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Modelos matemáticos para la predicción de los rendimientos y calidad de la madera aserrada

Mathematical models for the prediction of sawnwood yields and quality

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Resumen

La investigación se realizó en rodales de *Pinus cubensis* Griseb y aserradero en la Empresa Agroforestal Sierra Cristal, desde enero de 2019 a diciembre 2020, con el objetivo de estimar modelos matemáticos que posibiliten predecir el rendimiento y calidad de la madera aserrada. Se evaluó la influencia de los parámetros dendrométricos y presencia de nudos, a partir de la magnitud del diámetro, altura hasta la primera rama, altura de copa, altura total, área basal, conicidad y la calidad de la madera en pie. El modelo de mejor resultados fue el 3: rendimiento = 33,39 + 0,69 $d_{1,\ 30}$ -3,13X_1 -7,45$X_{2.}$
Palabras clave: Aserradero, Modelos matemáticos, Rendimiento, Dendrométricos.

Abstract
The research was conducted in stands of Pinus cubensis Griseb and sawmill in the Sierra Cristal Agroforestry Company, from January 2019 to December 2020, with the objective of estimating mathematical models that make it possible to predict the yield and quality of sawn timber. The influence of dendrometric parameters and the presence of knots was evaluated, based on the magnitude of diameter, height to the first branch, crown height, total height, basal area, taper and quality of standing timber. The best performing model was 3: yield = 33.39 + 0.69 d1, 30 -3.13X1 -7.45X2.

Keywords: Sawmill, Mathematical models, Yield, Dendrometric

Introduction

Álvarez, et al. (2010) state that in the new era of globalization, the sustainability of production processes in their entire context and the requirements of international treaties and conventions, impose new challenges on companies and institutions that need to improve their production methods and be able to offer the market a product that satisfies the interests and demands of society and, above all, that ensures both present and future generations the goods and services provided by forests.

They also explain that the primary wood processing industry worldwide is facing the challenge of improving the levels and quality of products and processes, since wood continues to be a highly appreciated product, not only for its characteristics that make it irreplaceable for some uses, but also for its multipurpose character and that it is obtained from renewable raw material sources.

The sawmilling industry in Cuba is very far from the average annual productivity results of a certain number of countries, expressing that there are many causes for this, but undoubtedly the inadequate infrastructure plays a predominant role; which has been exposed by Levsque (2009).

In Cuba, Pinus plantations have been increasing considerably, due to their versatility, playing a leading role in the country's reforestation plans, according to Linares, et al. (2009).

The changes experienced in technology and the tendency to try to satisfy the demands of a growing population imply a greater accuracy in the determination of timber volumes thus in the yield and quality in sawmills, according to Alvarez, et al.

However, Álvarez, et al. (2010), state that in recent years more modern sawmills have been implemented, with more advanced technology that favors the quality of the wood obtained, and allows increasing industrial productivity and technical and economic efficiency.

Predictions by means of mathematical models are very valuable tools that all forestry companies should implement in order to optimize lumber yield. These models are a necessity for companies to improve their income and, perhaps most importantly, to reduce timber loss, according to Leckoundzou (2011).

In the sawmills of Santiago de Cuba province, there are low levels of productivity and quality in sawn timber, which implies the need for planning in excess of the real needs of bolus wood in the sawmills and in the implementation of viable technology to reduce the extraction of wood from the forests, since it would work in an integral way from the forest to the industry, predicting the volumes and thicknesses of the trees to be cut to achieve the desired yields.

According to the above, the general objective of this work is to estimate mathematical models that make possible the prediction of yield and quality of sawn timber, based on dendrometric parameters of standing trees of Pinus cubensis Griseb.

Development

The Sierra Cristal Agroforestry Enterprise is located in the northwestern portion of the Segundo Frente municipality, with a territorial extension of 19,795.94 ha. The data were taken from lot 2, stands 9 and 11 of the Corea Silvicultural Unit, by means of random sampling, where the volume (V.ha-1) was used as the variable of interest.

To calculate the sample size, it was first necessary to determine the sampling intensity (f):

f = sampling intensity.

Where:

f= fraction or sampling intensity.

n= number of units or area sampled

N = number of units of the total population or surface area.

As (1-f) > 0.98; the population is infinite and the following formula is used:

As a function of variance:

As a function of the coefficient of variation:

Where:

t= Student's t distribution for a significance level 0.05, s2= variance.

E= error, cv= coefficient of variation and LE= limit of error.

The following formulas were used to determine the sampling errors:

Absolute error:

Relative error:

A simple random sampling was used, where the fundamental selection process from which all other procedures were derived, was to increase the accuracy of estimates and reduce survey costs according to the methodology of Aldana, et al. (2010).

Ten plots of 20 x 25 m (500 m2) were taken, where 10 trees were felled, the dendrometric parameters were measured and the quality of the trees was determined, then they were cut and marked for their identification and transfer to the sawmill to be processed and obtain information on volume, yield and quality.

The formula used by Henry, et al. (2010) and Alvarez et al. (2010) was applied to determine log taper:

$$Con = \frac{D_2 - D_1}{L}$$

To obtain the yield in percentage, the relationship used by Álvarez, et al.

(2010):

$$R_v = \left(\frac{Vma}{Vt}\right)*100$$

Methodology for determining the quality of standing trees

For the determination of the quality of standing trees, reference was made to the work carried out by Murillo and Camacho (1997) and Murillo (2001), who determined the quality of the whole tree or its first two logs (>2.5 m long), dividing them into four quality categories as shown in Figure 1.

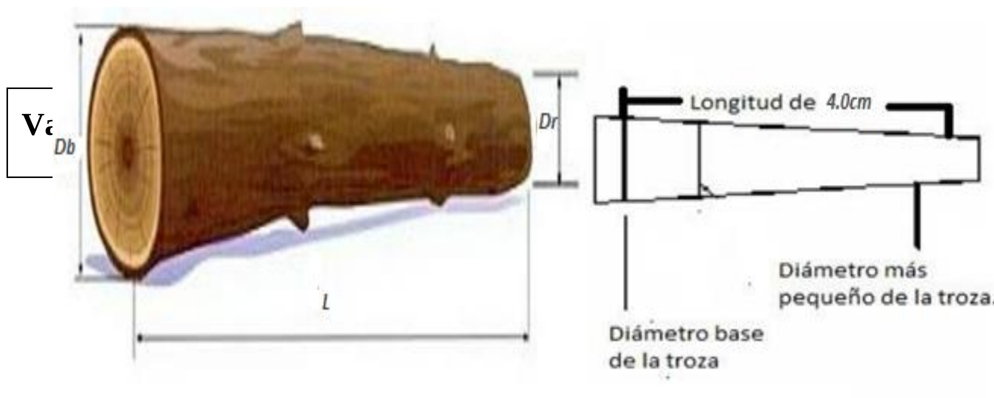

Figure 1. Graphical representation of log taper.

Source: Murillo (2001).

The assignment of wood quality is based on different quantitative and qualitative variables, which are examined in each individual. The variables considered are the following: diameter, taper, curvature, mechanical damage and length.

Mathematical modeling of the influence of the in-metric parameters of standing trees on lumber yields

Correlation and simple linear regression analyses were used to estimate the models. The independent or predictor variables used were diameters at 1.30 m (d1.30), commercial height, conicity and quality of the standing trees. The response or dependent variable used was lumber yield, in accordance with the work done by Egas, et al. (2001), Aranzeta, et al. (2004) and Ayessa (2011).

Table 1 shows the sample size calculation that was performed for an error of ±10% and a probability of 95%. The variable of interest was the volume per hectare (V.ha-1) and when statistically processed, the 10 plots of 100 m2 raised in the pilot sampling, it was determined that they were sufficient, which infers that the sampling carried out is representative.

It can be stated that when determining the relative error, it indicates that there is reliability of the sample size, with a relative error of 7.14% below that proposed, which indicates that the sample is representative for the volume per hectare in the research area.

Sample number	10	-
Mean	20,314	m^3/ha
Variance	0,004	$(m^3/0,01\ ha)^2$
Standard deviation ( )	0,066	$(m^3/0,01\ ha)^2$
Relative error (Er)	7,14	%

Table 1. Sample size in the ecosystem for mangrove species.

Source: Own elaboration.

Table 2 shows the correlation matrix of variables for the trunk with the volume of bolus wood (Vmb), as a dependent variable with respect to the independent variables. Diameter at 1.30 in the thinnest part, diameter in the middle, height of the shaft and commercial height, where it is observed that the variables that correlate more strongly are the three diameters, being stronger with the diameter at a half, since during the processing of the data in the correlation matrix, it was observed, that all quantitative variables have highly significant coefficients, with the dependent variable yield, ($p \leq 0.001$), in addition the diameter presents a greater strength in its linear relationship. This result coincides with that reported by Ayessa (2011).

		Diameter 1.30	Commercial Height	Total height	Conicity	Site index	Yield
Diameter 1.30	Pearson's correlation	1	,649**	,663**	-,562**	,642**	,911**
	Sig. (bilateral)		,000	,000	,000	,000	,000
	N	100	100	100	100	100	100
Commercial Height	Pearson's correlation	,649**	1	,763**	-,522**	,599**	,601**
	Sig. (bilateral)	,000		,000	,000	,000	,000
	N	100	100	100	100	100	100
Total heigh	Pearson's correlation	,663**	,763**	1	-,459**	,710**	,645**
	Sig. (bilateral)	,000	,000		,000	,000	,000
	N	100	100	100	100	100	100

Conicity	Pearson's correlation	-,562**	-,522**	-,459**	1	-,438**	-,584**
	Sig. (bilateral)	,000	,000	,000		,000	,000
	N	100	100	100	100	100	100
Site index	Pearson's correlation	,642**	,599**	,710**	-,438**	1	,619**
	Sig. (bilateral)	,000	,000	,000	,000		,000
	N	100	100	100	100	100	100
Yield	Pearson's correlation	,911**	,601**	,645**	-,584**	,619**	1
	Sig. (bilateral)	,000	,000	,000	,000	,000	
	N	100	100	100	100	100	100
**. La correlación es significativa al nivel 0,01 (bilateral).							

Table 2. Correlations

Source: Own elaboration

The success of any multivariate technique, including multiple regressions, begins with the selection of the variables to be used in the analysis. Since multiple regression shows a dependency relationship, it must be specified which variable is used as the criterion and which variables are used as predictors. The selection of both types of variables should be based mainly on conceptual or theoretical grounds according to the explanation of Hair, et al. (1999). Data transformations provide a means of modifying the variables in order to improve the correlation between variables in correspondence with Hair, et al. (1999).

Table 3 shows a summary of the models, where the one with the best performance was model 3, which includes diameter at 1.30 and quality, because although conicity is significant, the contribution to the decrease in R2 and standard error is not so relevant with the complexity of incorporating this variable into the model from a practical point of view.

Estimated regression equation: Yield= 33.39 + 0.69 d1,-3.13X1 -7.45X2 best fit and prediction behavior model corresponds to that reported by Barrio et al. (2004) in models of tree yield in various forest species.

Model	R	R square	R corrected square	Typical estimation error

1	,911[a]	,831	,829	3,024567
2	,927[b]	,860	,857	2,767620
3	,934[c]	,872	,868	2,651263
4	,938[d]	,880	,875	2,579653

Table 3. Summary of the model.

Source: Own elaboration

From this model it is possible to predict the yields and quality of the sawn wood of the species Pinus cubensis and it is important to guarantee from an economic point of view a better commercialization of the product, also from the environmental indicator it allows a better work in the ecosystem in function of guaranteeing a viable ecosystem, with an adequate management from the silviculture and the use.

Conclusions

There is a relationship between the yield of Pinus cubensis Griseb sawn timber, the diameter at 1.30 and the quality of the standing trees, to estimate the volumes of timber to be harvested according to the needs of the sawmills to meet their production plans.

The best performing mathematical model was 3: yield = 33.39 + 0.69 d1.30 -3.13X1 -7.45X2 , in order to guarantee the prediction of yields and lumber quality.

Bibliographic references

Aldana, E. (2010). *Ordenación de montes*. La Habana: Félix Varela.

Álvarez, D., Betancourt, Y., Rodríguez, J.F., Pastor, J.F., Villalba, M.J., Alaejos, J., Prades, C., Álvarez, E. y Candano, F. (2010). *Aprovechamiento Forestal*. La Habana: Félix Varela.

Alvarez, D., Dorado, M. y Fernández, H. (2010). *Tecnología de la madera*. Argentina: Universidad de Córdoba.

Alvarez, D., Egas, F. A., Esteves, I. Chávez, P. y Garcia, J. M. (2003). Análisis matemático para elevar la eficiencia en los aserraderos. *Revista Chapingo*. (9), 79-99.

Barrio, M., Álvarez, J. G. y Díaz Maroto, H. (2004). Elaboración de una tarifa con clasificación de productos para Quercus robur L. en Galicia basada en un modelo de cálculo porcentual. *Invest. Agrar: Sist. Y Recur. For. 13*(3), 506- 517.

Egas, F. A., Álvarez, D., Estévez, I. y García, J. M. (2001). Factores fundamentales para aumentar el rendimiento volumétrico en los aserraderos de Cuba. *Revista Chapingo, 7(*2), 163-168.

Hair, J. F., Anderson, R. E., Tatham, R. L. y Blanck, W. C. 1999. *Análisis multivariante*. Madrid: Prentice Hall Iberia.

Henry, P. P., García, J. M., González, A., López, R., García, M. V. y Moreno, I. (2010). Estudio de algunas características morfológicas del fuste de Cedrela odorata L. en plantaciones intensivas. *Revista Forestal Baracoa*, *29*(2), 57-65.

Leckoundzou. A. (2011). *Influencia de diferentes variables dendrométricos y calidad de árboles en pie sobre los rendimientos de madera aserrada de Pinus caribaea* Morelet var. Caribaea Barret y Golfari. (Tesis de Doctorado). Pinar del Rio, Cuba.

Levsque, M. (2009). *Industria forestal primaria. Diagnóstico de la industria forestal en Cuba*. Proyecto para el desarrollo del sector forestal. La Habana: Ministerio de la Agricultura.

Macdonald, W. (1972). *Estudio de la situación de los aserraderos en Cuba*. La Habana: INDAF.

Murillo, O. (2001). *Estado del desarrollo de la evaluación y control de calidad de plantaciones forestales en Costa Rica*. En V Congreso Mexicano de Recursos.

Murillo, O. y Camacho, P. (1997). *Metodología para la evaluación de la calidad de plantaciones recién establecidas*. *Agronomía Costarricense 21*(2), 189-206.

Zamora, A., Casado Sanz, M. y Pando Fernández, V. (2004). Modelo de estimación de volumen de madera aserrada que emplea variables de árboles en pie para Pinus Radiata D. Don. *Cuad. Soc. Esp. Cien. For. 18, 135-140.*