ISSN: 2310–3469 RNPS: 2347
Revista Cubana de Ciencias Forestales. 2020; September-December 8(3): 507-518

CFORES
REVISTA CUBANA DE CIENCIAS FORESTALES

Translated from the original in spanish

Original article

Yield and dimensional quality of *Samanea saman* Jacq. Sawn timber at Guantanamo Agroforestry Enterprise sawmill

Rendimiento y calidad dimensional de la madera aserrada de *Samanea saman* Jacq. en aserradero de la Empresa Agroforestal Guantánamo

Rendimento e calidade da dimensional madeira serrada de *Samanea saman* Jacq. no Serradiço da Empresa Agroflorestal Guantánamo

Ivian Leyva Miguel[1*] https://orcid.org/0000-0002-3785-5235

Daniel Álvarez Lazo[2] https://orcid.org/0000-0001-7627-0152

Yoilan La O Mundis[3] https://orcid.org/0000-0002-1625-6743

Gabriel Céspedes Correa[1] https://orcid.org/0000-0002-6948-2402

Yemicer Segurado Gil[1] https://orcid.org/0000-0003-2661-4484

[1]Universidad de Guantánamo. Departamento Forestal. Guantánamo, Cuba.
[2]Universidad de Pinar del Río "Hermanos Saíz Montes de Oca", Centro de Estudios Forestales. Pinar del Río, Cuba.
[3]Empresa Agroforestal Sierra Cristal. Cuba.

[*]Correspondence author: ibian@cug.co.cu

Received: March 21th, 2020.
Approved: October 30th, 2020.

ABSTRACT

The study was carried out in the San Justo sawmill belonging to the Guantanamo Agroforestry Enterprise from September 2018 to April 2019, with the objective of evaluating the yield and dimensional quality of the *Samanea saman* Jacq. sawn timber. The quality of the raw material was analyzed, and the yield and dimensional quality of the sawn timber was determined. A yield of 52.8 % was obtained, where the quality of the raw material, the diameters, length and conicity of the logs influenced. The logs are processed and assortments of 25 and 50 mm above the pre-established dimensions are obtained, although not enough to compensate for the volume losses due to the contraction and sawing variation that occur between and within the pieces, so the technical conditions of the machinery and the skill of the technical personnel must be taken into account.

Keywords: Yield; Dimensional quality; Assortment and Sawn timber.

RESUMEN

La investigación se realizó en el aserrío San Justo perteneciente a la Empresa Agroforestal Guantánamo de septiembre de 2018 a abril de 2019, con el objetivo de evaluar el rendimiento y calidad dimensional de la madera aserrada de *Samanea saman* Jacq. Se analizó la calidad de la materia prima, se determinó el rendimiento y la calidad dimensional de la madera aserrada. Se obtuvo un rendimiento de 52,8 %, donde influyó la calidad de la materia prima, los diámetros, longitud y conicidad de las trozas. Las trozas son procesadas y se obtienen surtidos de 25 y 50 mm por encima de las dimensiones preestablecidas, aunque no lo suficiente para compensar las pérdidas de volumen debido a la contracción y a la variación de aserrado que ocurren entre y dentro las piezas, por lo que se debe tener en cuenta las condiciones técnicas de las maquinarias y la habilidad del personal técnico.

Palabras clave: Rendimiento; Calidad dimensional; Surtido y Madera aserrada.

RESUMO

O trabalho realizou se no serradiço San Justo, pertence à Empresa Agroflorestal Guantánamo, de setembro de 2018 até abril de 2019, com o objetivo de avaliar o rendimento e calidade dimensional da madeira serrada de *Samanea saman* Jacq. Analisou se a calidade da matéria prima, e também determinou se o rendimento da calidade dimensional da madeira serrada. Obtém se como resultado, um rendimento de 52,8 %, influenciado pela calidade da matéria prima, os diâmetros, longitude e conicidade das troças, sendo processadas depois e obtendo-se delas, surtidos de 25 e 50 mm por acima das dimensões preestabelecidas, embora de que não tenha sido o suficiente para a contrapartida das perdas de volumem devido à contração e variação do serrado que ocorrem entre e dentro das peças, pelo que devem ter se em conta as condições técnicas das maquinarias e a habilidade dos assistentes técnicos

Palavras chave: Rendimento; Calidade dimensional; Surtido e madeira serrada.

INTRODUCTION

The sawmill industry consists of a series of operations that are necessary to make the conversion of logs into sawn wood a feasible process, at least from the economic point of view; coinciding with Fregoso *et al*., (2017).

The number and complexity of these operations vary depending on factors such as the size of the sawmill, the technology employed, the species or group of species used in the process, the characteristics of the raw material, the destination of the processed wood waste, dimensions and degree of finishing of the final product, among others.

Worldwide, different technologies have been implemented that allow improving the efficiency indicators in the expertise and skill of the sawmill's technical staff, also, in the characteristics of the raw material, those that start from optimization programs in the sawmills (Vanzetti *et al.,* 2019), to those based on the application of sawing practices, supported fundamentally in the analysis of the different variables and the decision making of sawing in a short interval of time.

From the works developed by Álvarez *et al.,* (2019), Leyva *et al.,* (2017) and Morais *et al.,* (2019), it is determined that the conicity and quality of the mechanical transformation process during sawing, directly affects the efficiency of the sawing processes, fundamentally, in the yield of the sawn timber. For this problematic situation is that, with this work, it is intended to determine the yield and dimensional quality of the sawn timber of *Samanea saman* Jacq. in the sawmill San Justo, Guantanamo Agroforestry Enterprise.

MATERIALS AND METHODS

Characterization of the work area

This research was conducted in the San Justo sawmill, belonging to the Guantanamo Agroforestry Enterprise, between the months of September 2018 and April 2019, located on Avenida de los Estudiantes between 6 and 7 East, it has 33 workers, of these 23 directly involved in production and 10 indirectly. The establishment has: a storage area for the bolo wood and another one for the sawn wood outdoors and indoors; a transporting cart, a winch, a band saw, a pendulum and an edger.

Sample size

The data were taken from a population of 100 logs for *Samanea saman Jacq* (Carob tree), to determine the number of representative units for the study, having as variable of interest the diameter at the base of the logs; to determine the number of representative units for the study, from the equation exposed by Chacko (1965), Freese (1967), Lima *et al.,* (2019) and Alvarez *et al.,* (2019) (Equation 1).

$$n = \frac{t_{\alpha}^{2} * S^{2}}{E^{2}} \quad (1)$$

Where:

n- sample size;
$t^{2}_{á}$- tabular value of t with (n-1) degrees of freedom;
S^2 Estimated Variance;
E - Allowable Error.

Results in 76 logs, and we continue working with the totality of the analyzed logs (100 logs), demonstrating that the sampling done is representative of the area under study, with an absolute error (Ea) of 5.99 and a relative error (Er) of 8.98, for an error limit of 10 %.

Determination of the Conicity of the Logs

To determine the conicity of the logs, the formula used by Santos *et al.,* (2019) and Álvarez *et al.,* (2019) (Equation 2).

$$Con = \frac{(D_2 - D_1)}{L} \quad (2)$$

Where:

Con- conicity, cm /m;
D_1 Minor diameter of the log, (cm);
D_2 - Larger log diameter, (cm);
L - Length of the log, (m)

Dimensional control of the sawn timber

Following the indications of Denig (1990) and Álvarez *et al.,* (2010), samples of 100 pieces were taken, 10 in each work day. In the 25 and 50 mm assortments according to the Ramal Standard 43-17/1983.

Six measurements were taken for each piece, three on each edge, equidistantly along the length of the pieces, taking care to establish a permanent sequence of measurements with respect to the direction of exit of the pieces from the saw (Álvarez *et al.,* 2019), with the objective of identifying possible problems in the equipment. The measurements were made with a Vernier caliper in areas of healthy wood, avoiding knots, rotting or other defects.

Due to the complexity and volume of the calculations, especially in the computation of thickness variations in the sawmill when a large sample is available, it was necessary to find an agile and feasible tool to process the data (Álvarez *et al.,* 2020).

For this purpose, the Control software version 5.1 was used to determine the optimal sawing dimensions; as well as the determination of the variation in thickness, which is based on the formulation proposed by Brown (1986), for the calculation of the optimal dimension of the assortment and other parameters that are described below (Equation 3).

Calculation of the optimal dimension (D_o)

$$D_o = \frac{DF + TC}{(1 - \%C)} + Z * St \qquad (3)$$

Where:

D_o - Optimal cutting dimension of green wood, mm;
DF- Final Dimension, mm;
TC- Tolerance for brushing on both sides of the assortment, mm;
%C- Wood shrinkage tolerance, %;
Z- minimum acceptable dimension factor (dimensionless);
St- Total sawing variation, mm.

(Equation 4).

$$St = \sqrt{Sd^2 + Se^2}$$

Sd- standard deviation of the sawing process within the pieces (mm.);
Se- standard deviation of the sawing process between pieces, mm.

ISSN: 2310–3469 RNPS: 2347
Revista Cubana de Ciencias Forestales. 2020; September-December 8(3): 507-518

(Equation 5).

$$Sd = \sqrt{\bar{S}^2} \qquad (5)$$

(Equation 6).

$$Se = S^2(\bar{x}) - \frac{Sd^2}{n}$$

$$Se = S^2(\bar{x}) - \frac{Sd^2}{n} \qquad (6)$$

Where:

$S^2(\bar{x})$- represents the variance of the averages of the thicknesses of each sampled piece;
n - number of measurements per piece.

On the other hand, the Critical Dimension (Dc) variable, which is related to the dimension of green wood, should be taken into consideration if pieces could be produced without sawing variation. The mathematical expression that makes it possible to determine this dimension is (Equation 7).

$$D_c = \frac{DF + TC}{(1 - \%\, C)} \qquad (7)$$

The percentage of tangential contraction (Álvarez *et al.,* 2019), of the evaluated species is determined from the works developed by Ibáñez *et al.,* (2001), defined in 2.30 %.

Determination of the sawn timber yield

The following ratio was used to obtain the percentage yield (Barth *et al.,* 2016; Orozco *et al.,* 2016; Casagrande *et al.,* 2019) (Equation 8).

$$R_v = \left[\frac{Vma}{Vt}\right] * 100 \qquad (8)$$

Where:

Rv - Total volumetric yield %;
Vma- Sawn timber volume, m^3;
Vt- Wood volume in logs, m^3;

The total volume of sawn wood in each log at the sawmills is determined on the basis of linear measurements obtained from sawn wood according to the following expressions (Equation 9).

$$Vma = \sum_{i=1}^{n} (a_i * g_i * l_i) \qquad (9)$$

Where:

Vma- Sawn timber volume of a log, m^3;
a_i, g_i I_i, width, thickness and length of the piece i obtained from a log or group of logs, m;
n- Number of pieces sawn from a log

The calculation of the gross volume of each log was made through the Smalian formula, taking into consideration the work developed by Casagrande *et al.,* (2019), as shown in the following equation (Ecuación 10).

$$Vmb = \frac{g_1 + g_2}{2} * L \qquad (10)$$

Where:

Vmb, volume of the wood in logs (m^3);
Vma, volume of sawn wood (m^3); g_1,
g_1 basal area at the thin end (m^2);
g_2, basal area at the thick end (m^2);
L, length of the log (m).

Statistical analysis

For each of the variables mentioned above (diameters at the three ends, length, conicity, yield and thickness of the different assortments), the statistical postulates, additivity of effects, non-correlation of errors were checked and the tests of normality (Kolmogorov-Smirnov) and homogeneity of variance were performed (Di Rienzo *et al.,* 2009).

RESULTS AND DISCUSSION

Characterization of the raw material

Table 1 shows the descriptive analysis of the logs used, taking into consideration the maximum, minimum, mean, standard deviation (SX) and standard error (S.E.) values.

The variables analyzed in these logs are the following: major diameter (Dg), minor diameter (Df) and length (L). The magnitude of the minimum diameter is 29 cm and can reach 118 cm with an average length of 2.50 cm.

ISSN: 2310–3469 RNPS: 2347
Revista Cubana de Ciencias Forestales. 2020; September-December 8(3): 507-518

Table 1. - Descriptive analysis of the logs

Factor	Medium ($\overline{X}$)	Minimum	Maximum	Typical deviation (Sx)	E.E
Dg, cm	75,05	35,00	118,00	25,29	2,53
Df, cm	67,79	29,50	110,00	22,79	2,28
L, m	2,50	2,10	3,70	0,37	0,24

The size of the logs is one of the factors that most affects the yield of sawn wood, since as the diameter increases, the yield also increases, and therefore has a positive influence, this coincided with the opinion of specialists such as Álvarez *et al.,* (2010), Ortiz *et al.,* (2016) and Leyva *et al.,* (2017), in research conducted where they indicate that the diameter of the log is one of the factors with the greatest incidence in sawing; demonstrating that as the diameter increases, the yield of logs in the sawing also increases; therefore, the procedure of small-sized logs implies low levels of yield and less profit in the sawmills.

Conicity analysis

This defect is the most important one that we should take into account when working with wood. Of the logs evaluated, 45 % have a small taper, 27 % medium and 28 % large. With maximum values of 11.90 cm/m, average values of 2.91 cm/m, standard deviation of 2.95 and an error of 0.295.

On the other hand, it can be established from the Brazilian standard for the classification of hardwoods (IBDF, 1984), that the logs of the four species investigated can be classified as superior quality logs or SU, based on the fact that these same logs present conicities below 3 cm/m, further defining that these conic magnitudes will not have a negative influence on the efficiency of the sawmill, coinciding with Santos *et al.,* (2019); reaffirming the approaches of Zhang *et al.*, (2005) and Leckoundzou (2011), exposed in the following mathematical expression, which has as references the analysis of elasticity (Equation 11).

$$E = (\text{Rend}, \text{Con}) = \left({}^{\partial \text{Rend}}/_{\partial \text{Con}}\right)\left({}^{\text{Con}}/_{\text{Rend}}\right) \qquad (11)$$

All of which defines that the very evaluation of the quality of the logs to be used as raw material in the sawing industry. They affect the final product and the same efficiency of the transformation process, coinciding in this sense with Andrea *et al.*, (2019).

Analysis of the optimal dimension of the sawn timber

Dimensional control

For the 25 mm set the wood should be cut to 29.94 mm and 26.73 mm and for the 50 mm set the wood should be cut to 51.59 mm and 60.12 mm. In both cases the wood is cut above the pre-established dimensions, although not enough to compensate for volume losses due to shrinkage, up to 12 % humidity and sawing variation as shown in the Table 2.

Table 2. - Dimensional variations of *Samanea saman* sawing

Parameters/Assortments	25 mm	50 mm
Average Dimension, mm	26,73	51,59
Optimum Dimension, mm	29,94	60,13
Critical Dimension, mm	25,48	50,95
Standard deviation within parts, mm	1,62	2,42
Standard deviation between parts mm	2,16	5,01
Total standard deviation (Total process)	2,71	5,56

Similar results to those obtained for the *Pinus caribaea* according to Álvarez *et al.,* (2005) in Pinar del Rio for the (assortments 13; 50 and 100 cm) in Rigo Fuentes, in addition to those obtained by Leyva *et al.*, (2017), for the assortments 25 and 50 mm for the *Pinus cubensis* in sawmill of Yateras, municipality of Guantánamo.

In addition, the results related to the total sawing variation for the assortments of 25 and 50 mm in the species with values between 2.71 and 5.56 are also presented. Similar results to those obtained by Álvarez *et al.,* (2005) for the Rigo Fuentes establishment for the same species mentioned above with values that, in a certain way, are close to those found, however they are above the values 1.14 - 1.75 mm reported by Steele *et al.,* (1992). The great variation of the cut is a result of the variations within and between the pieces.

The large variation in thickness within the pieces is due not only to excessive deviations of the saw blade from its normal trajectory, but also to the poor alignment of the squares of the carriage, which leads to obtaining all internal parts (parts attached to the squares of the carriage) with significant defect of wedge to one direction and external parts (parts away from the square of the carriage) free or random, affected by this defect to one direction or another.

In addition, the transport cart was missing two mounting brackets, being another cause for which the assortments do not come out uniform. The great variation in thickness that can be observed between pieces is also due to the inaccuracies committed by the sawmill that in many occasions' projects cutting schemes that tend to under-dimension or over-dimension the interior pieces.

The statistical control of the sawing process shows that the process is out of control and, therefore, it is necessary to analyze the quality of the raw material, the machinery used and the skill of the operator; coinciding with what has been exposed by Young *et al*., (2007), Barrera *et al.* (2016), Leyva *et al.*, (2017) and Álvarez *et al.,* (2019), in their investigations.

Fundamental aspects to achieve greater efficiency in the forestry industry where the use of mathematical models are very valuable tools in the sawmills.

ISSN: 2310–3469 RNPS: 2347
Revista Cubana de Ciencias Forestales. 2020; September-December 8(3): 507-518

Determination of yield

In determining the yield of *Samanea saman* in the San Justo sawmill (Figure 1), yield values ranging from 15 % to 85 % were obtained, with average values of 52.8 %.

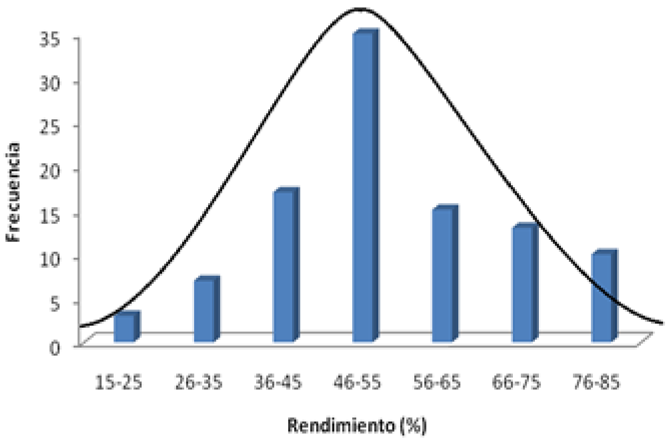

Figure 1. - *Samanea saman* yield histogram

The highest frequency of yield is between 46 % and 55 %, the same varies in the small and larger logs. This yield could have been better, but some factors influenced, for example: length, conicity, slicing diagram, type of saw, quality of the logs and diameter. According to Meza and Simón (2006), the latter has a great influence on the yield. For small diameter logs, the yield is lower, but as the diameter class increases, the yield increases.

CONCLUSIONS

The logs evaluated have a minimum diameter of 29 cm and can reach 118 cm with an average length of 2.50 cm with an average yield of 52.8 %.

The wood is sawn above the pre-established dimensions, although not enough to compensate for volume losses due to shrinkage and sawing variation that occur between and within the pieces, so it must be taken into account due to the technical conditions of the machinery and the skill of the personnel.

REFERENCES

ÁLVAREZ, D., GARCÍA, J.M., DOMÍNGUEZ, A., RODRÍGUEZ, J.C. y ALEJAOS, J., 2010. Lumber recovery Factory with low enviromemental impact in Pinar del Rio. *The International Forestry Review*, vol. 12, no. 5, pp. 303.

ÁLVAREZ LAZO, D., DOMINGOS DOMINGOS SEBASTIAO, J., NAZARE NAZARE BUANGA LELO, F., SILVA FUENTES, S. y ESTEVES VALDES, I., 2019. Análisis de la calidad del aserrado de maderas tropicales en Cabinda, Angola. *Revista Cubana de Ciencias Forestales* [en línea], vol. 8, no. 1, pp. 34-53. [Consulta: 23 marzo 2020]. ISSN 2310-3469. Disponible en: http://cfores.upr.edu.cu/index.php/cfores/article/view/452.

BARRIOS, R.O., MARTÍNEZ, S.D., RABANALES, D.E.V. y JUÁREZ, W.S., 2016. DETERMINACIÓN DEL COEFICIENTE Y CALIDAD DE ASERRÍO DEL GÉNERO Pinus EN LA REGIÓN SIERRA SUR, OAXACA, MÉXICO. *Colombia Forestal* [en línea], vol. 19, no. 1, pp. 79-93. [Consulta: 23 marzo 2020]. Disponible en: https://www.redalyc.org/jatsRepo/4239/423943446006/html/index.html.

BARTH, S., GIMENEZ, A.M., JOSEAU, M.J., GAYCHAT, M.E. y VIDELA, D., 2016. Influencia de la densidad de plantación y la posición sociológica en el rendimiento y la calidad de madera aserrada de Grevillea Robusta A. *Quebracho - Revista de Ciencias Forestales* [en línea], vol. 24, no. 1-2. Disponible en: https://www.redalyc.org/pdf/481/Resumenes/Resumen_48150051006_1.pdf.

BROWN, T.D., 1986. *Lumber size control. Forestry Business* [en línea]. USA: College of Forestry. Oregon State University. Disponible en: http://lumberquality.com/wp-content/uploads/2014/12 /Performance-Excellence-EM8731.pdf.

CASAGRANDE, M., OLIVEIRA, A.C., PEREIRA, B.L. y FREITAS, J.M., 2019. Yield in sawnwood and residue utilization of Quarea paraenses Ducke and Erismauncitum Warn. *Floresta, Curitiba, PR*, vol. 49, no. 2, pp. 257-266.

CHACKO, V.J., 1965. *A manual on sampling techniques for forest surveys* [en línea]. Delhi: Manager of Publications. [Consulta: 23 marzo 2020]. Disponible en: http://catalog.hathitrust.org/api/volumes/oclc/473838.html.

DENIG, J., 1990. *Control de la calidad en aserraderos de pino del sur*. S.l.: North Carolina Cooperative Extension Service.

DI RIENZO, J.A., CASANOVES, F., GONZALEZ, L.A., TABLADA, E.M., DÍAZ, M. y BALZARINI, M.G., 2009. *Estadística para las Ciencias Agropecuarias*. S.l.: Editorial Brujas.

FREESE, F., 1967. *Elementary statistical methods for foresters* [en línea]. Washington, D.C.: U.S. Dept. of Agriculture, Forest Service. Disponible en: https://www.worldcat.org/title/elementary-statistical-methods-for-foresters/oclc/2665498.

FREGOSO-MADUEÑO, J.N., GOCHE-TÉLLES, J.R., RUTIAGA-QUIÑONES, J.G., GONZÁLEZ-LAREDO, R.F., BOCANEGRA-SALAZAR, M. y CHÁVEZ-SIMENTAL, J.A., 2017. Alternative uses of sawmill industry waste. *Revista Chapingo serie ciencias forestales y del ambiente* [en línea], vol. 23, no. 2, pp. 243-260. [Consulta: 23 marzo 2020]. ISSN 2007-4018. DOI 10.5154/r.rchscfa.2016.06.040. Disponible en: http://www.scielo.org.mx/scielo.php?script=sci_abstract&pid=S2007-40182017000200243&lng=es&nrm=iso&tlng=en.

IBÁÑEZ, A., HERNÁNDEZ, C., GARCÍA, J.M. y SOSA, C., 2001. Propiedades y usos de 50 especies maderables que crecen en Cuba. Ciudad Habana, Cuba: Ministerio de la Agricultura, IIF.

IBDF - INSTITUTO BRASILEIRO DE DESENVOLVIMENTO FLORESTAL, 1984. Norma para medição e classificação de toras de madeiras de folhosas. Brasília: Brazilian measurement and grading rules for hardwood logs.

LECKOUNDZOU, A., 2012. *Utilización de variables dendrométricas para predecir los rendimientos de madera aserrada de árboles en pié de Pinus caribaea var. Caribaea*. Doctorado en Ciencias Forestales. Pinar del Río, Cuba: Universidad de Pinar del Río «Hermanos Saíz Montes de Oca».

LIMA, R.B.D., FERREIRA, R.L.C., SILVA, J.A.A.D., GUEDES, M.C., SILVA, D.A.S.D., OLIVEIRA, C.P.D., RABELO, F.G. y SILVA, L.F.D.C., 2020. Effect of species and log diameter on the volumetric yield of lumber in northern Brazilian Amazonia: preliminary results. *Journal of Sustainable Forestry* [en línea], vol. 39, no. 3, pp. 283-299. [Consulta: 23 marzo 2020]. ISSN 1054-9811. DOI 10.1080/10549811.2019.1636661. Disponible en: https://doi.org/10.1080/10549811.2019.1636661.

MENDOZA, Z., BORGES, P., MORAIS, P. y ELIAS, M., 2019. USE OF BETA REGRESSION TO ESTIMATE THE VOLUMETRIC YIELD COEFFICIENT IN LOGS OF NATIVE SPECIES OF THE LEGAL AMAZON. *Nativa* [en línea], vol. 7, pp. 323. DOI 10.31413/nativa.v7i3.6834. Disponible en: https://redib.org/Record/oai_articulo2278861.

MEZA-MONTOYA, A. y SIMÓN, D., 2006. Aserrío de trozas de diámetros menores. *Revista Forestal Mesoamericana Kurú* [en línea], vol. 4, no. 10, pp. ág. 63-65. [Consulta: 23 marzo 2020]. ISSN 2215-2504. Disponible en: https://revistas.tec.ac.cr/index.php/kuru/article/view/501.

MIGUEL, I.L., ROMERO, A.R. y GIL, Y.S., 2017. Determinación del rendimiento y calidad dimensional de la madera aserrada en aserríos en la Provincia de Guantánamo. *Revista Cubana de Ciencias Forestales* [en línea], vol. 5, no. 3, pp. 340-351. [Consulta: 23 marzo 2020]. ISSN 2310-3469. Disponible en: http://cfores.upr.edu.cu/index.php/cfores/article/view/212.

MINISTERIO DE LA AGRICULTURA NORMA RAMAL 43-17, 1983. Clasificación de la madera aserrada. La Habana, Cuba: Ministerio de la Agricultura.

OROZCO CONTRERAS, R., HERNÁNDEZ DÍAZ, J.C., NÁJERA LUNA, J.A., DOMÍNGUEZ CALLEROS, P.A., GOCHE TELLES, J.R., LÓPEZ SERRANO, P.M. y CORRAL RIVAS, J.J., 2016. Rendimiento en calidad de la madera aserrada de pino. *Revista mexicana de ciencias forestales* [en línea], vol. 7, no. 36, pp. 37-50. [Consulta: 23 marzo 2020]. ISSN 2007-1132. Disponible en: http://www.scielo.org.mx/scielo.php?script=sci_abstract&pid=S2007-11322016000400037&lng=es&nrm=iso&tlng=es.

SANTOS, M.F., GAMA, J.R., FIGUEREIDO, A.F., COSTA, D.L., RETSLAFF, F.A.S., SILVA-RIVEIRO, R.B. y RODE, R., 2019. Conicity and yield for lumber from commercial species from the Amazon. *Cerne*, vol. 25, no. 4, pp. 439-450.

STEELE., P., EL-RADI, T. y BULLARD, H.S., 1992. Direct comparison of processing technology in hardwood and softwood sawmills. *Proceedings of Structural Panels and Composites Lumber Symposium* [en línea]. USA: DEStech Publications, Inc, Disponible en: https://books.google.com.cu/books?id=G5qbBAAAQBAJ&pg=RA10-PA101&lpg=RA10-PA101&dq=Proceedings+of+Structural+Panels+and+Composites+Lumber+Symposium&source=bl&ots=HWlKGwYgYH&sig=ACfU3U1UEXGEeABDv0j5n6zvqP5iI7QF-g&hl=es-419&sa=X&ved=2ahUKEwijqIy0nbHoAhVjmuAKHW7hAKoQ6AEwAXoECAoQAQ

#v=onepage&q=Proceedings%20of%20Structural%20Panels%20and%20Composites%20Lumber%20Symposium&f=false.

VANZETTI, N., BROZ, D., CORSANO, G. y MONTAGNA, J., 2019. A detailed mathematical programming model for the optimal daily planning of sawmills. *Canadian Journal of Forest Research*, vol. 49. DOI 10.1139/cjfr-2019-0144.

YOUNG, T. y BOND, B., 2007. Implementation of a real-time statistical process control system in hardwood sawmills. *Forest Products Journal* [en línea], vol. 57, pp. 54-62. Disponible en: https://www.researchgate.net/publication/43257868_Implementation_of_a_real-time_statistical_process_control_system_in_hardwood_sawmills.

ZHANG, S.-Y. y TONG, Q.-J., 2005. Modeling lumber recovery in relation to selected tree characteristics in jack pine using sawing simulator Optitek. *http://dx.doi.org/10.1051/forest:2005013* [en línea], vol. 62. DOI 10.1051/forest:2005013. Disponible en: https://www.researchgate.net/publication/43326739_Modeling_lumber_recovery_in_relation_to_selected_tree_characteristics_in_jack_pine_using_sawing_simulator_Optitek.

Conflict of interests:

The authors declare not to have any interest conflicts.

Authors' contribution:

The authors have participated in the writing of the work and analysis of the documents.