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Variability of carbon content in mangrove species: Effect of species, compartments and tidal frequency

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ABSTRACT

As mangroves become recognized as important carbon storages, the need for quantifying and reducing the uncertainty of carbon inventories, such as those arising from specific carbon contents, becomes increasingly emphasized. In this sense, the present study tests the influence of plant parts, species (*Avicennia schaueriana*, *Rhizophora mangle*, *Laguncularia racemosa*) and tidal flooding frequency (physiographic types) on the carbon content ($n = 510$) of mangroves from Southeast-Brazil, using factorial ANOVA and Tukey post-hoc tests. Based on these tests, the impact of the using generic instead of specific carbon contents on the accuracy of carbon stock inventories was assessed. The results show that plant parts and species control, to a certain extent, the carbon content variability. However, we did not detect a clear pattern of influence of the physiographic types on the carbon content. The tests also indicated that woody parts (trunk, branches and prop roots), green parts (leaves and reproductive parts) and roots formed highly distinct groups. Based on the results of the third order interaction test, we propose the following specific carbon contents: woody parts for all species = 44.1 ± 1.4%; green parts of *A. schaueriana* and *L. racemosa* = 42.6 ± 1.4% and of *R. mangle* = 44.9 ± 4.5%; roots of *A. schaueriana* and *L. racemosa* = 42.6 ± 2.2% and of *R. mangle* = 40.0 ± 2.1%. It was estimated that the deviation resulting from the use of generic instead of specific carbon contents to convert biomass into carbon stock may reach undesirable levels: up to 13.6% for aboveground biomass and up to 25% for root biomass.

1. Introduction

Mangroves are globally recognized for their ecological and socio-economic importance (Ewel et al., 1998; Mazda et al., 2006; Nagelkerken et al., 2008). In the last decade, several studies have highlighted the role of mangroves for carbon storage (e.g. Bouillon et al., 2008; Donato et al., 2011; McLeod et al., 2011), showing that considerably more carbon is sequestered than in terrestrial forests, especially in the soil and in the belowground biomass.

The major sources of uncertainty of carbon stock inventories in mangroves are species-specific differences in carbon content and the variability caused by forest age, species composition, intertidal location, soil fertility and community structure (IPCC, 2014).

Several authors have shown that the carbon content in mangroves varies according to species and compartment (Alongi et al., 2003; Khan et al., 2007; Ren et al., 2010; Ray et al., 2011). However the effect of ecological factors, such as those caused by different tidal flooding frequencies, on the carbon contents remains as an important gap.

Despite the importance that the carbon content may have on the degree of uncertainty of carbon inventories in mangroves, the difficulty and cost of obtaining specific carbon contents lead several authors to use generic carbon contents, which are based on averages from global data compilations (e.g. Twilley et al., 1992—45%; IPCC, 2006—47%; Bouillon et al., 2008—44%). However, the assessment of the impact caused by the use of generic instead of specific carbon contents on the uncertainty of carbon stock inventories, such as in Martin and Thomas (2011) for terrestrial tropical forests, has not yet been performed for mangroves.

In this sense, the present study tests the influence of compartments (leaves, reproductive parts, branches, trunks, roots, and prop roots), species (*Avicennia schaueriana*, *Rhizophora mangle*,

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Laguncularia racemosa), tidal flooding frequency (physiographic types: fringe, basin, and transition with salt flats) and the interactions of these factors on the carbon content of mangrove forests. Based on the results of these tests, the impact of using generic instead of specific carbon contents on the accuracy of carbon stock inventories is assessed.

2. Material and methods

2.1. Study area

The study area is located in Guaratiba region, in the eastern portion of Sepetiba Bay, Rio de Janeiro, Brazil, and is part of the Guaratiba Biological Reserve (Fig. 1). The average annual temperature in Guaratiba is 23.5 °C, and the average annual precipitation is 1067 mm. Rainfall is higher in summer, and lower in winter (Estrada et al., 2013). The region is under a microtidal regime with an amplitude of less than 2 m. The inner parts of the intertidal zones are reached only by the high spring tides, resulting in salt flats. Almeida (Unpublished results) estimated a total area of 43 km^2 of mangroves in Guaratiba, with 33.6 km^2 of forests, and 9.3 km^2 of salt flats. Three typical mangrove species occur in the study area: *A. schaueriana* Stapf & Leechm. ex Moldenke, *L. racemosa* (L.) C.F. Gaertn., and *R. mangle* L. Because of the existence of an extensive coastal plain, the structure of the mangrove forests in Guaratiba varies according to the frequency of tidal flooding and to the relative position of the sources of continental drainage (river and groundwater). These factors enable the identification of three physiographic types: fringe (high frequency of tidal flooding); basin (intermediate-to-low frequency); and transition with salt flats, where the trees assume a shrub architecture due to the conditions imposed by the low frequency of tidal flooding (Estrada et al., 2013). According to these authors, such forests are characterized by a gradient of reduction of the structural development from the fringe to the transition forests (Table 1). In the same direction, interstitial water salinity increases (Table 1) as a response to a gradually lower tidal flooding frequency. Among the species found in this region, *R. mangle* and *A. schaueriana* alternate as dominants, or co-dominants, in the fringe, basin, and transition forests, depending on the prevailing environmental conditions and the successional stage of the forest.

2.2. Methods

Samples from the following compartments of the three species were collected: trunks, branches, roots, prop roots (spongy and woody, as defined by Soares and Schaeffer-Novelli, 2005), leaves, and reproductive parts. For each compartment, 10 samples were collected from distinct, randomly chosen individuals, for each of the three species, and in each physiographic type (fringe, basin, and transition forest). Therefore, samples were collected from 90 individuals, for a total of 510 samples. The sampling procedure consisted of extracting at least the sufficient mass to allow the carbon quantification in an elemental analyzer. However, to increase the precision of the analysis, the collected material was at least ten times higher than the sufficient mass. This material was then mixed to make a compounded sample.

In general, the method of carbon quantification followed Hedges and Stern (1984) with minor adaptations. After sampling, the plant material was dried in an oven at temperatures lower than 70 °C. Subsequently, the samples were ground in a crusher. Approximately 2 mg of this dried material was taken to a Carlo Erba EA 1110 elemental analyzer. Carbon quantification was performed through a cystine calibration curve. For each batch of 10 samples, the accuracy of carbon measurements was checked with a PACS-2 (NRCC) standard marine sediment.

The results obtained for the organic carbon content in the different compartments, species, and physiographic types were tested using a factorial analysis of variance (ANOVA) and the Tukey post-hoc test (both in the Statistica 6.0 StatSoft), to identify differences

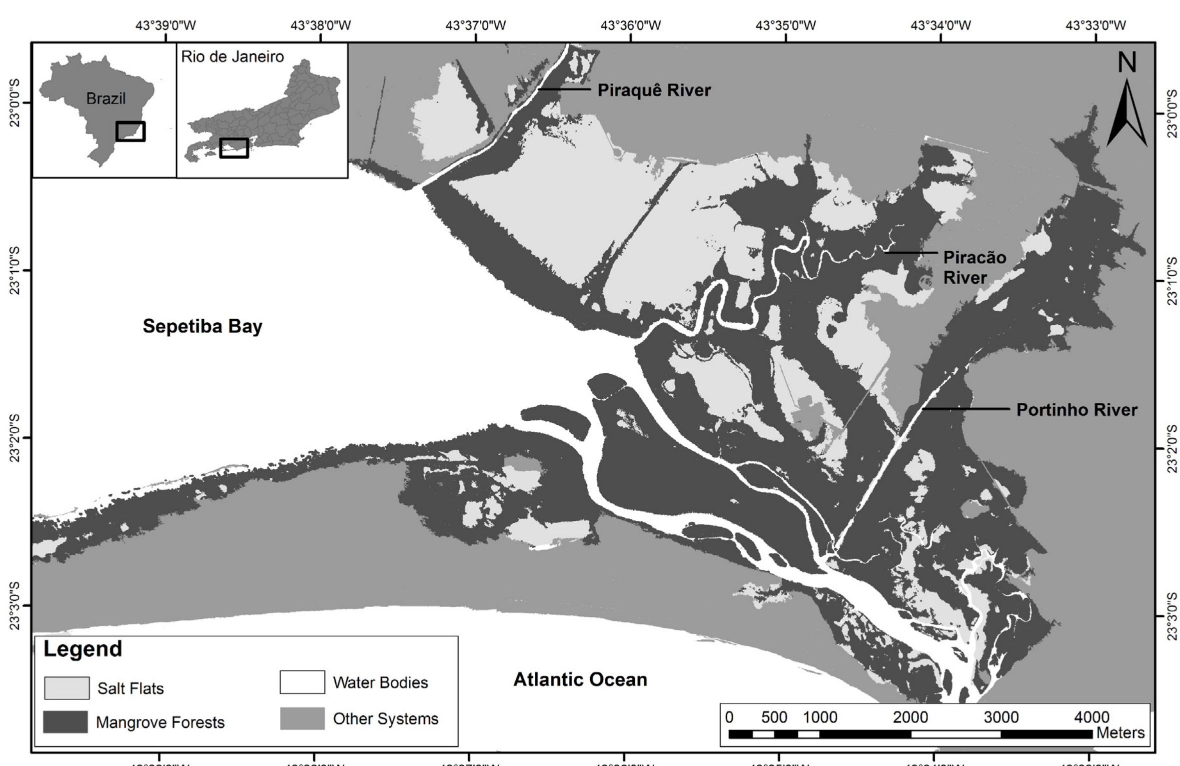

Fig. 1. Map showing the study area in Guaratiba region (Rio de Janeiro, Brazil).