Australian Journal of Basic and Applied Sciences

2018 Aug; 12(8): pages 65-69
DOI: 10.22587/ajbas.2018.12.8.13

Research Article AENSI Publications

Volume Equations and Volumetric Stock Evaluation of *Hovenia dulcis* in Araucaria Forest

Carlos Henrique Boscardin Nauiack, Afonso Figueiredo Filho and Mailson Roik

Central Western Parana State University, UNICENTRO, Postgraduate Program in Forest Sciences. PR 153 km 7 - Riozinho - 84500-000 Irati-Paraná, Brazil

Correspondence Author: Carlos Henrique Boscardin Nauiack, Central Western Parana State University, UNICENTRO - Campus-Irati, Postgraduate Program in Forest Sciences. PR 153 km 7 - Riozinho - 84500-000.
E-mail: carlosnauiack@yahoo.com.br

Received date: April 2018, **Accepted date:** 28 July 2018, **Online date:** 5 August 2018

Abstract

Background: The exotic invasive species *Hovenia dulcis* is a contaminant of different vegetation types in southern Brazil. Due to the threats for the country native forest, control mechanisms of *Hovenia dulcis* must be sought in order to establish strategies to mitigate the adverse impacts on ecosystems. **Objective**: The aim of this study was to develop volume equations for *Hovenia dulcis* under natural regeneration in Araucaria Forest, belonging to the Atlantic Forest Biome, to evaluate the mean individual commercial stem volume and the volume production per diameter class. **Methods:** The research was carried out on 16 native forests fragments located in the municipality of Fernandes Pinheiro, Central-South region of Paraná, Brazil. The volume models were adjusted with 80 cubed trees data, for the cubing process it was used the absolute method, which recommends the prior definition of the stem measurement points and their application to all trees. The bark diameters were measured at the following absolute heights (m): 0.1; 0.7; 1,3; 2,3; 4,3; and every 2 meters up to the total height. The most common regression statistics were used in the evaluation of the model: adjusted coefficient of determination (R^2adj), the estimate standard error in percentage (Syx%) and the graphical residual (Res%). The best model was used to define an evaluate the total volume production and the mean individual commercial stem volume per diameter class for *Hovenia dulcis* measured in 16 forest fragments. **Results:** The Schumacher-Hall model was chosen to estimate the total stem volume for *Hovenia dulcis,* with satisfactory adjusted statistics. In general, the dual input models (DBH and height) were superior to the simple input models (DBH). The population of *Hovenia dulcis* have a total stem volume of 72.32 m^3 and it was observed a bimodal curve with two production peaks for the volume production by diameter class. The volume production curve follows a growth trend in the first four classes and from 5th class it assumes a decreasing trend, mainly, by the sharp decrease in the number trees. The same first four class contains 41.6% of the total volume and have 69.7% of the trees, that is, more than two thirds of the population. The last five classes with diameters above 22 cm contribute with 58.3% (42.2 m3) of the total volume with only 30.3% (274) of the trees. **Conclusion:** The adjusted volume models can be used efficiently to determining the commercial stem volume of *Hovenia dulcis*. Volume production and frequency of trees per diameter class can be used to determine management methodologies for *Hovenia dulcis.*

Key words: invasive exotic species, japanese raisin tree, Araucaria forest, dendrometric equations

INTRODUCTION

Invasive Alien Species (IAS) are considered an environmental problem in Brazil and in the world, mainly because of the great impact they cause on the biodiversity of ecosystems, on the economy and on human health, with different situations for each country. When these species are disseminated they dominate the ecosystems, offering risks to their equilibrium due to the pressure on the native species. By threatening the biological communities and genetic resources of countries, IAS receive special attention from affected nations in the pursuit of joint strategies to mitigate adverse impacts on ecosystems, whether by eradication, control or monitoring of the invasion.

One of the first steps for impacts mitigation is the creation of an official list that recognizes IAS in invaded ecosystems. In this case, the state of Paraná (located in Southern Brazil) recognizes an official list of IAS, which are regulated by law specific devices. In the list, among other diverse flora species, is *Hovenia dulcis*. According to the specific law device, it is a contaminant tree species of the Mixed Ombrophilous Forest (MOF) (Araucaria Forest) and two other ecosystems in the State. It has a specific framework that prohibits its transportation, creation, release or translocation, cultivation, propagation (by any form of reproduction), trade, gift or intentional acquisition in any form.

Hovenia dulcis belongs to the Rhamnaceae family endemic to East Asia. It occurs naturally in Japan, Korea, eastern China to the Himalayas at a maximum altitude of 2,000 m, grows adequately in situations of direct exposure to the sun on sandy or clayey soils. It is cultivated in plantations in China and considered invasive of tropical forests in South America and Tanzania, in several countries such as USA, Australia, New Zealand and Central Africa, was introduced as an ornamental species (HYUN et al., 2010).

There are scientific studies that prove the presence of *Hovenia dulcis* inside the (MOF), such as the works carried out by Schaaf et al. (2006). The authors evaluated the floristic-structural changes of a MOF fragment between 1979 and 2000, they describe that between the measurement periods that is 21 years, the number of *Hovenia dulcis* that entered the system was quite representative and surpassed several native species in relation to participation in the forest structure. It should be noted that in the first measurement (1979) no tree from the species were found above 20 cm in diameter.

In order to mitigate the effects caused by the expansion of *Hovenia dulcis* on native forest, the Paraná state environmental agency encourages and permits selective cutting. The objective is minimizing the competition with the native species and especially reduce the IAS dispersal capacity. However, cutting permission as a sole and exclusive action tends to be ineffective, since in this case all responsibility is transferred to the landowner.

Joint actions between all those involved with the problem should be thought and implemented through control programs for each IAS. One of the

Citation: Carlos Henrique Boscardin Nauiack *et al*., Volume Equations and Volumetric Stock Evaluation of *Hovenia dulcis* in Araucaria Forest. Australian Journal of Basic and Applied Sciences, 12(8): 65-69. DOI: 10.22587/ajbas.2018.12.8.13

mechanisms that could contribute is the establishment of joint and coordinated action with the research institutes such as Universities and technology rural development Institutes, which would contribute to the study and dissemination of management techniques, considering *Hovenia dulcis* a forest resource with the potential to generate regular and constant wood flows. Based on the principle of promoting income and improving the quality of life of the rural population and seeking environmental conservation.

Looking for information to support the management plans for *Hovenia dulcis*, efficient methods of volume estimation are extremely important. Such methods must quantify the current and future stock accurately and efficiently. According to Machado and Figueiredo Filho (2003), the volume equations are fundamental tools for the forest manager's decision making, and for this reason, many equations were developed to estimate the volume of natural or planted forests, mainly using as an independent variable DBH (Diameter at Breast Height) and height and, as dependent variable, the volume.

The objective of the present work was to develop volume equations for *Hovenia dulcis* under natural regeneration in the native forest, to evaluate the mean individual commercial stem volume per diameter class in 16 private forest fragments in Paraná, Brazil.

MATERIAL AND METHODS

Study areas:

The present research was carried out on 16 native forests fragments in small proprieties located in the municipality of Fernandes Pinheiro, Central-South region of Paraná. This municipality is located in the parallel 25°24'46 " south latitude intersection with the meridian 50º32'52" West longitude, in the Paraná state Center-South portion, Brazil. According to Köppen classification the climate of the region is Cfb - Subtropical Moist Mesothermic. The average annual temperature is 17° C and it is between 13 ° C to 18 ° C, with summers characterized as cool and winters cold, with frost. There is no dry season due to the distribution of rainfall occurring regularly during the year.

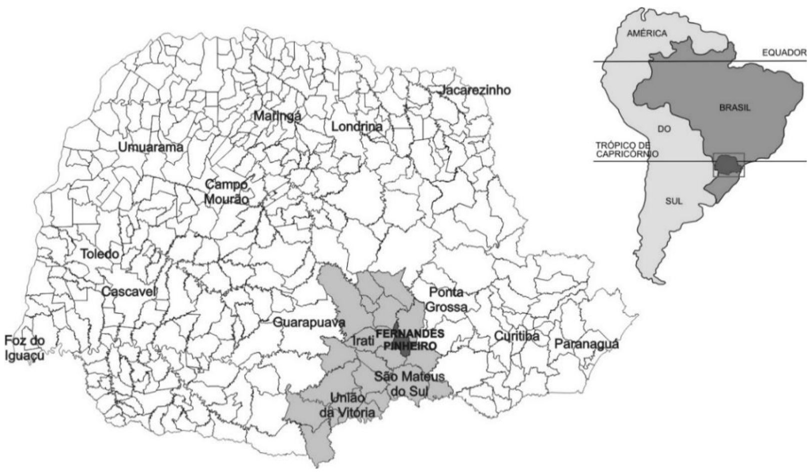

Fig. 1: Location of the Fernandes Pinheiro municipality, state of Paraná.

Datacollection:

The database used in the adjustments of the volumetric models counted on 80 cubed trees, distributed in 10 diametric classes with three centimeters between classes and amplitude ranging from 10 cm to < 37 cm of DBH. The grouping in diametric classes was performed by Nauiack (2015) from the 100% forest inventory data for *Hovenia dulcis* in 16 native forest fragments. In this survey was measured the DBH and the commercial stem height of 904 trees, the statistics presented by the author show that the mean DBH was 19.7 cm with a standard deviation of 6.8 cm and a variation coefficient of 34.5%.

During the cubing process, the measurement points along the stem were performed by the absolute method, which recommends the prior definition of the stem measurement points and their application to all trees. Thus, the bark diameters were measured at the following absolute heights (m): 0.1; 0.7; 1,3; 2,3; 4,3; and every 2 meters up to the total height. At all measurement points the thickness of the bark was collected, with the aid of a bark meter and always on two opposite sides of each other.

For the real volume calculation it was used the SMALIAN method, applying the following formula (1):

$$v = v_0 + \sum \frac{g_i + g_{i+1}}{2}\ l_i +\ g_n\, l_n \left(\frac{1}{3}\right) \qquad [1]$$

Where: v: total volume; v_0: stump volume; g_i: cross-sectional area at the i*th* position; l_i: length of the section in the i*th* position; g*n*: cross-sectional area of the cone; l*n:* cone length.

Volumetric models:

The volumetric models (Table 1) were adjusted with 80 cubed trees data base by testing two single input models and four dual input models.

Table 1. Mathematical models tested to estimate the total volume with bark.

Author	Model	Nº
Berkhout	$v = \beta_0 + d^{\beta_1}$	[2]
Hohenadl - Krenn	$v = \beta_0 + \beta_1 d + \beta_2 d^2$	[3]
S.H. Spurr	$v = \beta_0 + \beta_1 (d^2 h)$	[4]
Schumacher-Hall	$v = \beta_0 d^{\beta_1} h^{\beta_2}$	[5]
Stoate	$v = \beta_0 + \beta_1 d^2 + \beta_2 (d^2 h) + \beta_3 h$	[6]
Näslund	$v = \beta_0 + \beta_1 d^2 + \beta_2 (d^2 h) + \beta_3 (d h^2) + \beta_3 h^2$	[7]

V: volume (m^3); d: diameter at 1.3 m from the ground (cm); h: total height (m); β0, β1, β2, β3: coefficients of the model.

Statistical analyses:

For the analysis and selection of the regression models we considered the adjusted coefficient of determination (R^2adj), the estimate standard error in percentage (Syx%), the graphical residual (Res%) and the significance of each coefficient (α = 5%), from the p value. The best performing function according to the criteria described was selected. If the coefficient is not significant, it should be excluded and the equation should be readjusted. Gujarati (2006) describes the p value as the level of exact or observed significance that, technically, is the lowest level of significance at which the null hypothesis can be rejected. All nonlinear models were adjusted by the Levenberg-Marquardt algorithm.

Determination of stock and average individual volume per diameter class:

The current stock, that is, the stock in the diameters measurement year was quantified and qualified. The volumetric quantification was performed by diameter classes for all trees collected in the 100% forest inventory, which has been described in the previous item. In addition, the mean individual commercial stem volume per diameter class was determined and evaluated.

Within this scenario, it was possible to identify and rank the classes with the highest production. Equations (8) and (9) were used to quantify the total volume produced and the mean individual commercial stem volume per diameter class, respectively.

$$Vt = \sum_{j=1}^{J} Q_j \qquad [8]$$

Where: Vt: total commercial stem volume per diameter class, in m^3; Q_j: quantity of the jth tree stem volume per diameter class, in m^3; J: total trees stem volume.

$$Vm = \frac{\sum_{j=1}^{J} Q_j}{n} \qquad [9]$$

Where: *Vm*: mean individual commercial stem volume per diameter class, in m^3; Q_j: quantity of the jth tree stem volume per diameter class, in m^3; *n*: total number of trees per diameter class; J: total number of trees.

RESULTS AND DISCUSSION

Adjusted models:

The statistical parameters results generated in the regression models adjustments for estimate the total stem volume with bark are summarized in Table 2. The statistics are similar among the models, even for models of double and single entries, linear or non-linear.

The Hohenadl-Krenn, Brenac and S.H. Spurr models expressed a non-significant p value at 5% probability level for the β_0 coefficient, in these cases the intercept was considered zero, without influence on the model. Gujarati (2006) describes that the value of R^2 in this case can not be compared among the models because they are incompatible. However, in this work the coefficients β_0 were maintained in the equations even if considered as null in the equations adjustment, since the main objective is precisely the comparison and definition of the most adequate model to estimate the stem volume for *Hovenia dulcis*.

The Schumacher-Hall, Stoate and Näslund double input models presented better results than the other models for R^2adj and Syx (%). Among those models, the Näslund model was slightly better. The S.H. Spurr model, although also containing two independent variables (DAP and height), follows a different pattern from the other double input models, as the results of its statistics were lower. The results of the statistics among the simple input models were similar, but the Berkhout model, the only nonlinear model, was superior to the others.

Table 2: Coefficients, adjustments statistics and accuracy of the tested models for the total stem volume estimate with bark..

Author	Coefficients	R^2adj	Syx (m^3)	Syx (%)	Nº
Berkhout	β_0 = 0,00049*	0,9108	0,12	20,39	[2]
	β_1 = 2,10055*				
Hohenadl – Krenn	β_0 = -0,02263ns¹	0,9096	0,12	20,54	[3]
	β_1 = -0,006ns*				
	β_2 = 0,00074*				
S.H. Spurr	β_0 = 0,01779ns¹	0,9036	0,13	21,20	[4]
	β_1 = 0,00004*				
Schumacher-Hall	β_0 = 0,000136*	0,9264	0,11	18,53	[5]
	β_1 = 2,09801*				
	β_2 = 0,45204*				
Stoate	β_0 = -0,35021*	0,9287	0,10	18,23	[6]
	β_1 = 0,00069*				
	β_2 = 1,8E-06ns*				
	β_3 = 0,02078*				
Näslund	β_0 = -0,17373*	0,9297	0,10	18,10	[7]
	β_1 = 0,00069*				
	β_2 = 2,1E-05ns*				
	β_3 = -2,3E-06ns*				
	β_4 = 0,00059*				

* significant at 5% probability level; ns *: not significant; ns¹: intercept maintained in the equation although not significant at 5% probability level; β0, β1, β2, β3, β4: models coefficients estimates.

In the graphical residual analyze (Figure 2), it is possible to observe that the S.H. Spurr, Stoate and Näslund models indicate some tendency for smaller diameters (<20 cm). In the case of the S.H. Spurr model, the estimated values were overestimated and for the Stoate and Näslund models, the values below 20 cm were underestimated. The residuals for the Schumacher-Hall model are closer to the x-axis compared to the other models and, because this model obtained results for the other statistics among the best, it was chosen to estimate the total stem volume for *Hovenia dulcis*.

There are several scientific studies of adjustments volume models for native species, mainly for the species of the Brazilian Amazon region. It can be affirmed that the models adjusted in this work have similar statistics to the models used to determine the volume of native species, among which we can cite the works of Barros e Silva Junior (2009); Thaines et al. (2010); Santos et al. (2012).

Citation: Carlos Henrique Boscardin Nauiack *et al*., Volume Equations and Volumetric Stock Evaluation of *Hovenia dulcis* in Araucaria Forest. Australian Journal of Basic and Applied Sciences, 12(8): 65-69. DOI: 10.22587/ajbas.2018.12.8.13

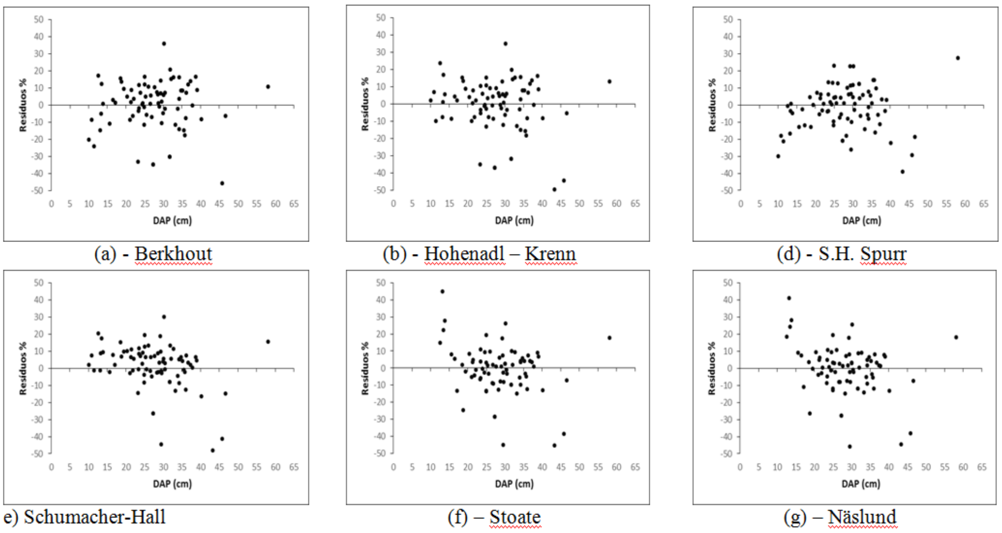

Fig. 2: Residuals distribution (%) for volumetric models.

Stock and average individual volume per diameter class:

Figure 3 shows the behavior of the total production (volume em m^3) in percentage for the commercial stem volume per diameter class. The 904 trees measured in 16 forest fragments have a total volume of 72.32 m^3 and the total volume curve explains the production behavior according to observed frequency in each diameter class, it is a bimodal curve with two production peaks. The total volume curve follows a growth trend in the first four classes and from 5th class it assumes a decreasing trend, mainly, by the sharp decrease in the number trees, a decrease of 33,57% when compared to 4th class. The same first four class contains 41.6% of the total volume and have 69.7% of the trees number, that is, more than two thirds of the population.

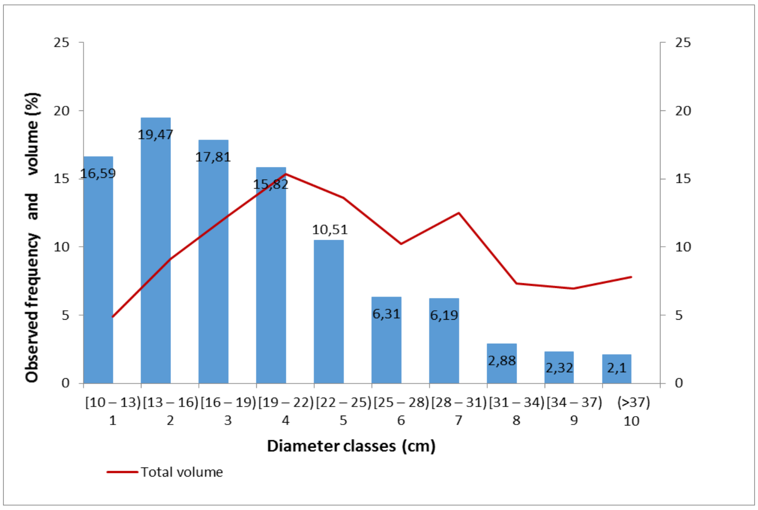

Fig. 3: Total production (%) per diameter class.

The peak production occurs in the 4th class (diameters between 19 and 22 cm) with a production of 15.3% (11.09 m3) which is the 3th class with greater frequency, with a total of 15.8% (143) of the trees. The last five classes with diameters above 22 cm contribute 58.3% (42,2 m3) of the total volume with only 30.3% (274) of the trees numbers. These analyzes are fundamental precisely to define the moment of exploration, from which class it may be interesting to start the selective cut and how many trees per class can be harvested so that production can be maintained over time. In this perspective, the results in volume production can be potentiated, which will certainly lead to a late exploration (last cutting cycles) of the first classes trees. Enabling management for the control of the alien invasive species, but at the same time generate gradual and continuous financial resources over time for forest owners.

Several authors have proposed management methodologies for unequal ages native forests from diameter classes and the passage time, which is the time that the trees take to go from one class to another, as the works of Mackay (1961), Souza et al. (1993) and Souza and Soares (2013).

Figure 4 shows the mean individual commercial stem volume per diameter class. Obviously, the curve of the individual mean volume follows an increasing tendency, basically because how greater diameter bigger will be the volume of a tree. It is observed that the relation diameter and volume is extremely strong, but does not follow a proportional pattern, since the second independent variable that is the height also exerts a direct influence on the volume.

The columns represent the difference in percentage of the mean individual volume between the lower class and their respective upper class. It shows that classes 2, 3, 4, and 5 have the largest variations in the mean individual volume, which ranging 37.4% from the first to the second class and 25.1% from the fourth to the fifth class. This fact clearly shows the growth pattern of the species. The largest growth in volume occurs in the first classes, being gradually diminished with the advancement of the diameter classes. This fact can be verified by evaluating the last two classes, which have the lowest percentage difference of the mean individual volume in relation to their underlying lower classes, being 15.3% and 19.4% for classes 9 and 10, respectively.

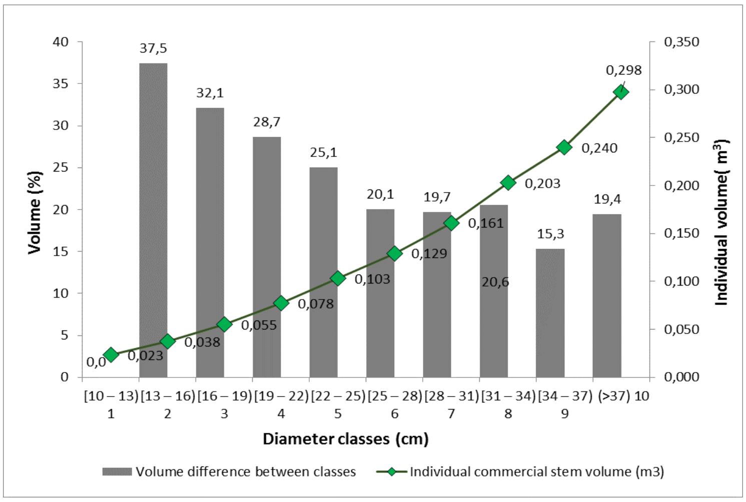

Fig. 4: Mean individual commercial stem volume (m^3) and the difference between classes (%) for the mean individual commercial stem volume.

Conclusion:

The results show that the adjusted volume models can be used efficiently in determining the stem volume of *Hovenia dulcis*. Volume production and frequency of trees per diameter class can be used to determine management methodologies for *Hovenia dulcis*. In the same way, the mean individual stem volume per class can serve as a reference for the species management parameters. Studies about the dynamics of the species (growth, entry and mortality) in the contaminated natural ecosystems are fundamental, so that an effective and feasible species control alternatives can be generated.

REFERENCES

Barros, P.L.C., A.T. Silva Junior,2009. Equações de volume para árvores de uma floresta tropical densa no município de Anapú, oeste do Estado do Pará, Amazônia Oriental. Revista de Ciências Agrarias, Belém, 51: 115-126.

Gujarati, D.N., 2006. Dasar-dasar Ekonometrika. Edisi ketiga, Erlangga, Jakarta.

Hyun, T.K., S.H. Eom, C.Y. YU, T. Roitsch, 2010. *Hovenia dulcis* – an Asian traditional herb. Planta Medica, Stuttgart, 76: 943-949.

Machado, S.A., A. Figueiredo Filho, 2003. Dendrometria. Curitiba: [s.n.], 1-309.

Mackay, E., 1961. Fundamentos y métodos de la ordenacion de montes. Madrid: [s.n.], 2ed, 768.

Nauiack, C.H.B., 2015. Regimes de manejo para *Hovenia dulcis* Thunb. em Floresta Ombrófila Mista como alternativa de controle e geração de rendas. 193f. Dissertação (Mestrado em Ciências Florestais) – Universidade Estadual do Centro-Oeste, Irati, PR.

Santos, A.T., P.P. Mattos, E.M. Braz, N.C. Rosot, 2012. Equações de volume e relação hipsómetrica em plantio de *Ocotea porosa*. Pesquisa Florestal Brasileira, Colombo, 32: 13-21.

Schaaf, L.B., A. Figueiredo Filho, F. Galvão, C.R. Sanquetta, 2006. Alteração na estrutura diamétrica de uma floresta ombrófila mista no período entre 1979 e 2000. Revista Árvore, 30(2): 283-295.

Silva, J.N.M., 1996. Manejo florestal. Brasília: Embrapa-SPI, 46.

Souza, A.L., P.A. Araujo, J.C. Campos, F. Paula Neto, 1993. Dinâmica de crescimento em diâmetro de uma floresta primaria sem interferência: uma análise pelo tempo de passagem entre classes diamétricas. Revista árvore, 17(2): 129-145.

Souza, A.L., C.P.B. Soares, 2013. Florestas nativas: estrutura, dinâmica e manejo. Viçosa: Universidade Federal de Viçosa, 322.

Thaines, F., E.M. Braz, P.P. Mattos, A.A.R. Thaines, 2010. Equações para a estimativa de volume de madeira para a região da bacia do Rio Ituxi, Lábrea, AM. Pesquisa Florestal Brasileira, 30(64): 283-289.