Global Ecology and Conservation 2 (2014) 378–384

Contents lists available at ScienceDirect

Global Ecology and Conservation

journal homepage: www.elsevier.com/locate/gecco

Original research article

Root behavior of savanna species in Brazil's Pantanal wetland

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HIGHLIGHTS

- Field data were collected to calculate the root biomass of savanna woody species as a function of tree diameter.
- Tree diameter at ground level is useful for estimating the root biomass of savanna woody species.
- Shorter root systems and lower root biomass can be an indication of savannas in wetland areas due to the effects of elevated water table.

ARTICLE INFO

Article history:
Received 20 September 2014
Received in revised form 13 October 2014
Accepted 14 October 2014
Available online 27 October 2014

Keywords:
Adaptation
Allometric equation
Biomass
Diameter
Root architecture
Tree

ABSTRACT

The objective of this study was to determine the maximum depth, structure, diameter and biomass of the roots of common woody species in two savanna physiognomies (savanna woodland and open woody savanna) in Brazil's Pantanal wetland. The root systems of 37 trees and 34 shrubs of 15 savanna species were excavated to measure their length and depth and estimate the total root biomass through allometric relationships with stem diameter at ground level. In general, statistical regression models between root weight and stem diameter at ground level showed a significance of $P < 0.05$ and R^2 values close to or above 0.8. The average depths of the root system in wetland savanna woodland and open woody savanna are 0.8 ± 0.3 m and 0.7 ± 0.2 m, respectively, and differ from the root systems of savanna woody species in non-flooding areas, whose depth usually ranges from 3 to 19 m. We attribute this difference to the adaptation of woody plant to the shallow water table, particularly during the wet season. This singularity of woody species in wetland savannas is important when considering biomass and carbon stocks for national and global carbon inventories.

1. Introduction

Woody plants in savanna ecosystems maintain their physiological activities during the dry season, despite very low rainfall (Quesada et al., 2004). They come into leaf, flower, and fructify in the dry season (Oliveira and Gibbs, 2000), indicating the access of root to groundwater and the water table. For instance, Canadell et al. (1996) noted roots of woody plants reaching great depths, in the order of 40 m in arid biomes such as deserts, sclerophyllous forest, and tropical savannas.

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http://dx.doi.org/10.1016/j.gecco.2014.10.009

The plants in Brazil's central-western savannas exhibit root behavior similar to that of savannas around the world (Rawitscher et al., 1943). Rossato et al. (2012) identified woody species in Brazil's central-western savannas with conspicuous access to groundwater at several depths, including the water table. These plants can develop root systems reaching depths of 3 to 19 m (Rawitscher et al., 1943).

In the savannas of Venezuela, Africa, and Brazil's central-west, the ratio between below-ground and above-ground plant biomass (BG:AG) is usually >1 (Castro and Kauffman, 1998; Rutherford, 1983; Sarmiento and Vera, 1979). However, Ribeiro et al. (2011) found a BG:AG ratio of <1 in Brazil's central-western savanna. Jackson et al. (1996), who reviewed the BG:AG ratios in several vegetation biomes, found <1 only in cultivated areas and forest. The literature contains few reports about root biomass in savannas, although such information is important for estimating biomass and carbon stocks in wetland savannas.

The Pantanal region is an important wetland in central-South America in Brazil, Bolivia and Paraguay, covering an area approximately of 140,000 km^2 in Brazil (Silva and Abdon, 1998). The main type of vegetation in this wetland is savanna (locally known as 'cerrado'). Most plant species in the Pantanal wetland are the same species that occur in Brazil's non-flooding central-western savanna (Ratter et al., 2003). Both regions have unfertile soils, with a predominance of sandy spodosols in the Pantanal (Fernandes et al., 2007) and oxisols and spodosols in the non-flooding savannas of Brazil's central-west (Reatto et al., 1998). The regional climate is markedly seasonal, with rainfall prevailing between October and April, with an annual average of 1500 mm in the non-flooding central-western region (Gan et al., 2004) and 1180 mm in the Pantanal wetland (Soriano and Alves, 2005).

The present study aims to determine the variation in depth, structure and biomass of the roots of common trees and shrubs species in two savanna physiognomies in Brazil's Pantanal wetland. Given that root studies are usually time consuming, difficult and expensive, an additional goal of this work is to develop statistical regression models of stem diameter at ground level and root biomass, enabling possible future estimations of root biomass based solely on stem diameter data and thus, preventing destructive tree sampling.

2. Materials and methods

2.1. Study site

Flooding in the Pantanal varies greatly in annual and interannual intensity due to changes in rainfall distribution and quantity in both plains and highlands. The plains landscape is almost flat, with a declivity of less than 25 cm km^{-1}, where water flows slowly through the terrain (Carvalho, 1986). In savanna woodland (broken tree canopy, with underlying shrubs and ground-level vegetation) and open woody savanna (broken woody layer of shrubs with sparser trees and grasses), flooding occurred only during the exceptionally wet years of 1905, 1913, 1920, 1982, 1988 and 1995 (Bergier and Resende, 2010). Annual flooding, however, has never reached the savanna forest (dense canopy with sparser ground-level vegetation and semideciduous forest, located on somewhat higher terrain (Fig. 1)). The vegetation types in relatively higher topography are in fact the product of a non-flooding area. However, despite the absence of flooding, the level of the water table rises in the rainy season to about 1.5 m below the soil surface (Gradella et al., 2009).

2.2. Root surveys

Woody native species were sampled in two savanna physiognomies: savanna woodland (19°00′42.7″S; 56°38′29.5″W) in April 2008, and open woody savanna (18°59′45″S; 56°39′44″W) in November 2009 in the Nhumirim Experimental Farm, located in the sub-region of Nhecolândia, Pantanal wetland, Brazil.

The usual botanical definitions presented by Font Quer (1985) were considered for shrubs as woody plants, with a height of less than 5 m, and multiple ramifications from the base, without a dominant stem; subshrubs as plants with a woody base, ramified, with heights ranging from 0.5 to 2 m; and trees as woody plants at least 5 m in height with a dominant stem that ramifies after reaching a certain height, forming the tree canopy.

Ten or more individuals of the most common species with different stem diameters were sampled in both savanna physiognomies (Castro and Salis, 2012; Salis et al., 2008). The subshrub species *Annona dioica* A.St.-Hil. (25), shrub species *Byrsonima cydoniifolia* Mart. (10), and tree species, *Curatella americana* L. (10) and *Mouriri elliptica* Mart. (10) were sampled by the wandering-quarter method (Brower and Zar, 1984), and were excavated and weighed to develop statistical regression models to estimate root biomass. Fourteen trees of 10 species in the savanna woodland were also sampled: *Bowdichia virgilioides* Kunth, *Caryocar brasiliense* Cambess., *Casearia sylvestris* Sw., *Cecropia pachystachya* Trécul, *Dipteryx alata* Vogel, *Sapium haematospermum* Müll.Arg., *Simarouba versicolor* A.St.-Hil., *Stryphnodendron adstringens* (Mart.) Coville, *Tabebuia aurea* Benth. & Hook.f. (2) and *Zanthoxylum rigidum* Humb. & Bonpl. (4) by the wandering-quarter method (Brower and Zar, 1984). These trees were excavated and analyzed as a single category to model the root biomass for less common species, following the methodology described by Anderson and Ingram (1993). Some individuals of *Annona dioica, Mouriri elliptica* and *Tabebuia aurea* were sampled in both savanna physiognomies.

The trees were uprooted using a tractor. The soils of the Pantanal of Nhecolândia are sandy, with 94% to 99% of sand content (Cunha, 1980), which makes fieldwork easy. After the roots were loosened, the broken roots, including lateral