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Root biomass under stem bases and at different distances from trees

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ABSTRACT

Aboveground and root biomass and the root:shoot ratio were determined in six areas of *caatinga*. The aboveground biomass was estimated using allometric equation. The root biomass was collected from 0.5 × 0.5 m^2 trenches, opened under stem bases and in areas away from the stem bases, separated in 20 cm deep layers down to 1 m. Roots were separated into five diameter classes: < 2 mm; 2.1–5 mm; 5.1 mm–10 mm; 10.1–20.0 mm; and >20.1 mm. The total aboveground biomass was 46.5 Mg ha$-^1$. The root biomass in trenches under the stem base was ten times higher than in the other trenches but the area of the stem bases was 11 times smaller, so root biomass under the bases was 41% of the total root biomass (10.6 and 25.6 Mg ha^{-1}, respectively). The root:shoot ratio was 0.56. The highest proportion of roots was in the upper soil layer and under the stem base and most of them were coarse roots (>20.1 mm). It is essential to consider the root biomass below the stem base to obtain a proper estimation of the root biomass.

1. Introduction

The capacity of plants to absorb atmospheric CO_2 and to store it as biomass attributes to forest ecosystems an important role for CO_2 mitigation. Determining forest biomass is important not only to estimate this mitigation but also to study productivity and nutrient cycling, as well as to support forest management policies and the use of forest resources (Costa et al., 2002). Despite this importance there are still few regional assessments of carbon stocks in terrestrial environments (Vieira et al., 2009) and even less that include root biomass (Mokany et al., 2006).

The difficulty for data collection explains why underground biomass estimates are lacking (Almagro et al., 2010; Martínez-Yrízar, 1995; Mendoza-Ponce and Galicia, 2010; Raherison and Grouzis, 2005). One of the problems in root biomass determinations is the absence of sampling under the stem bases (Mokany et al., 2006). Underestimation of root biomass due to this failure can be important as biomass of root crowns can represent 41% of total root biomass (Mokany et al., 2006).

Considering root collection difficulties, root biomass has often been estimated as a function of the aboveground biomass (Cairns et al., 1997; Djomo et al., 2011; Kurz et al., 1996; Mokany et al., 2006; Vogt et al., 1996, 1998) which is much easier to determine or estimate using allometric methods (Cairns et al., 1997; Kenzo et al., 2010).

Generally, root:shoot ratios are determined in selected areas and afterwards applied to estimate root biomass in larger areas using aboveground biomass data. These ratios have been determined in several sites and vegetation types (Cairns et al., 1997; Costa et al., 2014; Mokany et al., 2006) being more scarce in tropical forests and especially rare in tropical dry forests. However, many of these assessments did not consider root biomass under stem bases and might have underestimated the ratios.

In the semiarid region of Northeast Brazil, aboveground biomass estimates in *caatinga* are also few and range from 2 to 156 Mg ha^{-1} (Amorim et al., 2005; Costa et al., 2002; Kauffman et al., 1993; Sampaio and Silva, 2005). Root biomass estimates in the *caatinga*, besides being rare, concentrate especially on fine roots (Salcedo et al., 1999), except the recent work by Costa et al. (2014). None of these estimates determined root biomass under stem bases. Costa et al. (2014) found that the root biomass in *caatinga* was much

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higher than previous estimates (Sampaio and Costa, 2011), in spite of the shallow soils, and that the root:shoot ratios were higher than most of those of other tropical forests, attributing them to the high water deficit of the region. In general, the ratios are negatively correlated with mean annual precipitation and vegetation height and positively correlated with plant density (Mokany et al., 2006). The low precipitation, low height and high plant density of *caatinga* (Sampaio, 1995) justify its high root:shoot ratio and the high plant density and shallow soils indicate that a high proportion of the root biomass may be under the stem bases.

Considering the importance of adequate root biomass estimates and the scarcity of data for *caatinga* and other tropical dry forests, the aim was to determine the proportion of roots under stem bases and to estimate total root biomass at different sites. We hypothesize that: 1) the concentration of root biomass under the stem bases is much higher than in areas between trees; 2) the proportion of the root biomass under the stem bases in *caatinga* is higher than in most other tropical forests; 3) considering the biomass under the stem bases, the root:shoot ratio in *caatinga* is one of the highest among forests in the world and the belowground biomass is much higher than previously estimated; and 4) therefore, the stock of biomass in the *caatinga* area has been underestimated.

2. Material and methods

2.1. Study areas

The study has been carried out in six different sites under sustainable forest management, three of which in Pernambuco state and another three in Ceará state. All sites are located in the semiarid region with irregular rainfall and mean annual precipitation ranging from 480 to 700 mm and covered with arboreal to shrubby caatinga (IBGE, 2004).

The Pernambuco sites were: Caroalina district in Sertânia municipality (latitude South −08° 16′ 10.70434″, longitude West −37° 33′ 09.85045″); Brejinho settlement area in Betânia municipality (−08° 13′ 48.25886″ S and −38° 04′ 51.26937″ W); IPA Research Station at the Saco Farm in Serra Talhada municipality (−07° 54′ 37.52203″ S and −38° 17′ 35.26512″ W). These sites belong to the Southern Sertão Depression ecoregion where Litholic (Lithic Leptosol or Ustorthent, according to international and American soil classifications, respectively), Planosol (Planosol or Alfisol) and Luvisol (Luvisol or Alfisol) are dominant (EMBRAPA, 2001).

In Ceará, all sites are located in the Caucaia municipality, Maturi Farm and have been designated as Caucaia I (−03° 48′ 50.51530″ S and −38° 41′ 41.88818″ W), II (−03° 48′ 26.52881″ S and −38° 42′ 29.49363″ W) and III (−03° 48′ 18.25979″ S and −38° 42′ 39.57996″ W). The farm is located in the Rio Ceará watershed, in the northern part of the state, in the Northern Sertão Depression ecoregion. Dominant soils are Yellow and Greyish Argisols (Acrisols or Ultisols), Litholic (Lithic Leptosol or Ustorthent) and Planosol (Planosol or Alfisol) (Gomes and Alves, 2010). Also in this ecoregion, rainfall is irregular with mean annual precipitation ranging from 500 to 700 mm.

2.2. Data collection

2.2.1. Aboveground biomass and basal area

At each site, a forest inventory was conducted in a 20 m × 20 m plot, set up at least 50 m from the forest border and avoiding tracks, rock outcrops and inundated plains. In each plot, the circumference at breast height (CAP, at 1.3 m from the soil) of all trees with CAP ≥ 6 cm was measured. Aboveground biomass of each plant was estimated by the allometric method using the biomass equation determined for *caatinga* trees and shrubs (Sampaio and Silva, 2005), using diameter at breast height (DBH) as the independent variable: dry biomass (kg) = $0.173\ DBH_{(cm)}^{2.295}$ ($R^2 = 0.9184$). Total plot basal area was obtained as the sum of all individual tree basal areas, calculated from each CAP.

In each plot, an individual tree was selected representing the local "mean tree". Criteria such as most abundant species and most frequent size of trees were considered in the selection. The selected tree was cut and aboveground biomass was separated in trunk, branches and leaves, all weighed in the field and sampled for dry matter determination in laboratory, after obtaining oven dry constant weight.

At the Caroalina site a Catingueira tree (*Poincianella pyramidalis* Tul., Fabaceae, Caesalpinoidea) was cut, in Brejinho settlement a Jurema de Embira (*Mimosa ophthalmocentra* Mart ex Benth., Fabaceae, Mimosoidea), in Serra Talhada, a Marmeleiro (*Croton blanchetianus* Muell. Arg., Euphorbiaceae), in Caucaia I, a Sabiá (*Mimosa caesalpiniifolia* Benth., Fabaceae, Mimosoidea), in Caucaia II, a Marmeleiro (*C. blanchetianus*) and in Caucaia III, a Catanduva (*Piptadenia moniliformis* Benth., Fabaceae, Mimosoidea).

2.2.2. Root biomass

Root biomass measurements were carried out in seven trenches of 0.5 × 0.5 m^2 in each plot. In each trench, roots were collected in 20 cm layers down to 1 m deep or until an impermeable layer in shallow soils.

The positioning of the seven trenches followed a systematic distribution. A first trench, called "position A", was centred around the base of the cut tree; a second called "position B", was distant about 50 cm from the stem of a living tree and was replicated twice; a third called "position C", was distant about 1 m from a the stem of a living tree and also replicated twice; and, finally, a fourth "position D", also replicated twice, was located between two trees, distant at least two meters from each other.

The soil from each layer was sifted using a 4 mm mesh in order to collect the roots manually. These were stored in paper bags and separated per diameter class for determination of oven dry weight in the laboratory. Roots were separated into five diameter classes: class I, < 2 mm; class II, 2.1 mm–5 mm; class III, 5.1 mm–10 mm; class IV, 10.1 mm–20.0 mm; and class V, > 20.1 mm. Diameter measurements were conducted using a digital pachymeter *Lee Tools*®. No distinction was made between live and dead roots, neither between plant and species from which the roots originated.

2.2.3. Root biomass calculation per area

Root biomass under stem base was calculated according to the following steps: (1) regression determination between root biomass under stem base and aboveground biomass of the respective trees, using six data pairs corresponding to the trees cut in each of the six plots; (2) calculation of the "average tree" of each plot as the proportion between total estimated aboveground biomass and the number of trees, for each plot; (3) using the regression equation of step 1, root biomass under stem base of each "average tree" was determined using the aboveground biomass of this "average tree", in order to correct the difference between root biomass of the selected and cut tree "mean tree" and the plot "average tree"; (4) determination of total root biomass under stem bases of all trees, in each plot, multiplying root biomass under stem base of the "average tree" by the number of trees in the plot; (5) determination of total plot area under stem bases, multiplying the trench area (0.25 m^2) by the number of trees in the plot; and (6) determination of root biomass under stem bases in Mg ha^{-1} as the relation between total root biomass from step 4 and total plot area under stem bases from step 5, considering the plot area (400 m^2).

Determination of root biomass in the other positions (B, C and D) would have been conducted similarly, considering the circle