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Allometric equations to estimate volume, biomass and carbon of *Schizolobium parahyba* var. *amazonicum* (Huber ex Ducke) Barneby in a commercial stand in southwestern Amazonia

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Abstract: Forest plantations with tropical species lack allometric equations to estimate yield. This study aims to test allometric models for estimation of volume, biomass and carbon stock for stems of *Schizolobium parahyba* var. *amazonicum*, a species with great potential for using in homogeneous stands. A plantation of *S. parahyba* was inventoried, rigorously cubed and wood disks with bark were collected to obtain the biomass and carbon stock of the stem. Allometric models were fitted using as independent variables diameter at 1.30 m from the ground, total height, basic wood density and carbon content. The biomass and carbon stock of the stand were 124 Mg ha^{-1} and 58 Mg C ha^{-1}, respectively. The selected equations for volume estimation with and without bark were $V = \exp\,(-9.600 + 0.937 * \ln d^2h)$ and $V = \exp\,(-9.622 + 0.938 * \ln d^2h)$, respectively; for biomass. the selected equation was $B = \exp(-9.566 + 0.936 * lnd^2h + 1.014 * ln\rho)$. and to estimate carbon stock $C = \exp(-9.797 + 0.937 * lnd^2h + 1.026 * ln\,\rho + 0.699 * lnt)$. The allometric equations for volume, biomass and carbon stock fitted in this study can generate more accurate yield estimates for *S. parahyba* plantations in the Amazon region. Brazil’s commitment under the Paris Agreement to reforest 12 million hectares by 2030 makes improving estimates of volume, biomass and carbon a high priority.

Keywords: Paricá, Silviculture, Yield, Carbon content, Bark, Amazon, Brazil.

1. Introduction

Brazil has 9.93 million hectares of silvicultural plantations that store 1.79 billion tCO$_2$eq, and the country has 6 million hectares of natural forests for conservation purposes, which store 2.67 billion tCO$_2$eq (IBA, 2022). In general, these plantations are made up of exotic species (*Pinus* sp. and *Eucalyptus* sp.), and populations/stands of native species are still scarce in Brazil (SNIF, 2021). Plantations with native species are becoming more prominent, with *Schizolobium parahyba var. amazonicum* (Huber ex Ducke) Barneby standing out on the national scene as one of the native species with the largest planted area in the country, accounting for approximately 90,000 ha (SNIF, 2021; IBA, 2019, 2021). Brazil’s commitment under the Paris Agreement includes reforesting 12 million hectares by 2030 (Brazil, 2016).

S. parahyba is a pioneer deciduous species that occurs naturally in primary forests and especially in the secondary forests of unflooded land and in high floodplains. It is fast-growing, has a straight stem and wood that fetches high prices on the domestic and foreign markets. Because of these characteristics, the species has been cultivated by timber companies in the north and northeast of Brazil. The processing of the wood stands out because it is easy to remove the bark, laminate, dry and press; 80% of the wood is used for lamination (Marques et al. 2006). It is widely used for plywood and because the wood is a light (basic density ≈ 0.49 g cm^{-3}; SFB 2022). The basic density of *Schizolobium parahyba* wood is similar to that of *Pinus caribaea* var. *hondurensis* (Sénécl.) W.H. Barrett & Golfari in the Amazon region (0.49 g cm^{-3}; Silva et al. 2022) and of *Eucalyptus grandis* W. Hill (0.49 g cm^{-3}). The basic density of wood is an important characteristic because the lower the wood density (softwoods), the lower the amount of carbon stored per volume of wood (Romero et al., 2022).

In homogeneous stands, *Schizolobium parahyba* has a volumetric increase of between 30 and 35 m^3 ha^{-1} $year^{-1}$, which is higher than the increases found for *Pinus* sp. (≈ 30.4 m^3 ha^{-1} $year^{-1}$) and *Tectona grandis* L.f. (≈ 23 m^3 ha^{-1} $year^{-1}$) (IBA 2021; Mascarenhas et al. 2021). The volumetric increase is greater in *S. parahyba* stands than in stands with exotic species. This justifies commercial plantations with native species. However, despite the high volumetric increase, forests planted with *S. parahyba* still face a number of technical, scientific and operational problems due to the limited research on the planting of this species (Sales et al., 2021).

An alternative is to fit volumetric equations for tropical species established in plantations. Some volumetric equations have already been fitted for pure plantations of *Schizolobium parahyba var. amazonicum* in the northern and central-western portions of Brazil (e.g., Tonini et al., 2005; Feitosa et al., 2014; Leão, 2019). However, especially in the southwestern Amazon, where pure plantations with exotic and native species are few in number and lack production monitoring, there are still not many volumetric equations adjusted for these species.

Allometric equations for estimating biomass and carbon are also scarce for planted forests in the southwestern Amazon, especially for tropical species such as *S. parahyba*. The aim of this study is to generate allometric equations for volume, biomass and carbon for stems of the species *Schizolobium parahyba var. amazonicum* in a commercial stand in southwestern Amazonia. The equations generated will make it possible to reduce the uncertainties associated with estimating forest production and the biomass and carbon stocks of *S. parahyba* stands.

2. Materials and Methods

2.1. Study site

The study was carried out in an even-aged and homogeneous commercial *S. parahyba* stand (11º43'22.70"S, 61º42'05.50"W), owned by the company Lano da Amazônia in Rolim de Moura, located in Brazil's state of Rondônia, in southwestern Amazonia (Figure 1).

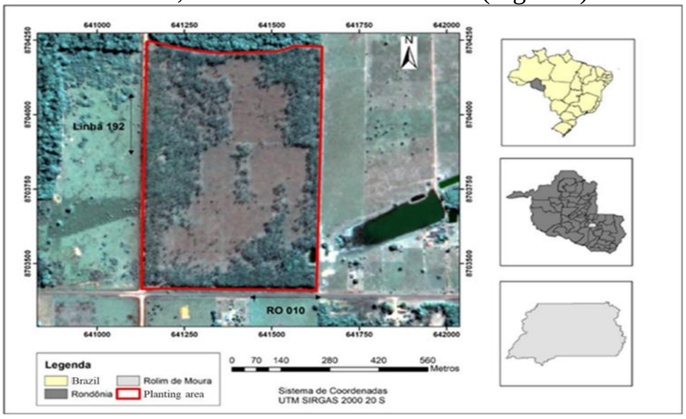

Figure 1. Location of the Schizolobium parahyba var. amazonicum stand in southwestern Amazonia, Brazil.

According to the Köppen-Geiger classification, the climate in the region is Aw, with annual precipitation between 2300 and 2500 mm and an average annual temperature of 27.6 ºC (Alvares et al., 2013; Beck et al., 2018).

The relief of the municipality of Rolim de Moura is flat, with slight undulations in some points. The altitude varies between 260 and 300 m above sea level; the municipality is in the Machado River basin. The soils in the region vary between latosol (yellow and dark red), podzols and cambisols, depending on the slope of the terrain. The open ombrophilous forest is the predominant vegetation in the municipality, but areas of *Cerrado* (savana) physiognomies are also found (Januário, 2009).

The stand was established from seed in 2012 in an area of approximately 40 ha, with a spacing of 3 m × 3 m. Site preparation included harrowing and subsoiling, followed by the application of lime (1.5 Mg ha^{-1}). NPK (4-14-8) fertilization was applied at 150 g per plant, followed by side-dressings of NPK fertilizer up to 3 years after planting. Phytosanitary thinning to remove dead and/or non-commercial trees was carried out in the first four years, in addition to pruning and weed control (Neves et al., 2022). In the stand was attacked by a cicada (*Quesada gigas*) in 2018 and 2019.

2.2. Selection of sample trees and data collection

The ideal sampling intensity for each diameter class was obtained using the formula $n = \frac{t^2 \cdot (CV\%)^2}{E\%^2}$ where n = ideal sampling intensity in number of trees; t = tabulated value of the Student's t statistic (n-95%); CV = volume coefficient of variation in %; and E = required precision, in this case 10%. Based on the calculated n, trees were distributed into diameter classes with ranges of 3 cm, totaling nine diameter classes. In some diameter classes, fewer trees were sampled (*n-sampled*) than initially expected (n) due to technical criteria and company demands (Romero et al., 2020).

Rigorous cubing was performed using the Smalian method. Diameters with bark were measured, using a tree caliper, at different heights: 0.1 m; 0.3 m; 0.7 m; 1.3 m; 2.0 m; and, thereafter in sections every 2.0 m until the total length of the stem was reached. The stumps had their diameters measured, regardless of their height, which varied between 0.1 m and 0.5 m in the sampled individuals. The volume with and without bark ($v_{c/c}$ or $v_{s/c}$; m^3) of the individual stem sections was obtained using the Smalian formula.

After rigorous cubing was completed, the stem was divided into 1.4-m logs (Figure 2) to comprise the assortment used by the company and, thus, not interfere with the company's meeting its commercial demands. A wood disk 5.0 cm in width was collected from each log section for stem analysis. Disks from the base (0-10% of the total height), middle (40-50% of the total height) and top (80-90% of the total height; Figure 2) were selected to determine the carbon content and the basic density of the wood and bark.

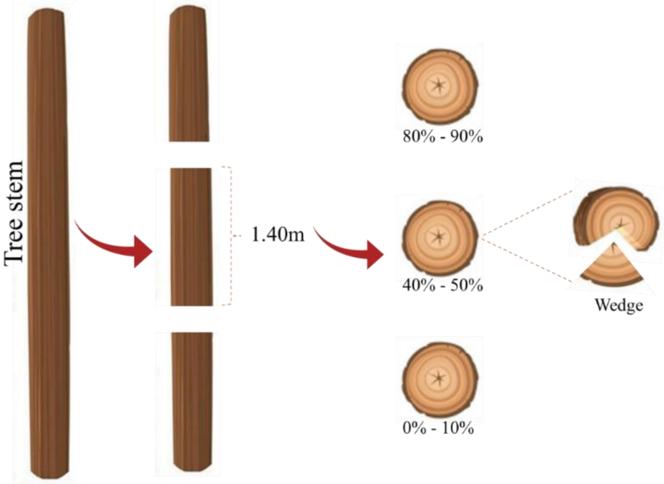

Figure 2. Detail of the position of collection of wood disks used in this study.

In the laboratory, the wood disks were organized, separated and analyzed. When any sign of deterioration was observed in the disk (Figure 2), such as a fissure or attack by fungi or xylophagous insects, the damaged disk was discarded and a disk in a higher or lower position in the stem was used (depending on the physical and pathological conditions of the disks).

Bark thickness was measured using a caliper, and the bark was then removed from the disks and two opposing wedges were obtained using a circular saw. After that, for the sampling units of wood (n = 6, being 3 disks per individual and 2 wedges per disk) and bark (n = 12, being 3 disks per tree and 4 repetitions per disk) the basic density was determined following the procedures described by ASTM D2395-17 (ASTM, 2017). The basic density of the wood was obtained from the average of the six sample units evaluated for each tree. The basic density of the bark was obtained in a similar way, considering the twelve sampling units per tree.

Biomass of the stem and bark were calculated as the product between the volume and the mean basic density of each tree. Carbon content from wood and bark were determined using the methodology proposed by Bezerra Neto & Barreto (2011). Carbon stock in the wood and bark of each tree was obtained multiplying their biomasses by their carbon contents. Total carbon stock of the stem was summed and divided by the sampled area (0.1521 ha) to obtain the carbon stock per hectare.

2.3. Tested models

To estimate the volume with and without bark (V, m³), five models were tested (Table 1 adapted from Romero 2018 and Romero et al., 2020), with the independent variables diameter at breast height (*d*, cm) and total height (*h*, m), in addition to their combination.

Table 1. Mathematical models tested to estimate volume with and without bark of *Schizolobium parahyba* var. *amazonicum* in southwestern Amazonia, Brazil

Nº	Model	Author
1	$V = exp(\beta_0 + \beta_1 \ln(d) + \varepsilon)$	Husch (1963; linearized)
2	$V = \beta_0 + \beta_1(d^2h) + \varepsilon$	Spurr (1952; combined variable)
3	$V = \beta_0 + \beta_1 d + \beta_2 h + \varepsilon$	Simple linear model
4	$V = exp(\beta_0 + \beta_1 \ln(d^2h) + \varepsilon)$	Spurr (1952; linearized)
5	$V = \exp(\beta_0 + \beta_1 \ln(d) + \beta_2 \ln(h) + \varepsilon)$	Schumacher and Hall (1933; linearized)

To estimate stem biomass (*B*, Mg), six models were used (Table 2; adapted from Romero, 2018; Romero et al., 2020). The independent variables of these models were diameter at breast height (*d*, cm), total height (*h*, m) and basic wood density (ρ, g cm^{-3}), in addition to their combinations.

Table 2. Mathematical models tested to estimate stem biomass of *Schizolobium parahyba* var. *amazonicum* in southwestern Amazonia, Brazil.

Nº	Model	Author
1	$B = exp(\beta_0 + \beta_1 \ln(d) + \beta_2 \ln(\rho) + \varepsilon)$	Chave et al. (2005)
2	$B = exp(\beta_0 + \beta_1 \ln(d^2h) + \beta_2 \ln(\rho) + \varepsilon)$	Loetsch et al. (1973)
3	$B = exp(\beta_0 + \beta_1 \ln(d) + \beta_2 \ln(h) + \beta_3 \ln(\rho) + \varepsilon)$	Schumacher and Hall (1933; linearized)
4	$B = exp(\beta_0 + \beta_1 \ln(d) + \beta_2 \ln(h) + \varepsilon)$	Schumacher and Hall (1933; linearized)
5	$B = \beta_0 + \beta_1 d + \beta_2 h + \varepsilon$	Simple linear model
6	$B = \beta_0 + \beta_1 \mathrm{d} + \beta_2 h + + \beta_3 \rho + \varepsilon$	Simple linear model (modified by Romero 2018)

Five models were tested for the estimation of stem carbon stock (*C*, Mg) (Table 3; adapted from Romero 2018 and Romero et al. 2020), using the independent variables diameter at breast height (*d*, cm), total height (*h*, m), basic wood density (ρ, g cm^{-3}) and carbon content (*t*, dag kg^{-1}), in addition to their combinations.&

Table 3. Mathematical models tested to estimate stem carbon stock of *Schizolobium parahyba* var. *amazonicum* in southwestern Amazonia, Brazil.

Nº	Model	Author
1	$C = exp(\beta_0 + \beta_1 \ln(d^2h) + \beta_2 \ln(\rho) + \beta_3 \ln(t) + \varepsilon)$	Loetsch et al. (1973; modified by Romero 2018)
2	$C = exp(\beta_0 + \beta_1 \ln(d) + \beta_2 \ln(h) + \beta_3 \ln(\rho) + \beta_4 \ln(t) + \varepsilon)$	Schumacher and Hall (1933; modified by Romero 2018)
3	$C = \beta_0 + \beta_1 d + \beta_2 h + \varepsilon$	Simple linear model A
4	$C = \beta_0 + \beta_1 d + \beta_2 h + \beta_3 \rho + \varepsilon$	Simple linear model B (modified by Romero 2018)
5	$C = \beta_0 + \beta_1 d + \beta_2 h + \beta_3 \rho + \beta_4 t + \varepsilon$	Simple linear model C (modified by Romero 2018)

In models in which the dependent variable was logarithmic, to allow comparison with other fitted equations, the bias associated with logarithmic regression was removed using Meyer's correction factor (FM) given by $FM = e^{0.5*S_{yx}^2}$, where S_{yx} = standard error of the estimate. Independence (Durbin Watson test), normality (Komolgorov-Smirnov test) and homogeneity of residual variance (Breusch-Pagan test) were examined to verify compliance with linear regression assumptions.

Student's t test was applied to determine the significance of the coefficients. The criteria for selecting the best fitted equation were high adjusted coefficient of determination ($R^2_{aj.}$), lowest standard error of the estimate as a percentage ($S_{yx}\%$) and graphical analysis of the residuals. All statistical analyses were performed using the R 4.1.3 software (R Core Team 2022).

3. **Results**

3.1. Dendrometric parameters

The stand shows a behavior tending to heterogeneity, which can be seen from the variability in dendrometric variables such as total height and diameter at breast height (Table 4). Volume with bark is another variable that corroborates this heterogeneity, since it has a coefficient of variation of 66.3%. The basal area of the stand was 31.96 m² ha^{-1}.

Table 4. Dendrometric characteristics of trees sampled in a 8-years stand of *Schizolobium parahyba* var. *amazonicum* in southwestern Amazonia, Brazil.

Variable	Range	Mean (CV%)
Total height (m)	11.10 - 27.34	19.12 (17.1)
Commercial height (m)	6.30 - 18.42	13.06 (18.2)
Diameter at breast height (cm)	9.50 - 34.90	18.52 (25.3)
Volume with bark (m³)	0.054-1.090	0.29 (66.3)
Bark thickness (mm)	0.74 - 4.01	2.18 (26.9)
Basic wood density (kg m^{-3})	238.7-509.4	380 (14.2)
Basic bark density (kg m^{-3})	291.2-556.6	439 (12.1)
Wood carbon content (%)	44-50	47 (2.6)
Bark carbon content (%)	28-45	39 (9.4)

The diameter distribution of the sampled trees (Fig. 3) shows the trend expected for even-aged stands, but slightly skewed to the right.

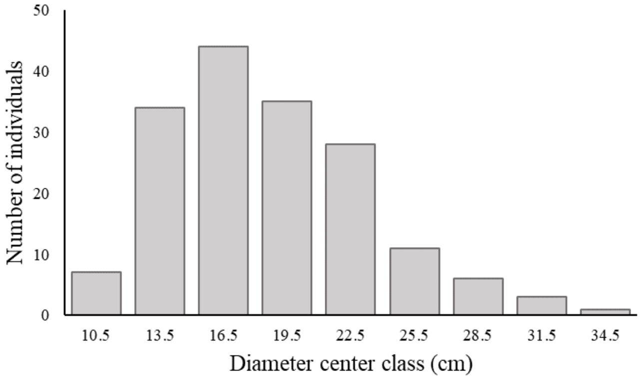

Figure 3. Diameter distribution of trees sampled in an 8-year-old stand of *Schizolobium parahyba* var. *amazonicum* in southwestern Amazonia, Brazil.

Stand volume with bark was 320 m³ ha^{-1}. Total biomass was 124.6 Mg ha^{-1}, of which 116.4 Mg ha^{-1} was wood and 8.2 Mg ha^{-1} was bark. Bark contributed 6.6% of the total biomass of the stem, which demonstrates the potential of this compartment for biomass production. The total carbon stock in the stand was 57.8 Mg C ha^{-1} (wood = 54.6 Mg C ha^{-1}; bark = 3.2 Mg C ha^{-1}).

3.2. Tested models

All regression parameters of the equations fitted to estimate volume with and without bark (Table 5) were significant by Student's t test ($p < 0.05$). The equations to estimate volume with bark that met regression assumptions were Equation 4 ($R^2_{aj.} = 0.99$; $S_{yx}\% = 7.60\%$), followed by Equation 1 ($R^2_{aj.} = 0.97$; $S_{yx}\ \% = 11.65\%$). Regarding the equations to estimate the volume without bark (Table 5), the same trend was observed: Equation 1 ($R^2_{aj.} = 0.97$; $S_{yx}\% = 11.89\%$) and Equation 4 ($R^2_{aj.} = 0.99$; $S_{yx}\% = 7.97\%$) were also the ones with the best fits.

Table 5. Volume with and without bark: regression parameters, adjusted coefficient of determination (R2aj.), standard error of the estimate in percentage (Syx%), sum of squared residuals (SQRes) and Meyer's correction factor (FM) for the tested models.

Nº	Regression parameters			$S_{yx}\%$	R^2_{aj}	SQ_{Res}	FM
	β_0*	β_1*	β_2 *				
Volume with sbark							
1	-8.478	2.439	-	11.65	0.97	0.19	1.0056
2	0.0177	0.0000	-	7.83	0.98	0.08	-
3	-0.5153	0.0334	0.0096	16.90	0.93	0.39	-
4	-9.600	0.937	-	7.60	0.99	0.08	1.0022
5	-9.5457	1.9085	0.8859	7.67	0.98	0.08	1.0023
Volume without bark							
1	-8.471	2.436	-	11.89	0.97	0.17	1.0056
2	0.0166	0.0000	-	8.24	0.98	0.08	-
3	-0.4836	0.0324	0.0088	17.23	0.93	0.36	-
4	-9.622	0.938	-	7.97	0.99	0.08	1.0025
5	-9.5563	1.9148	0.8780	8.00	0.99	0.08	1.0025

*Significant by the Student's t test at the 5% error probability level.

The equations showed a uniform distribution of residuals, with a slight tendency to underestimate volume (Figure 4). Based on the goodness-of-fit criteria, equation 4 was selected as the best for estimation of volume with and without.

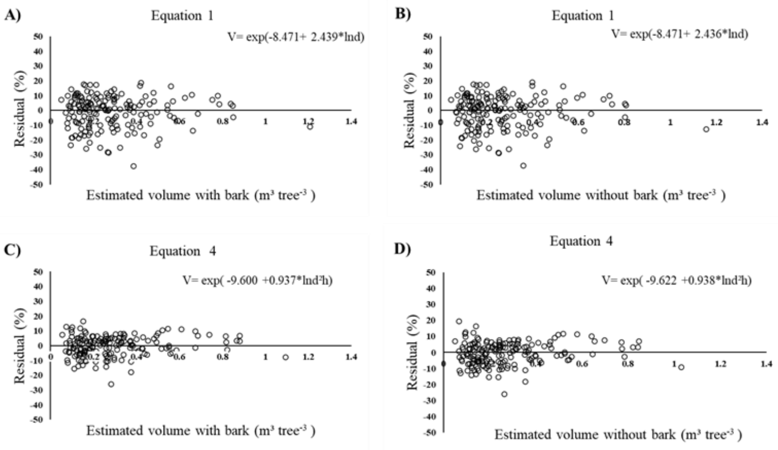

Figure 4. Residual plots for Equation 1, volume with bark (A) and without bark (B) and for Equation 4, volume with bark (C) and without bark (D).

Among the five tested models to estimate biomass, Equation 1 ($R^2_{aj} = 0.97$; $S_{yx}\% = 11.76\%$), Equation 2 ($R^2_{aj} = 0.99$; $S_{yx}\% = 7.77$), Equation 3 ($R^2_{aj} = 0.99$; $S_{yx}\% = 7.86\%$) and Equation 4 ($R^2_{aj} = 0.93$; $S_{yx}\% = 17.61\%$) were the ones that met regression assumptions. All regression parameters of these models were significant by the Student's t test ($p < 0.05$).

Table 6. Stem biomass: regression parameters, adjusted coefficients of determination ($R^2_{aj.}$), standard errors of the estimate in percent (S_{yx}%), sums of squared residuals (SQ_{Res}) and Meyer's correction factors (FM) for the tested models.

Nº	Regression parameters				S_{yx}%	$R^2_{aj.}$	SQ_{Res}	FM
	β_0*	β_1*	β_2*	β_3*				
1	-8.366	2.431	1.081	-	11.76	0.97	0.03	1.0052
2	-9.566	0.936	1.014	-	7.77	0.99	0.01	1.0022
3	-9.464	1.931	0.846	1.019	7.86	0.99	0.01	1.0022
4	-10.991	1.923	1.035	-	17.61	0.93	0.06	1.0134
5	-0.212	0.012	0.005	-	20.57	0.91	0.09	-
6	-0.267	0.012	0.004	0.189	18.13	0.93	0.07	-

*Significant by the Student's t test at the 5% error probability level.

Distribution of the residuals varied between homogeneous distributions (Figure 5 B and C) and distributions with a tendency towards underestimation of biomass (Figure 5 A and D;). Equations 2 and 3 had similar distributions of residuals. Considering the goodness-of-fit criteria, Equation 2 was considered the best for stem biomass estimation (Figure 5).

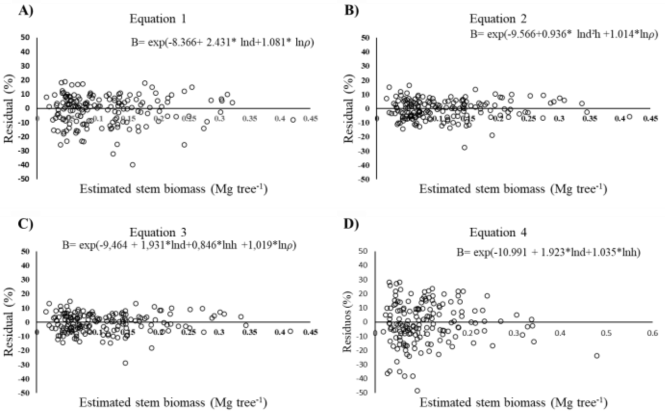

Figure 5. Stem biomass estimation: residual plots for Equations 1 (A), 2 (B), 3 (C) and 4 (D).

Regarding the equations for estimating carbon stock (Table 7), Equation 1 (R^2_{aj} = 0.99; S_{yx}%= 7.96) and Equation 2 (R^2_{aj} = 0.98; S_{yx}%= 8.48) met the regression assumptions. The regression parameters of all equations were significant by the Student's t test ($p < 0.05$).

Table 7 Stem carbon stock: regression parameters, adjusted coefficients of determination ($R^2_{aj.}$), standard errors of the estimate in percent (S_{yx}%), sums of squared residuals (SQ_{Res}) and Meyer's correction factors (FM) for the tested models.

Nº	Regression parameters					S_{yx}%	R^2_{aj}	SQ_{Res}	FM
	β_0*	β_1*	β_2*	β_3*	β_4*				
1	-9.797	0.937	1.026	0.699	-	7.96	0.99	0.003	1.00229
2	-9.687	1.930	0.849	1.030	0.171	7.96	0.99	0.003	1.00228
3	-0.099	0.006	0.002	-	-	20.86	0.90	0.019	-
4	-0.126	0.006	0.002	0.090	-	18.29	0.93	0.014	-
5	-0.147	0.006	0.002	0.089	0.047	18.31	0.93	0.014	-

*Significant by the Student's t test at the 5% error probability level.

The distributions of the residuals of the two equations were similar, *i.e.* both showed uniformity and a slight tendency towards underestimation of stem carbon stock (Figure 6). Equation 1 was selected to estimate the carbon stock of the stand, based on the goodness-of-fit criteria.

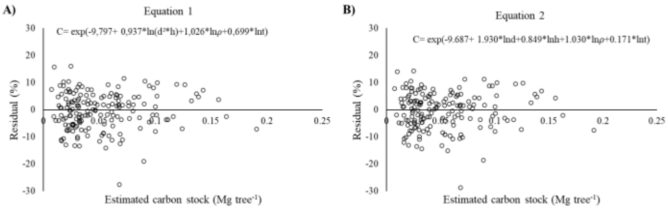

Figure 6. Stem carbon stock: residual plots for Equations 1 (A) and 2 (B).

The graphs of the estimated values by the selected equations as a function of the observed values are shown in Figure 7. For the volume with and without bark, Equation 4 had the best fit; Equation 2 was the best for estimating stem biomass, and Equation 1 was the best for stem carbon stock.

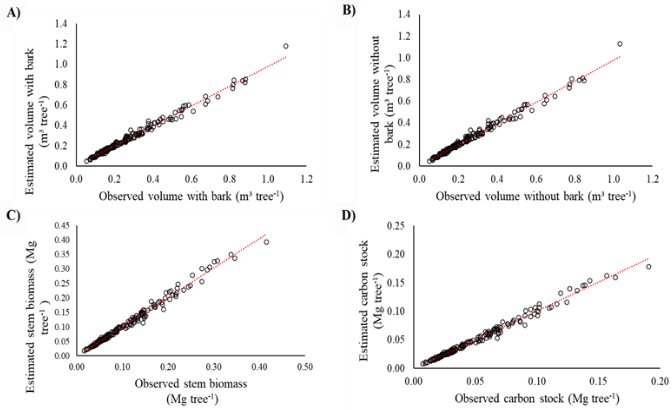

Figure 7. Plots of the observed and estimated values of the equations with the best fits for estimating volume with bark (A) and without bark (B), stem biomass (C) and stem carbon stock (D).

4. Discussion

In this study, volume, biomass and carbon stock were quantified in a plantation of *S. parahyba* in Brazilian Amazonia, and allometric equations were generated. The high variability presented by the dendrometric variables, which is exemplified by the variation in wood basic density (Table 4), may be related to the seed source used for planting the stand, which implies high genetic variability among trees. In addition, the stand was attacked by an insect pest (*Quesada gigas*). This heterogeneity is also visible in the diameter distribution, which is slightly skewed to the right (Figure 3).

These factors may have contributed to the non-compliance with the regression assumptions by some equations. This might be associated with the phytosanitary thinning performed in the stand, which caused the opening of gaps. Thus, there was a change in the levels of competition between individuals. Trees located near gaps had a reduction in competition and a higher incidence of solar radiation than those that remained inside the plantation. This could be a cause for the heterogeneity observed in the dendrometric variables of the stand, which may have also negatively influenced the goodness-of-fit of the tested models.

Considering volume modeling, the selected equation (Equation 4) includes the variables height and diameter, a combination that provides better estimates (Chave et al. 2005; Goodman et al. 2014), which was also seen by a volume underestimation of only 2% in the present study. We highlight the importance of using locally developed equations. For instance, the use of a volumetric equation fitted for *S. parahyba* stands in Roraima (R^2aj.= 0.79; Syx%= 14.08; Tonini et al. 2005), underestimated the volume of the studied stand by about 12%.

Regarding biomass and carbon stock, Equation 2 underestimated the results by about 1%, in addition to including the basic wood density as an independent variable, which is known to contribute to the generation of more accurate estimates of biomass. Despite the relevance of wood density, many studies avoid using this variable because it is time-consuming and costly to assess (Chave et al. 2005; Feldpausch et al. 2011; Goodman et al. 2014). It is therefore important to create databases with this information for native species, a task to which this study may be contributing. By ignoring basic wood density, the effects of the other predictor variables (*d* and *h*) are enhanced, which may increase estimates' magnitude of error.

The yield of the studied *S. parahyba* stand was higher than the yields in other studies that have focused on volume (97.50 - 152.84 $m^3 ha^{-1}$; *e.g.* Cordeiro et al. 2015; Neves et al. 2022) and biomass

(34.53 Mg ha^{-1} - 82.40 Mg ha^{-1}; *e.g.* Batista 2019; Neves et al. 2022). Major reasons for this could be age differences between the stands, since the studied stand of *S. parahyba* was, older than most stands that have been studied. In addition, differences in the genetic material, site, spacing, fertilization and silvicultural treatments can generate significant differences in terms of growth and production in volume, biomass and carbon (Miranda et al. 2016).

The carbon stock obtained in this study (57.79 Mg C ha^{-1}) indicates the potential that *S. parahyba* plantations have in contributing to the mitigation of climate change. The partition of carbon stock in the evaluated stand was higher for the stem (54.62 Mg C ha^{-1}), but the bark also represented an important component in arboreal carbon storage, with 5.5% (3.17 Mg C ha^{-1}) of the total stem carbon stock. The carbon stock value was higher than the value obtained by Neves et al. (2022) in the same study area, but when the stand was six years old (12.48 Mg ha^{-1}). The increase in carbon stock by 437.7% in two years highlights the influence of age on carbon accumulation, which is related to trees' physiology − a greater development of the canopy in the juvenile stage and in the stem at maturity (Martins et al. 2020).

The studied stand had a significant gain in carbon stock in just 2 years (437.7%), despite having suffered an invasion of vines and phytosanitary problems related to the attack of a pest (*Quesada gigas*), which can cause losses of up to 20% of the total planted area (Lunz et al. 2010). This shows the importance of investing in studies of genetic improvement, silviculture and management of *S. parahyba* in order to reach the real productive potential of these plantations (Neves et al. 2022).

Finally, it is expected that the information generated in this study will help to improve estimates of volume, biomass and carbon stock in *S. parahyba* plantations in southwestern Amazon. Studies like this should be replicated in other parts of Brazilian Amazonia to better understand the yield potential of tropical timber species and their contribution to carbon storage.

5. Conclusions

The allometric equations for volume, biomass and carbon stock fitted in this study can generate more accurate yield estimates for *S. parahyba* plantations. Studies like this are relevant to forestry plantations, with commercial native species. This is because *S. parahyba* populations in the southwestern Amazon have importance that goes beyond lamination, being also providers of ecosystem services, such as the sequestration and storage of atmospheric carbon in plantation biomass. Despite the adversities suffered by the studied population, the species showed a considerable accumulation of biomass and carbon stock.

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