

Allometry of aboveground biomasses in mangrove species in Itamaracá, Pernambuco, Brazil

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Abstract Allometric equations to estimate aboveground biomass (AGB) and plant part biomasses (PPB) of three mangrove species, *Rhizophora mangle*, *Avicennia schaueriana*, and *Laguncularia racemosa*, were determined in Itamaracá, Pernambuco, Brazil (7°48'44"S and 34°49'39"W). Twenty-three to thirty-six trees of each species, ranging in height (H) from 1.6 to 11.8 m and in diameter, at breast height or above prop roots (D), from 2 to 21 cm, were measured, cut, and separated into stems, branches, leaves, and prop roots. Biomass proportions in each tree part were similar among species, excluding prop roots: stems 37–47%, branches 41–46%, and leaves 11–17%. Prop roots represented 37% of AGB in *R. mangle*. Tree size had a significant but not large influence on biomass distribution among plant parts: as stem diameters increased the proportions allocated to leaves decreased and those to stems and branches increased. AGB and PPB were significantly related to D and $D^2 \times H$ and the best fittings

were obtained with power equations. A few equations from literature fitted the data reasonably well for AGB of one or two of the species but resulted in large errors for the others. Applying the equations to previous measurements of tree diameters in a sample area, AGB for the mangrove site was estimated at 105 Mg ha⁻¹, with 78, 19, and 3% corresponding to biomasses of *R. mangle*, *L. racemosa*, and *A. schaeuriana* trees, respectively.

Keywords Allometry · Biomass · Mangroves

Introduction

Woody vegetation is the basis for most economical and ecological services provided by mangroves. In some countries, the trees are cut for wood and other products (Ong et al. 2004). In other countries, like Brazil, cutting is forbidden by law but animals feeding on parts of these plants (Norhaus et al. 2006) are an important economic resource (Glaser 2003). In all these countries, determining the aboveground biomass (AGB) of these plants and their different parts is an important step in planning the sustainable use of mangrove resources. This determination is also required for other types of studies, from nutrient cycling to carbon sequestration (Lovelock et al. 2005).

Biomass determination can be done in a direct way, by cutting and weighing all the plants in sample areas. This requires considerable effort and time,

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destroys the vegetation in these areas and, in some situations, is not desirable or may even be illegal. Therefore, several methods have been devised to estimate biomasses, the most frequently used being based on allometric relationships of biomass and plant measurements, such as stem diameter, plant height, and wood specific gravity (WSG) (Ter-Mikaelian and Korzukhin 1997; Zianis and Mencuccini 2004; Chave et al. 2005). Allometric equations to estimate biomasses of total aboveground and other plant parts have been calculated for several types of vegetation, including mangrove species (Putz and Chan 1986; Day et al. 1987; Clough and Scott 1989; Komiyama et al. 2000, 2002, 2005; Sherman et al. 2003; Ong et al. 2004; Kahn et al. 2005; Chave et al. 2005; Soares and Schaeffer-Novelli 2005; Smith III and Whelan 2006). Most of the studies refer to Southeast Asia and Australia with just a few on South American species (Soares and Schaeffer-Novelli 2005; Smith III and Whelan 2006). Only three have been published on Brazilian mangroves (Silva et al. 1991, 1993; Soares and Schaeffer-Novelli 2005) in spite of the large area they occupy in the country and the relatively high proportion they represent among mangroves in the continent.

The objective of this work was to determine the proportions of AGB allocated to different plant parts and to determine allometric equations to estimate aboveground and plant part biomasses (PPB) of the three most important mangrove species in Northeastern Brazil: *Rhizophora mangle* L., *Avicennia schaueriana* Stapf and Leechman, and *Laguncularia racemosa* (L.) Gaertn.

Methods

The study was conducted in 1994, in the mangrove area close to Vila Velha, Itamaracá, Pernambuco, Brazil, around the Paripe river (7°48'44"S and 34°49'39"W). The mangrove site covers 37 ha and is almost flat, being flooded for 2–3 h at high tide. Water salinity (Practical Salinity Scale), except at the river mouth, varies from 20 to 34. Rainfall in the area varies around 2,200 mm per year, mostly concentrated from March to August. The average temperature is 26°C, with slight daily (20–30°C) and monthly (25–27°C) variations. Predominant winds come from southeast at speed of 2–3 m s⁻¹.

Rhizophora mangle was represented by 36 trees, *L. racemosa* by 35 and *A. schaueriana* by 23, chosen to cover the common range of stem diameters registered in the area (Silva 1995). The largest registered diameters were not represented because they refer to exceptional trees, that are difficult to find and not recommended to cut. The minimum diameter was 2 cm at 1.3 m height diameter at breast height (DBH) for all species, except above prop roots in the case of *R. mangle*. The trees were selected at random, searching for ones that fit the sizes still lacking in the diameter range but excluding those with any sign of clear abnormality (crown braking, parasites, very inclined stem growth due to heavy shading or dead leaning trees, etc.).

Each selected individual's girth at 1.3 m height (at breast height) for all species except above prop roots was measured, plus the length of the longest axis of the crown projection area and its longest orthogonal axis. Perimeters were transformed to diameters (D), assuming a circular shape, and also to basal area (BA). When branching occurred below measuring height, the area of each branch was calculated and all the areas added to a single BA, from which a median diameter was calculated. The crown projection area was calculated assuming an elliptical shape. After measuring, the tree was cut at the base in such a way that the crown fell onto a canvas sheet on the ground. Then, measurements of tree height (H) were taken, adding the part corresponding to the stump.

The tree was then separated into three parts: (1) stem, up to the first branching; (2) branches; and (3) leaves. The total mass of the different parts was weighed and sampled for subsequent analysis. Wooden disks for specific gravity (WSG) determination were taken from the stem and the largest branches. Dry matter was determined after oven heating at 60°C until constant weight. The weight of the stump was calculated from its volume and WSG and added to the weight of the tree.

The whole tree biomass and also the tree parts biomass relationship to tree measurements were determined using single variables and also different combinations of tree measurements, either summed or multiplied. The data were fitted to six types of regression equations (linear, quadratic, cubic, logarithmic, exponential, and power function) using common statistical programs and fitting evaluation was based on the coefficient of determination (R^2)

and also on the square root of the error mean square (standard error), because of the different number of variables in some equations. Only the best fitting equations are shown. Also, to evaluate precision of fitting, the deviation from the estimated biomass to the real biomass of each tree was calculated, using the whole set of plants of each species or the combined set of the three species. These calculation were done for the equations developed in this work and also for equations that have been presented in different papers (Putz and Chan 1986; Day et al. 1987; Clough and Scott 1989; Silva et al. 1991; Fromard et al. 1998; Komiyama et al. 2000, 2002, 2005; Sherman et al. 2003; Ong et al. 2004; Kahn et al. 2005; Chave et al. 2005; Soares and Schaeffer-Novelli 2005; Smith III and Whelan 2006). An equation was considered as adequate when the sum of deviations from the real biomasses was <15% of the total biomass of all trees in the set.

Results

The size range of *R. mangle* trees was much larger than the other two species, especially of *A. schaueriana* (Table 1). The largest selected *R. mangle* reached 21 cm in stem diameter (D), 14 m height (H), and 526 kg of AGB, while the largest *A. schaueriana* had only half these D and H and about 6% of this biomass. The larger *R. mangle* trees reflect the better adaptation of the species to the site, which is also confirmed by dominance in plant density (74% of total density of 3,487 stem ha⁻¹) and in BA (66% of total BA of 14.1 m² ha⁻¹) in the site (Silva 1995). The opposite was true for *A. schaueriana* with only 6% of the total density and 8% of the total BA (Silva 1995). *L. racemosa* occupied an intermediate position, both in size range (the largest

tree with 18 cm D, 12 m H and 132 kg AGB) and position in the mangrove tree community (density 20% and BA 26%). WSG varied little within species and the averages of *R. mangle* and *L. racemosa* were similar (0.93 g cm⁻³) and higher than *A. schaueriana* (0.73 g cm⁻³).

Tree size had a significant but not large influence on the biomass distribution among tree parts. For all three species, as stem diameters increased the proportion allocated to leaves decreased. Plants in the ≤5 cm diameter class had 16% leaf biomass and this proportion decreased to 7% in plants >15 cm (the intermediate classes >5–10 and >10–15 cm had 12 and 9%, respectively). The proportion of biomass in *R. mangle* prop roots also decreased with increase in diameter, from 42 in the smallest to 30% in the largest diameter class. In all three species, the proportions allocated to branches and stems were roughly similar, having much lower values in *R. mangle* (35–20%) than in the other two species (50–40%) because of prop root participation in the former species.

Except for the biomass allocated to prop roots, there were no large differences among species in proportions in each plant part. The slight differences in averages (Table 2) reflect the influence of the different size range. Thus, the proportion in leaves is slightly lower in *R. mangle* (11%) than in *A. schaueriana* (14%) because of contribution from larger trees of the former species.

Total aboveground biomasses (AGB) were significantly related to diameter (D), in all three species. Power equations fitted the data best (Table 3), with lower *R*² for *A. schaueriana* (0.78). For all species, biomass estimation was improved if plant height (H) was also considered (D² × H), but this increase was rather small for *R. mangle* and *L. racemosa*. This probably occurred because the D fitting for these two

Table 1 Size range of selected trees of the three mangrove species (*Avicennia schaueriana* Stapf and Leechman, *Rhizophora mangle* L., and *Laguncularia racemosa* (L.) Gaertn.), in Itamaracá, Pernambuco, Brazil

Variable	<i>A. schaueriana</i>		<i>R. mangle</i>		<i>L. racemosa</i>	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Stem diameter (cm)	3.4	10.2	2.5	20.7	2.1	17.8
Height (m)	3.1	7.5	1.8	14.0	1.6	11.8
Crown area (m ²)	2.0	10.7	1.1	73.9	0.9	35.9
Biomass (kg)	3.0	29.6	4.1	526.0	0.9	132.4

species was already good (R^2 of 0.92 for *R. mangle* and 0.96 for *L. racemosa*) and because D and H were highly correlated (R^2 of 0.87 for *R. mangle* and 0.71 for *L. racemosa*). The fitting for *A. schaueriana* increased when H was included (R^2 of 0.84) and the relationship of D to H was weak (R^2 of 0.38). Inclusion of WSG improved fittings very little, in most cases with no statistical significance. Considering all plants together, of the three species

(Table 4), AGB was still significantly related to the diameter ($R^2 = 0.89$) with small increases in the coefficients of determination when height ($R^2 = 0.90$) and WSG ($R^2 = 0.91$) were included.

Stem, branch and leaf biomasses could also be estimated using power equations based on D (Table 3). The fitting was good for *R. mangle* and *L. racemosa* but for *A. schaueriana* only the equation for branches had a significant R^2 (0.76). For the other two species, the lowest coefficients of determinations were obtained for leaves. Inclusion of height and/or WSG did not significantly improve fittings, even in the case of *A. schaueriana*. Considering all plants (Table 4), the diameter was still a good estimator of stem ($R^2 = 0.85$), branch ($R^2 = 0.91$), and leaf ($R^2 = 0.74$) biomass. Inclusion of height and/or WSG slightly improved fittings.

Diameter was also a good estimator of crown area (CA) for both *R. mangle* ($CA = 2.6356D$, $R^2 = 0.82$) and *L. racemosa* ($CA = 1.4423D$, $R^2 = 0.72$) but not for *A. schaueriana* ($R^2 = 0.24$).

Table 2 Average proportions of total aboveground biomass allocated to different plant parts in three mangrove species [*Avicennia schaueriana* Stapf and Leechman, *Rhizophora mangle* L., and *Laguncularia racemosa* (L.) Gaertn.], in Itamaracá, Pernambuco, Brazil

Plant part	<i>A. schaueriana</i>	<i>R. mangle</i>	<i>L. racemosa</i>
Leaves	14	11 (17)	12
Branches	45	29 (46)	41
Stem	41	23 (37)	47
Prop roots	–	37	–

Data in parenthesis refer to proportions excluding prop roots

Table 3 Equations to estimate biomass (kg) of different plant parts based on stem diameter at 1.3 m height, for all species except 20 cm above prop roots (D, cm) and total tree height

(H, m) of three mangrove species [*Avicennia schaueriana* Stapf and Leechman, *Rhizophora mangle* L., and *Laguncularia racemosa* (L.) Gaertn.], in Itamaracá, Pernambuco, Brazil

Plant part	<i>A. schaueriana</i>		<i>R. mangle</i>		<i>L. racemosa</i>	
	Equation	R^2	Equation	R^2	Equation	R^2
Leaves	$0.2436D^{0.8826}$	0.21	$0.0479D^{2.165}$	0.83	$0.0407D^{1.7324}$	0.85
Branches	$0.0324D^{2.6643}$	0.76	$0.0549D^{2.5638}$	0.90	$0.0330D^{2.6091}$	0.94
Stem	$0.01375D^{1.7807}$	0.38	$0.0499D^{2.4911}$	0.89	$0.0787D^{2.2276}$	0.90
Prop roots	–		$0.1705D^{2.1505}$	0.85	–	–
Aboveground	$0.2309D^{2.0685}$	0.78	$0.2938D^{2.384}$	0.92	$0.1442D^{2.325}$	0.96
Aboveground	$0.1327(D^2H)^{0.8298}$	0.84	$0.2752(D^2H)^{0.8529}$	0.94	$0.1214(D^2H)^{0.8615}$	0.97

R^2 , coefficient of determination

Table 4 Equations to estimate biomass (kg) of different plant parts based on stem diameter at 1.3 m height, for all species except 20 cm above prop roots (D, cm), total tree height (H, m), and wood specific gravity (WSG, $g\ cm^{-3}$) of plants

belonging to three mangrove species [*Avicennia schaueriana* Stapf and Leechman, *Rhizophora mangle* L., and *Laguncularia racemosa* (L.) Gaertn.], in Itamaracá, Pernambuco, Brazil

Plant part	Diameter		Diameter and height		Diameter, height, and wood specific gravity	
	Equation	R^2	Equation	R^2	Equation	R^2
Aboveground	$0.1346D^{2.525}$	0.89	$0.1129(D^2H)^{0.9241}$	0.90	$0.1273(D^2H\ WSG)^{0.9252}$	0.91
Leaves	$0.0341D^{2.0687}$	0.74	$0.0292(D^2H)^{0.7595}$	0.76	$0.0325(D^2H\ WSG)^{0.7587}$	0.76
Branches	$0.0336D^{2.6901}$	0.91	$0.0307(D^2H)^{0.9666}$	0.89	$0.0357(D^2H\ WSG)^{0.9625}$	0.89
Stem	$0.0633D^{2.3277}$	0.85	$0.0485(D^2H)^{0.8715}$	0.90	$0.0548(D^2H\ WSG)^{0.871}$	0.91

R^2 , coefficient of determination

Discussion

The maximum sizes of the trees studied were smaller than those found at the same site by Silva (1995). For *R. mangle* and *A. schaeuriana* the differences in diameter were only a few centimeters but for *L. racemosa* there was a difference of more than 10 cm. The very large trees were not sampled because they were few and were found clumped in one place at the edge of the mangrove. In fact, in Silva's survey they constituted the only trees in the 30–40 cm diameter class, with no *L. racemosa* in the class below (20–30 cm). Even including these plants, the mangrove trees at Vila Velha, Itamaracá, were much smaller than those in other sites in the region (Souza and Sampaio 2001; Deus et al. 2003) and in other countries, be it in South America (Fromard et al. 1998) or in Asia (Komiyama et al. 2005), where they may reach around 30 m height and more than 50 cm diameter. However, several other sites in the Brazilian Northeastern (Sampaio 1996) and Southeastern states (Soares 1999; Bernini and Rezende 2004; Soares and Schaeffer-Novelli 2005) have trees of similar or even smaller size than those of Vila Velha. The same occurs in other countries, including dwarf mangroves <5 m tall (Lovell et al. 2005). The reason for the limited size at Vila Velha is not known. It could be that the vegetation is still developing from previous cuttings but there are no records of complete or severe cuttings and mangroves are protected by law. Environmental conditions (temperature, rainfall, and sediment) are similar to those of the Piauí site (Deus et al. 2003), except for a greater influence of sea water at Vila Velha. It is known that high salinity tends to limit the growth of mangrove plants (Sherman et al. 2003; Soares and Schaeffer-Novelli 2005).

The average proportions of tree biomass in stems (23–47%), branches (29–45%), and leaves (11–17%), of all three species, and of prop roots (37%) of *R. mangle*, were similar to those found in other studies (Fromard et al. 1998; Komiyama et al. 2000; Kahn et al. 2005), except when the majority of trees measured in these studies were much larger (Sherman et al. 2003). In this latter study, at an even aged, 50-year-old stand at Dominican Republic, with trees averaging 24 m height, the proportions in the stems were higher (63–83%) and those in branches and twigs (10–12 and 3–6%) and in leaves (2–4%) were

lower than in Vila Velha. Larger trees, in general, follow this pattern, with a higher relative biomass allocation to structural tissue and lower to leaves (Ong et al. 2004; Soares and Schaeffer-Novelli 2005). This results from a gradual increase in the absolute mass of stem and branches while the absolute mass of leaves tends to stabilize after a certain tree size is reached (Fromard et al. 1998; King 2005). It must be emphasized that comparing branch and twig data is complicated because there is no uniformity of criteria in their sizes and in some cases these sizes are not even informed.

Several plant variables and statistical models have been tested in search of the best estimator of plant and community biomasses. The subject was reviewed recently, listing many models, including diameter (D), height (H), and WSG as variables (Chave et al. 2005). Some of these models were designed specifically for mangroves. In general, it was found that inclusion of the three variables resulted in the best fitting of the data and that the single best predictor was DBH. For Vila Velha data, stem diameter was also the best single predictor, both for isolated species and for the three species together, and adding height ($D^2 \times H$) and WSG ($D^2 \times H \times WSG$) improved estimation but to a small degree and sometimes not significantly (R^2), mainly considering that extra variables are being added. WSG is an important variable when many species, with large differences, are included in the estimation (Clough and Scott 1989; Komiyama et al. 2002; Chave et al. 2005). It was not the case in this study, with only three species, two having similar WSG.

Inclusion of height improved estimation in most cases but only for *A. schaeuriana* there was a reasonable difference. This probably occurred because D and H were highly correlated in the other two species but not in *A. schaeuriana*. Apparently, *A. schaeuriana* trees were dominated by those of the other species and occupied whatever space was left to them. Some trees, enclosed by the others, grew tall, and thin, while others, with more space, had a more regular growth. Thus, biomass estimation improved when considering both vertical and lateral growth. This adaptation of growth also resulted in a low relation between diameter and CA, contrary to that found for *R. mangle* and *L. racemosa*, respectively

Tree height is not easily measured in closed communities, and its determination in large groups of

plants is a laborious task. Therefore, available data for communities are scarce and recommendations to obtain them are followed with reluctance. Since, in most cases, height as an isolated variable is not a good estimator and the improvement in adding it to diameter is small, some authors have concluded that it is not worthwhile including it in their allometric equations (Haase and Haase 1995; Rayachhetry et al. 2001; Chave et al. 2005). Smith III and Whelan (2006) found a good relation between height and biomass in Florida mangroves but diameter gave a similar fit and they recommended the use of this last variable. The data at Vila Velha support this recommendation.

The power equation fitted the data better than any other model, as has been found by several other studies, both for mangrove species (Chave et al. 2005) and for species belonging to other vegetation types, under many different conditions (Ter-Mikaelian and Korzukhin 1997; Zianis and Mencuccini 2004). The fact that data for all three species can be fitted by a common equation with reasonable precision could facilitate future estimations of biomasses in other mangrove areas. It is a valuable tool which substitutes the need of destructive sampling by a simple plant measurement. However, these estimations must be done with caution because: (1) extrapolation to plants larger than those used to fit the equation should not be done unless they are very few and represent a small proportion of the total community biomass; (2) the range of *R. mangle* tree sizes was larger than those of the other species and this influenced the common equation which was more similar to the specific equations for this species than to the others; (3) the equation may not apply to trees of other areas, in spite of being the same species. This is well illustrated by the general failure of fitting equations developed for mangrove trees of other areas to the data of trees at Vila Velha.

Of the several models and equations suggested in literature (Putz and Chan 1986; Day et al. 1987; Clough and Scott 1989; Silva et al. 1991; Komiyama et al. 2000, 2002, 2005; Sherman et al. 2003; Ong et al. 2004; Kahn et al. 2005; Chave et al. 2005; Soares and Schaeffer-Novelli 2005; Smith III and Whelan 2006), only a few fitted Vila Velha data with reasonable precision, considering either isolated species or the three together. Assuming that under or overestimation of the real biomass of all 94 plants

should not exceed 15%, only five equations fitted the data well for the three species together. All of them were developed for *Rhizophora* species and four were power equations with similar parameter values, after transformation from the original format: (1) the equation developed by Soares and Schaeffer-Novelli (2005), specifically for *R. mangle* at their Bertioiga site (equivalent to $B = 0.133D^{2.617}$); (2) the equation developed by Fromard et al. (1998), also specific for *R. mangle* ($B = 0.128D^{2.6}$); (3) the equation developed by Clough and Scott (1989), for *Rhizophora* spp. (equivalent to $B = 0.105D^{2.685}$); and (4) the equation developed by Putz and Chan (1986) for *Rhizophora apiculata* Blume (equivalent to $B = 0.171D^{2.516}$). The fifth adequate equation, developed by Silva et al. (1991), was a modified exponential equation (equivalent to $B = 1.41e^{0.3D}$). However, none of these equations fitted the isolated data set of *R. mangle* well at Vila Velha, with the estimated biomasses under or over estimating the real value by more than 35%. A few other equations fitted the data set of a single species well but not that of the other two species.

The search for a general model, fitting many species at different locations, has been justified by the extreme difficulty of developing and applying species-specific equations for the large diversity of tropical vegetation (Chave et al. 2005). It is backed by the observation that the range of biomasses for a given set of plant characteristics is not very large (Zianis and Mencuccini 2004), that the parameters for the same type of equation are not very different for different species and sites, including those growing under very different conditions (Sampaio and Silva 2005) and that the range of variation is restricted by theoretical considerations of structural mechanics (King 2005). The good fitting of some of the equations developed for other mangrove to our data confirms the rough similarity in the range of biomasses. However, many more of the equations resulted in poor fittings and there was no discernible way of knowing beforehand which would fit and which would not. Therefore, the search for general equations shall go on, refining and standardizing methodologies and gathering larger data sets. Currently, regionally developed equations have to be used, with due caution in their application. For mangroves, especially South American ones, that do not have as high species richness as other tropical vegetation types, the task is not so difficult and specific site equations may still be the best option.

The equations for plant parts exhibited a larger variation and had lower coefficients of determination than those for total biomass, a fact explained by the possible compensation of biomass among plant parts: a shorter stem, for instance, compensated by a larger branching crown and vice versa. Lower R^2 of equations for leaves than for other plant parts have been frequently reported (Komiyama et al. 2000; Sherman et al. 2003; Ong et al. 2004; Soares and Schaeffer-Novelli 2005; Smith III and Whelan 2006). This weaker relationship of leaf biomass and plant measurements could result from limitations on the compensating factor, leaves being of a completely different structure from stems and branches, and from the possibility of larger variations, in the same plant, along the year, leaves having a shorter turnover rate than the other plant parts. In spite of the somewhat low precision, estimation of leaf biomass provides important information on this fundamental source of the mangrove food chain (Norhaus et al. 2006).

The three species equations (Table 3) were used to estimate biomass of the Vila Velha community, based on Silva's (1995) phytosociological data. Total AGB was 105 Mg ha⁻¹, with 78, 19, and 3% represented by *R. mangle*, *L. racemosa*, and *A. schaueriana*, respectively (Table 5). This biomass is in the lower quarter of the wide range (7–436 Mg ha⁻¹) reported for mangrove biomasses (Saenger and Snedaker 1993) and reflects the relatively small diameters and heights reached by most trees. The community leaf biomass was estimated as 9 Mg ha⁻¹, slightly lower than the leaf biomass (13 Mg ha⁻¹) found by Komiyama et al. (2000) in a site with 92 Mg ha⁻¹ of AGB and higher than the biomasses (3–7 Mg ha⁻¹) obtained by Sherman et al. (2003) and Fromard et al. (1998) in sites

with much larger AGB (123–385 Mg ha⁻¹). Considering that this standing biomass is renewed each year, it provides detritivores with an important resource in the area. In the Brazilian Pará state, a similar leaf biomass (11 Mg ha⁻¹) was collected as litterfall, along 1 year, about 80% of which was estimated as being consumed by crabs (Norhaus et al. 2006).

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Table 5 Biomasses (Mg ha⁻¹) at Itamaracá community, for three mangrove species [*Avicennia schaueriana* Stapf and Leechman, *Rhizophora mangle* L., and *Laguncularia racemosa* (L.) Gaertn.], calculated from equations based on stem diameter and phytosociological data (obtained from Silva 1995)

Plant part	<i>A. schaueriana</i>	<i>R. mangle</i>	<i>L. racemosa</i>
Leaves	0.32	7.61	1.42
Branches	1.30	24.16	9.39
Stem	1.14	20.49	9.54
Prop roots	–	29.41	–
Total	2.76	81.67	20.35

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