to made two perpendicular measurements in each log extremity (Figure 1) so obtaining the thin top (Tn_t) and the thick top (Tk_t) following the equations 1 and 2.

$$Tn_t = \frac{Tn_t' + Tn_t''}{2} \quad (1)$$

$$Tk_t = \frac{Tk_t' + Tk_t''}{2} \quad (2)$$

Then the arithmetic mean was made between the two tops diameters to obtain the log diameter (D) parameter following the equation 3.

$$D = \frac{Tn_t + Tk_t}{2} \quad (3)$$

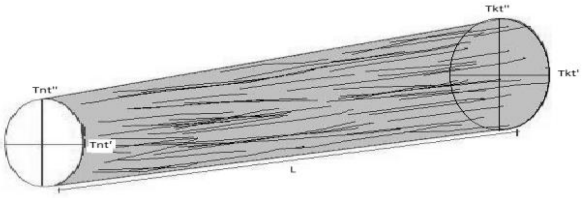
Where:
D = Diameter (cm);
Tn_t = Thin top diameter (cm);
Tk_t = Thick top diameter (cm).

With these data, the volume was calculated by applying the *Smalian* method according to equation 4.

$$L_v = \frac{D^2 * \pi}{40000} * L \qquad (4)$$

Where:
Lv = Log volume (m³);
D = Diameter (cm);
L = Length (m).

Figure 1. Illustration of the method used to obtain the log average diameter and length to calculate the volume.



Source: adapted of Oliveira *et al.* (2003).

Sawn wood volume

After the logs sawing, all the pieces generated from each log were grouped into lots and had their dimensions measured for later counting and so multiplied by the number of pieces to obtain the wood volume from each log.

The pieces were measured using a measuring tape and the individual piece volume were obtained using the equation 5.

$$Ipv = \frac{a * b * c}{10^6} \qquad (5)$$

Where:
Ipv = Individual piece volume (m³);
a = Piece width (cm);
b = Piece thickness (cm);
c = Piece lenght (cm).

Then the individual's pieces volumes were multiplied by the number of pieces generated of each log, according to equation 6:

$$Wv = Np * Ipv \qquad (6)$$

Where:
Wv = Wood volume (m³);
Np = Number of pieces;
Ipv = Individual piece volume (m³).

Processed wood volumetric yield (%)

The individual lumbering yield of each log was determined by the percentual ratio between lumber volume and log volume, according to equation 7.

$$Y = \frac{Wv}{Lv} * 100 \qquad (7)$$

Where:
Y = Percentual yield (%);
Wv = Wood volume (m³);
Lv = Log volume (m³).

Residue generated (%)

The byproducts amount generated in the log sawing was determined by the difference between the total (100%) and the percentual yield, according to equation 8.

$$R = 100 - Y \qquad (8)$$

Where:
R = Percentual residue (%);
Y = Percentual yield (%).

Statistical analysis

Following the precept of data homogeneity, a statistical analysis was performed comparing means based on analysis of variance (ANOVA), verifying if the treatment class diameter had any different effect on yield at 95% probability. With the difference in the analysis of variance verified, the *Tukey* means comparison test method was applied at 95% probability. Statistical equal means were represented by equal letters whereas statistical different means were represented by different letters.

These statistical analyzes were performed using the software “R” and Microsoft Excel 2016.

Mathematical models adjustment

The regression analysis was made using the minimum squares method, where 12 models, 6 linear models and 6 nonlinear, were tested according to Table 2. The models where adapted from Valério *et al*., (2009) and Danielli *et al*., (2016).

Table 2. Tested models to estimate the yield of Sucupira-Vermelha (*Andira parviflora* Ducke) sawn wood. Y: yield (m^3); D: diameter (cm); L: log length (m); Lv: log volume (m^3) and β0, β1 and β2: regression coefficients.

Nº	Models
1	$Y=\beta_0+\beta_1 D+\varepsilon$
2	$Y=\beta_0+\beta_1 D+\beta_2 L+\varepsilon$
3	$Y=\beta_0+\beta_1 D^2+\varepsilon$
4	$Y=\beta_0+\beta_1 D^2+\beta_2 L^2+\varepsilon$
5	$Y=\beta_0+\beta_1 DL+\varepsilon$
6	$Y=\beta_0+\beta_1 DL^2+\varepsilon$
7	$Y=\beta_0 * D^{\beta 1}+\varepsilon$
8	$Y=\beta_0 * D^{\beta 1} * L^{\beta 2}+\varepsilon$
9	$Y=\beta_0 * DL^{\beta 1}+\varepsilon$
10	$Y=\beta_0 * D^{\beta 1} * L_v^{\beta 2}+\varepsilon$
11	$Y=\beta_0 * L_v^{\beta 1}+\varepsilon$
12	$Y=\beta_0 * DL^{\beta 1} * L_v^{\beta 2}+\varepsilon$

Pearson's correlation test was performed to verify the correlation between the tested models variables involved. It was also verified if the independents variables were correlated with each other, characterizing the effect of multicollinearity (Graham, 2003). One of the regression assumptions says that there must be a low correlation between the independent variables used in the models (Gotelli e Ellison, 2010).

To evaluate the models quality, the statistical criteria indicated by Santos (1996) were considered, it is: higher adjusted determination coefficient (R^2_{adj}), lower estimative standard error (S_{yx}), lower variation coefficient (VC%) and most homogeneous residuals graphic distribution.

To calculate the adjusted coefficient of determination (R^2_{adj}) was used the equation 9.

$$R^2_{adj} = R^2 - \left(\frac{k-1}{n-k}\right) * (1 - R^2) \qquad (9)$$

Where:
R^2_{adj} = Adjusted coefficient of determination;
R^2 = Coefficient of determination;
k = Number of coefficients;
n = Number of logs.

To calculate the estimative standard error (Syx) was used the equation 10.

$$S_{yx} = \sqrt{\frac{\sum(y-y_{est})^2}{n-k}} \quad (10)$$

Where:
S_{xy} = Estimative standard error (m³);
y = Observed sawn wood volume (m³);
y_{est} = Estimated sawn wood volume (m³);
n = Number of logs;
k = Number of coefficients.

To calculate de variation coefficient was used the equation 11.

$$VC = \frac{S_{yx}}{\bar{X}} * 100 \quad (11)$$

Where:
VC = Variation coefficient (%);
S_{yx} = Estimative standard error (m³);
$\bar{X}$ = Sawn wood mean (m³).

To calculate the residual distribution was used the equation 12.

$$Res = \frac{(E_{wv}-O_{wv})}{O_{wv}} * 100 \quad (12)$$

Where:
Res = equation residual (%);
E_{wv} = estimated wood volume (m³);
O_{wv} = observed wood volume (m³).

3 RESULTS

The total volume of logs was 53.53 m³, which generated a total volume of 16.44 m³ sawn wood, thus achieving a yield of 29.52% with a confidence level of ± 1.12%.

Statistical analysis showed that there was a difference in yield ($p=3,11e^{-12}$) between diameter class 1 in relation to the others, being this class the one with the lower yield at 95% probability level (Table 3).

Table 3. Variance analysis (ANOVA) for sawn wood yield among the 4 diameter classes of Sucupira-Vermelha (*Andira parviflora* Ducke).

Font	Squared Sum	Liberty Degree	Mean Squared	P-value
Diameter Classes	674,9212	3	224,9737	3,22E-12
Residual	348,1105	52	6,694432	
Total	1023,032	55		

The table 4 presents statistical results of Tukey average comparison in yield of the four diameter classes studied regarding the data set collected of 56 logs of *Andira parviflora* Ducke. (Sucupira-Vermelha).

Table 4. Tukey test comparing the sawn wood yield average between the four diameter classes and the residues generated of Sucupira-Vermelha (*Andira parviflora* Ducke). Values followed by the same letter had no statistical difference at 95% probability.

Diameter class	Diameter range (cm)	Logs volume (m^3)	Sawn wood volume (m^3)	Yield (%)	Residue percentage (%)
1	30-39,9	6,79	1,61	23,71a	76,29a
2	40-49,9	10,73	3,26	30,38b	69,61b
3	50-59,9	14,68	4,57	31,13b	69,00b
4	60-69,9	21,33	7,02	32,91b	67,09b

The average yields evidenced in this study shows a tendency for increase in logs harnessing during the sawing with the increase in the class diameter. So, the class 1 was the one with the lower yield, which had a gradual increase until the class 4, the one with the higher yield.

It is important to point out that the Sucupira-Vermelha species has a high natural quality, so the logs do not presented defects like hollows, cracks or any kind of xylophages attacks.

Table 4 also shows that the residues volumes generated in the sawing logs process presented a gradual decrease from the smaller class to the largest class, following the inverse behavior of the yield. Class 1 (30-39.9 cm) was the only one that presented significant difference in relation to the others, being the one with the highest residues generation. The diameter classes 2, 3 and 4 did not present significant differences between them, being the class 4 the one with lower percentage of residues generation.

Analyzing the Pearson test were observed that the diameter and log volume independent variables had a high correlation level (0,993), so characterizing a multicollinearity problem between them. The models 10 and 12, despite having good qualitative adjust parameters, can be discarded because having this multicollinearity problem these equations become biased.

Moreover, one disadvantage of using models 10, 11 and 12 is the difficulty of collecting the independent variable volume in relation to the diameter variable.

In the equation adjustment were used 56 logs, independent of the diameter class. The results of the 12 mathematical models tested for the yield estimation in sawn wood are presented in Table

5, with their respective parameters of adjusted determination coefficient (R^2_{adj}), estimate standard error (S_{yx}) and the variation coefficient (VC%).

Table 5. Mathematical models tested and their respective coefficients generated to estimate the lumber yield of Sucupira-Vermelha (*Andira parviflora* Ducke). Y: log yield (m³); D: log diameter (cm); L: log length (m); L_v: log volume (m³); R^2_{adj}: adjusted determination coefficient; S_{yx}: estimative standard error (m³); VC%: variation coefficient.

o	Equation	Adjustment quality		
		R^2_{adj}	S_{yx} (m³)	VC(%)
	$Y=-0{,}38736956+0{,}01340091*D$	0,965	0,029	10,39
	$Y=-0{,}39123416+0{,}01339943*D+0{,}00087386L$	0,966	0,029	9,74
	$Y=-0{,}05950115+0{,}00013100*D^2$	0,957	0,031	10,49
	$Y=-0{,}07432499+0{,}00013089*D^2+0{,}00074383L^2$	0,956	0,030	9,83
	$Y=-0{,}36810386+0{,}00288593*DL$	0,946	0,033	11,21
	$Y=-0{,}04803206+0{,}00000621*DL^2$	0,950	0,034	11,61
	$Y=0{,}00001252*D^{2{,}54052440}$	0,968	0,027	9,31
	$Y=0{,}00000962*D^{2{,}53720420}*L^{0{,}18346204}$	0,968	0,027	9,23
	$Y=0{,}00000038*DL^{2{,}47808953}$	0,962	0,035	12,02
0	$Y=0{,}00005448*D^{2{,}17028013}*L_v^{0{,}18346204}$	0,968	0,029	9,83
1	$Y=0{,}30220171*L_v^{1{,}25681443}$	0,967	0,030	10,30
2	$Y=44157{,}69046423*DL^{2{,}17028013}*L_v^{2{,}35374216}$	0,968	0,029	9,83

The double entry equations with the variables diameter and length had bests quality parameters, mainly the equation 8, than those with single entry or squared variables. Equation 7, which is a non-linear and despite being a single entry, had goods quality parameters too. These two equations, in addition to having the bests qualitative adjustment parameters, they also show a low dispersion of residues as can be seen in Figures 2 and 3.

Figure 2. Residual distribution graph of the equation generated by model 7 to estimate the Sucupira-Vermelha lumber yield.

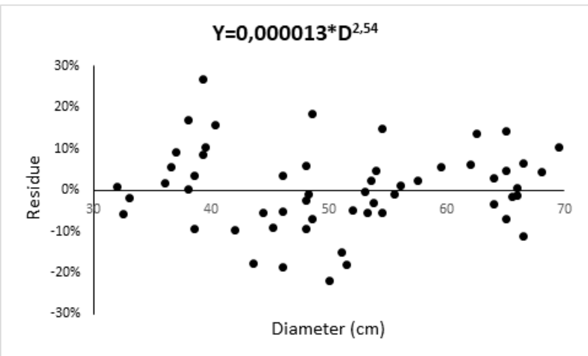
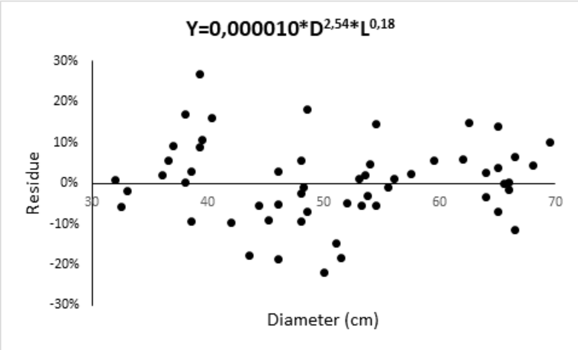


Figure 3. Residual distribution graph of the equation generated by model 8 to estimate the Sucupira-Vermelha lumber yield.



4 DISCUSSION

This study showed an average yield of 29.52% in Sucupira-Vermelha lumbering logs, thus, below the volumetric yield coefficient established by CONAMA Resolution nº. 474, of May 2, 2016, which is 35% of the log volume harnessing transformed into sawn wood not considering the use of residues.

Clement e Higuchi (2006) indicate a 30% yield for Amazonian species, this average is confirmed by data obtained from studies such as those performed by Danielli *et al.* (2016), which obtained 30.1% for the species Maçaranduba and, Marchesan *et al.* (2018), which obtained 26.43%, 29.22% and 33.99% yield for Jatobá, Muirapiranga and Muiracatiara species respectively. These data indicate the improvement needs in the sawing logs process aiming at a utilization of the raw material improvement, residue generation reduction and consequent increase in the product value added.

There are also studies that present higher average income results than the present study, such as those by Melo *et al.* (2016), which obtained an average of 52.18% for Cambará, Garcia *et al.* (2012) which obtained 46.39% and 49.64% for Tauari and Itaúba, species respectively, and, Carmo *et al*. (2020) wich obtained 49,79% for Teca. These large variations in yield between different species are influenced by several factors such as: different dimensions of parts produced, intrinsic characteristics of each species, technological level employed in the sawmill and market requirements (Melo *et al.* 2016). Due to this variety of tropical wood species and different performances during deployment, it is important to establish species specific volumetric yield coefficients.

The present study found a yield difference between diameter class 1 and the others, according to Rocha (2000), it is normal in sawmills that the smaller diameters logs have lower yields and that in larger logs there is a gradual increase in yield as the diameter classes increases. Especially in species with good stem formation and few defects such as hollows and cracks.

Marchesan *et al.* (2018) also observed a significant statistical yield difference only in the first diameter class for the species Jatobá, in relation to the other classes where yields had no significant statistical differences. These results corroborate with those found in this study, having the same behavior in the same diameter class, which indicates that some tropical species can be better utilized in sawmills when exploited with larger diameters, which would generate less waste of raw material in wood residue form.

The other two species studied by Marchesan *et al.* (2018): Muiracatiara and Muirapiranga, and, studies such as from Danielli *et al.* (2016) and Biasi e Rocha (2007), also showed a tendency of yield increase due to the logs diameter increase. However, these authors did not observe statistically significant differences between the diameter classes, even so, within a large-scale production these differences are important for making decisions aimed at reducing production costs and reducing residues generated by the sawmill.

The residue generation is inevitable when sawing a log, and there are several factors that determine the volume and types of pieces and fragments generated. The main factors are the log diameter and the final products dimensions. Other important factors are presence of cracks, hollows, knots, drills, stem tortuosity, among others. Danielli *et al.* (2016) observed an average residue generation of 70.06% for the species Maçaranduba and Marchesan *et al.* (2012) obtained 73.57%, 69.25% and 65.21% of sawing residues of Jatobá, Muiracatiara and Muirapiranga respectively. These data corroborate the 70.48% (± 1.13% confidence interval) obtained for the species studied in this work.

Model adjustment results of this work showed a strong correlation by Pearson's test between the independents variables diameter and log volume. This multicollinearity problem between these variables was also evidenced by Danielli *et al.* (2016) and Valério *et al.* (2009). Thus, the equations with the input of the log volume variable are not indicated for the estimation of lumber yield.

The equations with the bests results of estimated lumber yield generated by the present work were those of double entry with the variables diameter and log length, but is important to point out that model 7, also get good quality parameters. It is of simple input, with only the independent variable diameter (D) and is an important feature in choosing the equation due to the ease and convenience of measurement and has lower risk of sampling errors incidence (HIGUCHI *et al.* 1998).

Another important parameter used to evaluate the quality of the fit of mathematical models was the dispersion plots, where can be observed that the nonlinear equations 7, and 8 had a smaller dispersion of the estimation data, so being more accurate of this study.

Thus, the nonlinear models 7 (single input) and 8 (double input) presented the bests adjustments quality, both with adjusted determination coefficient (R^2) of 0.968, standard error of estimate (S_{yx}) of 0.0029 m^3 and variation coefficient (VC) of 9.83% and 9.74% respectively, besides having the most homogeneous residue distribution and having as independent variables the diameter (D) and length (L), which have a low correlation, being of great importance for the composition of mathematical models aiming the estimation of sawn wood. Thus, it is recommended to use models 7 and 8 to estimate sawn wood from logs of the *Andira parviflora* Ducke. species, 7 being the most practical because it is simple input (D) and 8 has a higher accuracy by have the lowest coefficient of variation (9.74%).

5 CONCLUSIONS

The tropical species Sucupira-Vermelha showed a yield increase due to the log diameter increase, and consequent residues generation decrease during the sawing log process.

This behavior of yield increasing as a result of logs diameter increasing shows that it is more viable to explore trees with larger diameters aiming at a better raw material utilization.

Nonlinear models 7 ($R = 0.000012 * D^{2.54}$) and 8 ($R = 0.000010 * D^{2.54} * L^{0.18}$), were the most suitable for Sucupira-Vermelha species sawn wood yield estimation.

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REFERENCES

Biasi, C. P.; Rocha, M. P. 2007. Rendimento em madeira serrada e quantificação de resíduos para três espécies tropicais. *Floresta,* v. 37, n. 1: 95-108.

Carmo, J. F.; Carmo, F., H., D., J.; Miranda, D., L., C.; Volpato, M.; Teixeira, K., T. 2020. Influência do desdobro tangencial no rendimento e na qualidade da madeira de *Tectona grandis* L. f. *Brazilian Journal of Animal and Environmental Research,* v. 3, n. 2: 808-814.

Conselho Nacional de Meio Ambiente, 2016. Resolução CONAMA nº 474/2016, 1: 74-75 (http://www2.mma.gov.br/port/conama/legiabre.cfm?codlegi=720). Acesso em 22/04/2019.

Danielli, F. E.; Gimenez B. O.; Oliveira C. K. A.; Santos J.; Higuchi N. 2016. Modelagem do rendimento no desdobro de toras de *Manilkara* spp. (Sapotaceae) em serraria do estado de Roraima, Brasil. *Scientia Forestalis*, v. 44, n. 111: 641-651.

Garcia, F. M.; Manfio, D. R.; Sansígolo, C. A.; Magalhães, P. A. D. 2012. Rendimento no desdobro de toras de Itaúba (*Mezilaurus itauba*) e Tauari (*Couratari guianensis*) segundo a classificação da qualidade da tora. *Floram,* v. 19, n. 4: 468-474.

Gotelli, N. L.; Ellison, A. M. 2010. *Princípios de estatística em ecologia.* 1ª ed. Artmed, Porto Alegre, 532p.

Graham, M. H. 2003. Confronting multicollinearity in ecological multiple regression. *Ecology*, v. 84, n. 11: 2809-2815.

Higuchi, N.; Santos, J.; Ribeiro, R. J.; Minette, L.; BIOT, Y. 1998. Biomassa da parte aérea da vegetação da floresta tropical úmida de terra-firme da Amazônia brasileira. *Acta Amazonica*, v. 28, n. 2: 253-166.

Higuchi, N.; Clement, C. R. 2006. A floresta amazônica e o futuro do Brasil. *Ciência e Cultura*, v. 58, n. 3: 44-49.

Iwakiri, S. 1990. Rendimento e condições de desdobro de 20 espécies de madeiras da Amazônia. *Acta Amazonica*, v. 20: 271-281.

Latorraca, J. V. F. 2004. *Processamento mecânico da madeira.* 1ª ed. Edur, Seropédica, 116p.

Marchesan, R.; Loiola, P. L.; Juizo, C. G. F.; França, M. C.; Rocha, M. P.; Klitzke, R. J. 2018. Rendimento em madeira serrada de três espécies amazônicas para duas classes de qualidade**.** *Ciência da Madeira,* v. 9, n. 3: 143-151.

Melo, R. R.; Rocha, M. J.; Rodolfo Jr., F.; Stangerlin, D. M. 2016. Análise da influência do diâmetro no rendimento em madeira serrada de cambará. *PFB,* v. 36, n. 88: 393-398.

Mendoza, Z. M. S. H., Borges, P. H. M., Morais, P. H. M., Santos, R. R. V. L. 2020. Resíduos madeireiros gerados pelo processamento mecânico em municípios de Mato Grosso. *Brazilian Journal of Animal and Environmental Research*, v. 3, n. 2: 616-628.

Oliveira, A. D.; Martins, E. P.; Scolfaro, J. R. S.; Rezende, J. L. P.; Souza, A. N. 2003. Viabilidade econômica de serrarias que processam madeira de florestas nativas – O caso do município de Jaru, Estado de Rondônia. *Cerne*, v. 9, n. 1: 001-015.

ROCHA, M. P. 2000. *Eucalyptus grandis Hill ex. Maiden e Eucalyptus dunnii Maiden como fontes de matéria prima para serrarias.* Tese de Doutorado, Universidade Federal do Paraná, Curitiba, Paraná. 185p.

Santos, J. dos. 1996. *Análise de modelos de regressão para estimar a fitomassa da floresta tropical úmida de terra-firme da Amazônia Brasileira*. Tese de Doutorado, Universidade Federal de Viçosa/ Instituto Nacional de Pesquisas da Amazônia, Viçosa, Minas Gerais. 121p.

Valério, A. F.; Watzlawick, L. F.; Balbinot, R.; Caldeira, M. V. W.; Figueiredo Filho, A. 2009. Modelagem para a estimativa do rendimento no desdobro de toras de *Araucaria angustifolia* (Bertol.) Kuntze**.** *Floresta*, v. 39, n.