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Short communication

Aboveground biomass stock of native woodland on a Brazilian sandy coastal plain: Estimates based on the dominant tree species

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Abstract

The restingas of coastal Brazil are vegetation mosaics that include forests and open woodlands. One of the most common restinga vegetation types in Rio de Janeiro state, an open woodland, is dominated by the crassulacean acid metabolism (CAM) tree *Clusia hilariana* Schltdl. (Clusiaceae). We provide allometric equations and biomass estimation for this species on three sites varying woody plant cover. Estimated aboveground biomass stock of *C. hilariana* plus the litter accumulated underneath the canopy of these plants ranged from 0.64 to 8.63 t ha^{-1} depending on plant cover. These values are often comparable to those of the entire woody component of many neotropical savannas, which have been claimed to have important impact on global carbon cycles. The litter-layer represents 31% of aboveground biomass, which is very high when compared to other tropical savannas. This indicates that slow decomposition may play an important role on carbon accumulation at the studied ecosystem. Thus, *C. hilariana*, despite its conservative strategy of carbon acquisition via CAM, gives a high contribution to biomass stock in this nutrient-poor coastal vegetation in the tropics.

Keywords: Aboveground biomass stock; *Clusia*; Allometry; Carbon sequestration

Estimation of stand biomass of managed forests is a usual practice to quantify fuel and wood stock. However, with the increasing concern about the rising of atmospheric CO_2 concentrations, there have been many efforts to estimate biomass stock and production on natural vegetation (see Clark et al., 2001a; Barbosa and Fearnside, 2005). Although special attention has been paid to tropical forests (Clark, 2002, 2004; Phillips et al., 2002), biomass measurements on natural tropical vegetation often face some methodological difficulties due to the high local diversity of plant species and life forms (Clark et al., 2001b). Features such as trunk deformity and buttress roots, for instance, are common sources of errors in biomass estimation when using allometry equations.

Coastal vegetation, and particularly woodlands, have traits that make them promising areas for CO_2 sequestration purposes, such as: (1) low quality of the litter and well-drained, nutrient-poor sandy soil that might impose unfavorable conditions for decomposition processes, and consequently provide carbon accumulation; (2) most native plant species are able do deal with harsh environmental conditions, maintaining elevated photosynthetic rates or rapidly recover them after unfavorable atmospheric condition events; and (3) even undisturbed vegetation have open areas that can be managed to enhance biomass stock (De Mattos and Scarano, 2002; Orellano and Isla, 2004; Scarano et al., 2005).

The Brazilian *restingas*, i.e. the vegetation mosaic found at the Quaternary sandy coastal plains covering most of the ca. 5000 km of Brazilian coastline (see Lacerda et al., 1993; Scarano, 2002), often show the above traits. However, although studies on biomass stock and production of Brazilian rain forests flourish (see Clark et al., 2001a), there is still a gap in regard to such studies for coastal woodlands (De Mattos and Scarano, 2002). Previous studies focused on species of the herb strata (Hay et al., 1982; Menezes and Araujo, 2000) and there is no previous information available for trees and shrubs.

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This study provides the first biomass allometric equations and estimation of aboveground biomass stock for the dominant plant species of the most typical vegetation type of the Restinga de Jurubatiba National Park (22°00′–22°23′S, 41°15′–41°45′W) state of Rio de Janeiro, south-east Brazil. This vegetation type has patches of trees and shrubs surrounded by white sand and sparse herbaceous clumps. It covers 40% of the total 14,000 ha of the National Park. It is called "*Clusia* formation" because *Clusia hilariana* Schltdl. (Clusiaceae) is the most conspicuous woody species in the site, reaching up to 8 m of height, and appearing as the central plant in most woody vegetation patches (Scarano, 2002). Morever, *C. hilariana* is also the dominant plant in the site, since it has the highest importance value (a phytosociological index that is the sum of relative frequency, density and basal area) among all woody species (Araujo et al., 2004). The main curiosity here is that this vegetation is probably one of the few types (if not the only type) of woodland in the world to have a predominant crassulacean acid metabolism (CAM) tree cover, since this tree obligatorily performs this photosynthetic pathway (Franco et al., 1999). Thus, the vegetation as a whole should be assimilating CO_2 24-h a day: during daytime by the C_3 cover and at night-time by the CAM cover. Although carbon assimilation is often not very high in obligatory CAM plants (Nobel, 1988), maximal rates of CO_2 uptake of *C. hilariana* during the night (ca. 6–10 μmol m^{-2} s^{-1}, unpublished data) is high enough to counterbalance the flux to the atmosphere of CO_2 respired during the night by C_3 plants. Detailed descriptions about the study site and *C. hilariana* can be found elsewhere (Liebig et al., 2001; Barbosa et al., 2004; Dias et al., 2005; Scarano et al., 2005).

We selected 15 individuals of *C. hilariana* ranging from the smallest (0.7 m) to the highest (7.5 m) height class for the construction of allometry equations. The criterion adopted to select the plants between these two extremes was to pick healthy individuals covering the entire height distribution range. Before harvesting the whole tree, we recorded trunk diameter, height, and the two larger canopy diameters perpendicular to each other. Canopy cover was calculated as an elliptical area, based on the two diameters recorded. Trunk diameter was recorded above aerial roots in order to assess the cylindrical portion of the trunk. Trees were harvested carefully, beginning by fine stems in order to avoid leaf losses. In the field, plants were separately weighted for leaf, fine stems, stems and trunks. For these same plant parts of each individual, sub-samples were collected and dried in laboratory at 60 °C until constant weight was reached. The relation between fresh and dry weight was used as a correction factor for total plant dry weight (biomass) determination.

Allometric equations were constructed for total above-ground biomass, leaf mass, stem mass and canopy cover area. For this purpose, we used the power function equation:

$$Y = aD^b;$$

where Y is one of the variables cited above, D is the trunk diameter and a and b are constants of the equation. Equations fit and parameter estimates were determined by the least square approximation using Levenberg–Marquardt method (Motulky and Christopoulos, 2003).

For estimation of *C. hilariana* aboveground biomass stock and canopy area cover, we used allometric equations and data of population structure of this species available for three sites within the Park. The three sites surveyed for population structure were located between Cabiúnas and Comprida Lagoons, comprising different percentages of plant cover (i.e., percentage ground area covered by the projection of the vegetation canopy; see Sampaio et al., 2005). On each site, two plots with 1 ha were placed where all individuals of *C. hilariana* had the trunk diameter recorded. Biomass and canopy area cover were estimated on a tree-by-tree basis, and then values of all individuals were added up in each site. For estimation of litter mass per square meter, we surveyed 12 patches dominated by *C. hilariana* on each site. These patches ranged from 7 to 10 m of diameter, which is the highest size class for this type of vegetation patch. In each of them, we placed four circular litter collectors with 20 cm diameter at the four cardinal points, where all litter (leaves + twigs) was collected. Litter samples were dried at 60 °C to constant weight. The estimation of litter mass per square meter was multiplied by *C. hilariana* canopy cover in each site in order to assess the litter stock.

Allometric equations fit allowed good estimation of biomass and canopy cover (Fig. 1; see Table 1 for fit parameters). Greater variation was observed on the model for leaf mass due to one individual that showed much lower observed than predicted leaf mass (Fig. 1B). However, the model was able to explain 84% of data variance (Table 1). It is not uncommon to find large individuals with lower leaf density, which is possibly associated with senescence process (Scarano et al., 2004). We opted to include this individual on the model construction, in order to account for this natural variability.

The aboveground biomass stock of *C. hilariana* on the study sites ranged from 0.44 to 5.87 t ha^{-1}. When we added the litter stock underneath the patches dominated by *C. hilariana* (which comprised litter of *C. hilariana* and of other plant species), the total aboveground biomass ranged from 0.64 to 8.63 t ha^{-1} depending on vegetation cover (Table 2). Savannas, that have been claimed to have important impact on global carbon cycles, have a similar woody plant cover to restingas (ranging from 10 to 50%, as defined by House and Hall, 2001). A recent survey on Amazonian savannas in Brazil points out for total values of aboveground biomass stock ranging from 1.6 to 11.7 t ha^{-1} (Barbosa and Fearnside, 2005). Since these authors indicate that the participation of herb plants amounts to 18–52% of these savanna figures, it appears that the contribution of restinga woody plants to biomass stock, judging from *C. hilariana* alone, is probably much higher than that found for woody plants of neotropical savannas. The fact that *C. hilariana* represents only 5–33% of the total vegetation cover in these areas (Table 2) is a strong evidence favouring this hypothesis. However, the values found for *C. hilariana* are on the lower limit of the range described for woody plants in African savannas, which varies from 5.7 to 33.0 t ha^{-1} (House and Hall, 2001).

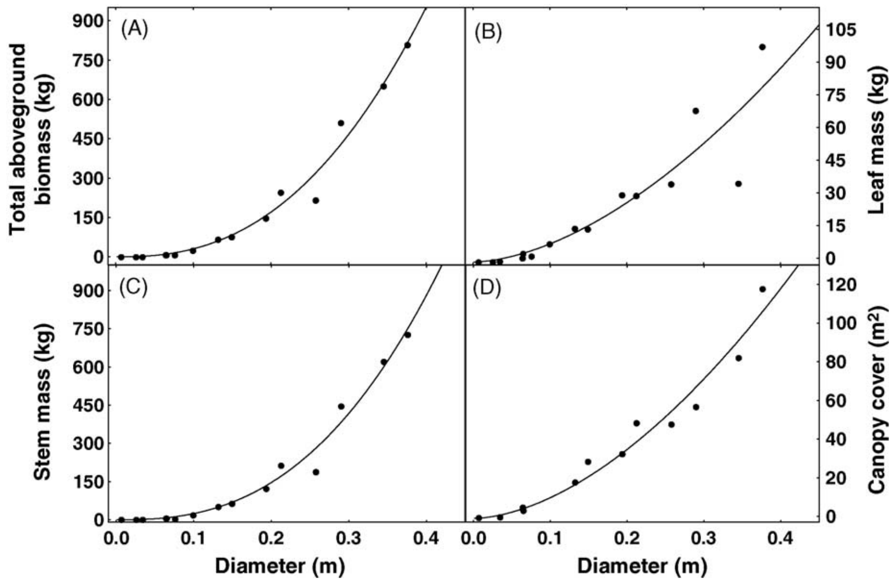

Fig. 1. Allometric models between trunk diameter above adventitious roots and (A) total aboveground biomass ($F = 460$; $P < 0.0001$), (B) leaf mass ($F = 62$; $P < 0.0001$), C) stem mass ($F = 480$; $P < 0.0001$) and (D) canopy cover area ($F = 292$; $P < 0.0001$) for *Clusia hilariana*. Parameters estimates and fit can be seen in Table 1.

Litter-layer represented 31% in average of the aboveground biomass of the patches dominated by *C. hilariana* in the restinga. This is a very high value compared to the 3% found by Chen et al. (2003) for a tropical Australian savanna and to the 6–9% found by Barbosa and Fearnside (2005) for Amazonian savannas. Considering that 70% of the litter underneath *C. hilariana* canopy is composed by its own leaves (Silva, 2003; Scarano et al., 2004), there is twice as much leaf biomass of *C. hilariana* on litter than on stand live biomass stock. Since leaf mortality of *C. hilariana* is not markedly seasonal (Rosado, 2006), the high litter stock in relation to living biomass suggests that slow decomposition, due to both low litter quality and harsh environmental conditions, may have an important role for carbon accumulation on this ecosystem. This is in contrast with tropical rain forests, where litter stock represents the accumulation of one year of production at most (Grace et al., 2001). Moreover, Suhett et al. (2004) showed high concentrations of dissolved organic carbon on the restingas' water table, reaching up to 168 mg C L^{-1} with 72% of humic fraction. The accumulation of humic compounds on the water table is the result of continual leaching of the litter-layer and this may increase the time of residence of carbon since humic compounds are very refractory to decomposition (Tranvik, 1998).

As shown by Zamith and Scarano (2006), the introduction of native species has great potential for restoration of species diversity and ecosystems functioning on degraded restingas areas. However, comparing with an evaluation of land cover change from unproductive dune to forested exotic woods on coastal barriers (Orellano and Isla, 2004), native restinga vegetation might be a poorer option for management with CO_2 fixation purposes. Even on a hypothetical scenario of 100% of *C. hilariana* cover, this would imply in 40.67 t ha^{-1} of live biomass and 18.17 t ha^{-1} of litter, adding up to 58.84 t ha^{-1} of total aboveground biomass stock. This value is still one order of magnitude lower than that found for the exotic, introduced tree

Table 1
Parameter estimates and standard errors of allometric equations ($Y = aD^b$; where D is trunk diameter) for total above biomass, leaf mass, stem mass and canopy cover area of *Clusia hilariana*

Component	Parameter	Parameter estimates	S.E.	*t*	R^2
Total	*a*	9219.26	1910.81	4.82	0.98
	b	2.48	0.19	13.31	
Leaves	*a*	345.93	145.68	2.37	0.84
	b	1.71	0.35	4.85	
Stem	*a*	9503.73	2004.99	4.74	0.98
	b	2.60	0.19	13.59	
Canopy area	*a*	580.43	120.55	4.81	0.96
	b	1.74	0.18	9.81	

In all cases $P < 0.05$.

Table 2
Estimates of aboveground biomass stock, percentage of canopy area cover and understorey litter stock of *Clusia hilariana* for three sites with different vegetation covers at the Restinga de Jurubatiba National Park

	Vegetation cover		
	High (42)	Intermediate (29)	Low (20)
Clusia cover (%)	14	11	1
Leaf mass (t ha^{-1})	0.91	0.72	0.07
Stem mass (t ha^{-1})	5.00	3.60	0.38
Total stand biomass (t ha^{-1})	5.87	4.33	0.44
Litter mass (t ha^{-1})	2.76	1.81	0.20
Total biomass stock (t ha^{-1})	8.63	6.14	0.64

The percent vegetation cover for the sites is given in parenthesis and follows Sampaio et al. (2005).

species in the study of Orellano and Isla (2004). Nevertheless, the use of native species for restoration of degraded areas may merge carbon fixation and biodiversity conservation purposes, since this ecosystem is highly endangered by land use changes as touristic land reclamation (Barbosa et al., 2004).

This study indicates that *C. hilariana*, despite its conservative strategy of carbon acquisition via CAM, gives a high contribution to biomass stock in the nutrient-poor restinga coastal vegetation in the tropics. The CAM photosynthesis maximizes water use efficiency, possibly enhancing persistence under short-term fluctuations of water availability on the restingas due to the sandy substrate. Moreover, the values found for this plant alone are often comparable to those of the entire woody component of many neotropical savannas. Although this points out for a high potential of CO_2 sequestration in the Brazilian restingas, further studies including other species and other ecosystem compartments shall be necessary to reach more precise estimates.

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