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Structure and tree species composition in different habitats of savanna used by indigenous people in the Northern Brazilian Amazon

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Abstract

Background

Woody plant diversity from the Amazonian savannas has been poorly quantified. In order to improve the knowledge on wood plants of these regional ecosystems, a tree inventory was carried out in four different habitats used by indigenous people living in the savanna areas of the Northern Brazilian Amazon. The habitats were divided into two types (or groups) of vegetation formations: forest (riparian forest, forest island, and buritizal = Mauritia palm formation) and non-forest (typical savanna). The inventory was carried out in two hectares established in the Darora Indigenous Community region, north of the state of Roraima.
New information

The typical savanna is the most densely populated area (709 stems ha\(^{-1}\)); however, it has the lowest tree species richness (nine species, seven families) in relation to typical forest habitats: riparian forest (22 species, 13 families and 202 stems ha\(^{-1}\)), forest islands (13 species, 10 families and 264 stems ha\(^{-1}\)), and buritizal (19 species, 15 families and 600 stems ha\(^{-1}\)). The tree structure (density and dominance) of the forest habitats located in the savanna areas studied in this work is smaller in relation to forest habitats derived from continuous areas of other parts of the Amazon. These environments are derived from Paleoclimatic fragmentation, and are currently affected by the impact of intensive use of natural resources as timberselective logging and some land conversion for agriculture.

Keywords

Floristic survey, species richness, lavrado, forest environment, non-forest environment.

Introduction

The Amazon is recognized as one of the world's region with the greatest biological diversity, with estimates of up to 16,000 tree species (Steege 2013). The entire region consists of a mosaic of different climates, topographical reliefs, hydrological cycles and soils, which drives the formation of a wide range of vegetation types associated with landscapes, which are home to many different species; many still unknown (Hopkins 2007). Within this large and complex Amazonian landscape, woody resources are widely used by both indigenous people and riverine communities, especially as timber (Miller et al. 1989, Milliken et al. 1992, Demarchi 2014). Human communities living in forest environments have greater biological diversity and availability of woody-based resources when compared with those inhabiting living in areas with open vegetation, such as the extensive areas of savanna in northern Amazon. This distinction is based on the fact that continuous forest areas are richer in tree species, and have greater biological diversity than those found in forest fragments within savanna ecosystems.

The savanna region of the state of Roraima is the largest savanna area of the Brazilian Amazon, occurring in the northern state of Roraima (Barbosa et al. 2007; Araújo et al. 2017). The savanna area of Roraima is locally referred as lavrado, “campos do rio Branco" or "campos de Roraima", and covers an area of over 40,000 km\(^2\) within the large Rio Branco-Rupununi landscape complex, which extends into the Republic of Guyana and Venezuela (Barbosa and Fearnside 2005, Barbosa and Campos 2011). Several indigenous lands are found within this large area of savanna. Among them, Raposa/Serra do Sol and São Marcos Indigenous Lands are prominent due to their large size.
The São Marcos Indigenous Land (TISM) comprises 654,110 ha and has 42 indigenous communities (Makuxi, Taurepang and Wapixana ethnicities). Most indigenous practices make use of the available woody plant resources in different habitats of the savanna matrix where these communities live. Since the savanna of the state of Roraima is formed by two large vegetation groups – forest and non-forest (Eden 1970, Santos et al. 2013, Barbosa et al. 2007), the tree species composition and the number of stems available to indigenous communities varies depending on the habitat. Recognizing and valuing these natural resources used by indigenous people in the Amazonian savannas improve the capacity to plan and understand the most appropriate forms of management of woody plant diversity in these areas, which are so poorly studied.

The aim of this study is to make available data of woody plants (trees and shrubs) from forest and non-forest formations used by indigenous communities of the Savanna Area of Roraima, Northern Brazilian Amazon, in order to increase the knowledge on species composition and structure of such environments. The Shannon diversity index and Pielou eveness were calculated and the results compared to other studies in Amazonian savanna areas.

**Project description**

**Title:** Use and conservation of plant resources in indigenous communities in the north of the state of Roraima, Northern Amazon.

**Study area description:** The study area is located in the Darora Community, a Makuxi ethnicity group living within the São Marcos Indigenous Land (3°10'42"N and 60°23'34"W; lat/long - DATUM WGS84), which is at approximately 90 km from the state capital, Boa Vista, northbound on the BR -174 and RR-319 highways, by the Uraricoera river ferry crossing. Based on data from the Boa Vista weather station, the climate in Darora can be defined as tropical (Aw) according Köppen classification (Alvares et al. 2014), with average annual temperature of 27.8 °C, and average annual rainfall of ~1,650 mm, with the driest period concentrated between December and March (± 9% annual precipitation), and the wettest period concentrated between May and August (± 70% annual precipitation) (Barbosa 1997, Barbosa et al. 2007). The study included four habitats occurring in the lavrado area, which are used by indigenous people from the Darora community: typical savanna (non-forest formation) and three forest environments (riparian forest, forest island and buritizal = Mauritia palm formation).

**Sampling methods**

**Sampling description:** Eight plots were installed (each 0.25 ha) at different distances from the Community: four in typical savanna area (non-forest), and another four in several forested habitats (two in riparian vegetation of the Tacutu river, one in a buritizal along the Maracajá igarapé (stream), and one in an isolated natural forest island) (Fig. 1). Each plot
was divided into 10 25m x 10m sub-plots. In the non-forest plots, all trees with diameter greater than or equal to 2 cm, at 2 cm from the soil (DSH $\geq$ 2 cm) were measured as suggested by Miranda and Absy (2000) and Barbosa et al. (2005). In the forest plots, all individuals with DBH (diameter at the breast high – 1.3 m) $\geq$ 10 cm were measured. Additionally, the maximum height of each individual was visually estimated (Suppl. material 1). The Shannon diversity index ($H'$) and Pielou evenness ($J'$) were calculated (Kent and Coker 1995) and the results compared to other studies in Amazonian savanna areas.

Samples of the species were collected, and taxonomic identification was made by expert botanical, parabotanists and local floras (Ribeiro et al. 1999, Melo and Barbosa 2007, Flores and Rodrigues 2010, Wittmann et al. 2010). The nomenclatures were searched in the website of The Plant List (The Plant List 2013). Samples were placed in the herbarium collection of the Universidade Federal de Roraima (UFRR), Boa Vista. Botanical classification followed the APG IV (2016) system. All required federal permissions were obtained (FUNAI: Process 08620.002869 / 2014-15; IPHAN: Process 01450.001678 / 2014-88; CEP-INPA / CONEP: 814370).

**Geographic coverage**

**Description:** The study area is located in the Darora Community in the São Marcos Indigenous Land, and comprises ca. 170 km$^2$ (Suppl. material 2). Coordinates: 3°10’42"N and 60°23’34"W.
Taxonomic coverage

Description: The study recorded 52 species belonging to 28 botanical families (Table 1). Only 13 species were identified at the genus level. The families with the greatest richness in species (S) were Fabaceae (12 spp.) and Malpighiaceae (5 spp.). Non-forest areas (typical savanna) are the most densely populated by tree individuals (709 stems ha\(^{-1}\)); however, they presented lower richness (nine species) when compared with typical forest habitats: riparian forest (22 species, 13 families and 202 ind ha\(^{-1}\)), forest island (13 species, 10 families and 264 stems ha\(^{-1}\)) and *buritizal* (19 species, 15 families and 600 stems ha\(^{-1}\)).

| Families/Species | Typical Savanna | Riparian forest | Forest island | Buritizal | UFRR |
|------------------|-----------------|-----------------|--------------|-----------|------|
| ANACARDIACEAE    |                 |                 |              |           |      |
| Tapirira guianensis Aubl. | 16 8431       |                 |              |           |      |
| Spondias mombin L. |                 | 3               |              |           | -    |
| ANNONACEAE       |                 |                 |              |           |      |
| Guatteria sp.    |                 |                 |              |           | 10   |
| Xylopia aromatica (Lam.) Mart. |                 |                 |              |           | 1    |
| APOCYNACEAE      |                 |                 |              |           |      |
| Himatanthus drasticus (Mart.) Plumel | 17 8487      | 2               |              |           | 8449 |
| Malouetia sp.    |                 |                 |              |           | 3    |
| ARECACEAE        |                 |                 |              |           |      |
| Mauritia flexuosa L. f. |                 |                 |              |           | 27   |
| Euterpe precatoria Mart. |                 |                 |              |           | 17   |
| BIGNONIACEAE     |                 |                 |              |           |      |
| Godmania aesculifolia (Kunth) Standl. |                 |                 | 3           |           | 8472 |
| BIXACEAE         |                 |                 |              |           |      |
| Bixa arboarea Huber |                 |                 |              |           | 1    |
| BURSERACEAE      |                 |                 |              |           |      |
| Trattinickia rhoifolia Willd. |                 |                 |              |           | 7    |

Table 1.

Occurrence of families and species in non-forest (typical savanna) and forest habitats (riparian forest, forest island and *buritizal*). UFRR = number of record in the Herbarium of the Universidade Federal de Roraima.
| Family                  | Species                                      | Code | Year |
|------------------------|----------------------------------------------|------|------|
| CARYOCARACEAE          | Caryocar microcarpum Ducke                   | 2    | 8447 |
|                        |                                               |      |      |
| CHRYSOBALANACEAE       | Couepia multiflora Benth.                    | 1    | 8450 |
|                        | Hirtella paniculata Sw.                      | 2    | 8435 |
| COMBRETACEAE           | Buchenavia capitata (Vahl) Eichler           | 1    | 8445 |
|                        |                                               |      |      |
| DILLENIACEAE           | Curatella americana L.                       | 18   | 8446 |
|                        |                                               | 7    |      |
|                        |                                               | 18   |      |
|                        |                                               | 1    |      |
| ERYTHROXYLACEAE        | Erythroxylum suberosum A. St.-Hil.           | 2    | 8457 |
|                        |                                               | 9    |      |
| EUPHORBIACEAE          | Alchomea sp.                                 | 6    | 8433 |
|                        |                                               |      |      |
| FABACEAE               | Anadenanthera peregrina (L.) Speg.           | 4    | 8475 |
|                        | Andira sp.                                   | 2    | 8465 |
|                        | Bowdichia virgilioides Kunth                 | 19   | 8471 |
|                        |                                               | 4    |      |
|                        | Cassia moschata Kunth                        | 3    | 8452 |
|                        | Cassia sp.                                   | 16   | 8456 |
|                        | Copailera pubiflora Benth.                   | 2    | 8454 |
|                        |                                               | 4    |      |
|                        | Cynometra bauhinifolia Benth.                | 8    | 8460 |
|                        | Etabalia sp.                                 | 20   | 8459 |
|                        | Hydrochorea corymbosa (Rich.) Barneby & J.W.Grimes | 1 | 8468 |
|                        | Machaerium aculeatum Raddi                   | 1    | 8473 |
|                        | Ormosia smithii Rudd.                        | 14   | 8437 |
|                        | Swartzia sp.                                 | 3    | 8478 |
| HUMIRIACEAE            | Humiria balsamifera Aubl.                    | 6    | 8429 |
| LAURACEAE              | Endlicheria sp.                              | 14   | 8432 |
| LECYTHIDACEAE          |                                               |      |      |
| Genus, Species | Code | Count | Code |
|---------------|------|-------|------|
| *Eschweilera* sp. | 3 | 8463 | 
| *Antonia ovata* Pohl. | 107 | 8485 | 
| *Bunchosia* sp. | 4 | 8462 | 
| *Byrsonima coccobotifolia* Kunth | 163 | 8483 | 
| *Byrsonima crassifolia* (L.) Kunth | 268 | 8482 | 
| *Byrsonima* sp. | 3 | 8443 | 
| *Byrsonima verbascifolia* (L.) DC. | 19 | 8480 | 
| *Ceiba* sp. | 2 | - | 
| *Sorocea duckei* W.C. Burger | 2 | 8455 | 
| *Virola mollissima* (Poepp. ex. A. DC.) Warb. | 11 | 8430 | 
| *Virola surinamensis* (Rol. ex Rottb.) Warb. | 5 | 8441 | 
| *Eugenia* sp. | 2 | 6 | 8464 | 
| *Myrcia* sp. | 1 | 8453 | 
| *Amanoa guianensis* Aubl. | 4 | 8448 | 
| *Roupala montana* Aubl. | 81 | 8484 | 
| *Genipa americana* L. | 10 | 3 | 8488 | 
| *Palicourea rigida* Kunth. | 17 | 8489 | 
| *Xyllosma benthamii* (Tul.) Triana & Planch. | 1 | 8474 | 
| *Vitex cymosa* Betero ex Spreng. | 8 | 8461 | 
| *Vitex schomburgkiana* Schauer | 10 | 8470 |
In non-forest habitat, the most abundant species were *Byrsonima crassifolia* (268 stems) and *B. coccolobifolia* (163), while in the forest habitat *Mauritia flexuosa* (27), *Etabalia* sp. (20) and *Curatella americana* (18) were found in greater numbers. *M. flexuosa* dominates *buritizal* areas; however, *C. americana* is a typical species of the non-forest habitat that was densely registered in all the forest environments, especially in the forest island. This is a reflection of the intense extractivism in these environments, enabling several small forest clearings to provide favorable conditions for the recruitment of non-forest species.

**Vertical and horizontal structure**

In non-forest environments, density and basal area were 709 stems ha$^{-1}$ and 2.174 m$^2$ ha$^{-1}$, respectively. The diameter was characterized by the predominance of initial classes (DSH $2$ cm < 5 cm) with a tendency of decrease of individuals in the major classes, in an inverted-J pattern, where the most individuals are distributed in the minor diameter classes while few individuals are found in the major diameter classes (Fig. 1). For vertical structure, most individuals (604) measured up to 2 m in height (Fig. 1), including all individuals of *Byrsonima verbascifolia* and *Palicourea rigida* (both dwarf shrub).

In forest habitats, the total density was 317 stems ha$^{-1}$, and basal area was 12.41 m$^2$ ha$^{-1}$. In *buritizal* habitat, basal area was 4.37 m$^2$ ha$^{-1}$, 5.42 m$^2$ ha$^{-1}$ in riparian forest and 2.62 m$^2$ ha$^{-1}$ in forest island. The distribution of individuals by diameter classes in riparian forest showed that 55 individuals (54%) presented DBH < 20 cm, and 36 (35%) had DBH between 20 and 40 cm, following by a decrease in the major classes, in an inverted-J form (Fig. 2). For vertical structure, the greatest number of individuals (96) occurred between 5 and 15 m in height (Fig. 2). In the forest island, 47 individuals presented DBH between 10 and 30 cm, and 54 individuals (82%) had DBH between 5 and 15 m. In *buritizal* habitat, 97 individuals (64%) presented DBH > 20 cm following a decrease in the major classes. In relation to the vertical structure, 107 individuals (71%) presented height lower than 15 m.

In spite of the differences in the sampling methods and in the criteria for the inclusion of woody individuals, the present results indicated structural and phytosociological similarities with other studies carried out in non-forest (Table 2) and forest (Table 3) formations in savanna areas in the Amazon located in the states of Roraima and Rondônia. The availability of woody resources and the structure of individuals in the sampled areas near the Darora Indigenous Community highlight the need to perform a greater number of floristic inventories in the savanna areas of Roraima. In addition to the impacts represented by the intensive use of woody resources, this large savanna area of northern Amazon has been threatened by the impact of the intense use of natural resources and the rapid expansion of agribusiness and corporate forestry (Aguiar et al. 2014). This threat indicates greater magnitude and a real chance of irreversibility. Therefore, the broad knowledge on plant diversity of the Roraima savanna (*lavrado*) is paramount, and requires a necessary extension of the discussion of public conservation policies for the greatest savanna area of the Amazon biome, as pointed out by Pinto et al. (2014).
Number of individuals sampled in forest habitats (riparian forest, forest island and Buritizal) in the north of the state of Roraima, expressed by diameter classes (DBH ≥ 10cm), and estimated height of individuals.
Table 2. Comparison of richness, diversity and evenness in studies carried out in non-forest habitats occurring in savannas areas of Roraima and state of Rondônia (RO), where: D = diameter used in the research, DBH = diameter at breast height, DSH = diameter at soil height, S = species richness, H’ = Shannon diversity index, and J’ = Pielou evenness. * Data correspond to a single study that was separately presented here in its different physiognomies to better compare the data.

| Municipality                  | Phytophysiognomy                        | Sampling methods               | D  | S      | H’        | J’          | References                    |
|------------------------------|-----------------------------------------|--------------------------------|----|--------|-----------|-------------|-------------------------------|
| Boa Vista and Amajari        | Savanna tree and Savannah park          | Quadrants (80 points) 4 transects | DBH ≥ 5 cm | 8      | 0.8-1.28  | 0.68-0.80  | Sanaiotti 1997               |
| Boa Vista                    | Savanna grassy-woody and Savanna park   | Plots (45 points) 6.75 ha      | DSH ≥ 2 cm | 71     | 1.12      | 0.26        | Miranda et al. 2003           |
| Alto Alegre and Boa Vista    | Savanna grassy-woody and Savanna park   | Plots (3 points) 0.9 ha        | DSH ≥ 2 cm | 29     | 0.87      | 0.26        | Barbosa et al. 2005           |
| Vilhena, RO                  | Cerradão                                | Plots 1 ha                     | DBH ≥ 10 cm | 60     | 3.45      | 0.84        | Miranda et al. 2006*          |
| Vilhena, RO                  | Campo sujo                              | Plots 1 ha                     | DBH ≥ 10 cm | 26     | 2.34      | 0.72        | Miranda et al. 2006*          |
| Vilhena, RO                  | Cerrado sensu stricto                   | Plots 1 ha                     | DBH ≥ 10 cm | 39     | 2.63      | 0.72        | Miranda et al. 2006*          |
| Vilhena, RO                  | Cerrado sensu stricto                   | Plots 1 ha                     | DBH ≥ 10 cm | 45     | 2.9       | 0.76        | Miranda et al. 2006*          |
| Boa Vista                    | Savanna grassy-woody                    | Plots (2 points) 1.1 ha        | DSH ≥ 6.5 cm | 19     | 0.59-1.2  | 0.20-0.46  | Araújo and Barbosa 2007       |
| Boa Vista                    | Savanna grassy-woody and Savanna park   | Plots (4 points) 1 ha          | DSH ≥ 2 cm | 9      | 1.7       | 0.77        | Present study                 |
Table 3.
Comparison of richness, diversity and evenness in studies carried out in forest habitats occurring in savannas areas of Roraima, where: D = diameter used in the research, DBH = diameter at breast height, DSH = diameter at soil height, S = species richness, H' = Shannon diversity index and J' = Pielou evenness. * Data correspond to a single study that was separately presented here in its different physiognomies to better compare the data.

| Municipality | Phytophysiognomy                        | Sampling methods          | DBH (cm) | S  | H'  | J'  | References        |
|--------------|----------------------------------------|---------------------------|----------|----|-----|-----|------------------|
| Cantá        | Riparian Forest                        | Plots / 0.4 ha            | 6        | 104| 6.16| 0.92| Sette-Silva 1993*|
| Cantá        | Forest Island                          | Plots / 0.08 ha           | 6        | 47 | 4.86| 0.87| Sette-Silva 1993*|
| Boa Vista    | Riparian Forest                        | Plots / 0.2 ha            | 6        | 59 | 5.41| 0.92| Sette-Silva 1993*|
| Boa Vista    | Forest Island                          | Plots / 0.28 ha           | 6        | 56 | 4.94| 0.85| Sette-Silva 1993*|
| Cantá        | Wooded savanna                         | Plots 0.35 ha             | 6        | 72 | 4.48| 0.73| Sette-Silva 1993*|
| Cantá        | Savanna - SeasonalForest Submontane    | Transects (2 points) 3.6 ha | 30       | 61 | 3.39| 0.82| Silva 2003       |
| Mucajaí      | Riparian Forest                        | Plots / 0.4 ha            | 9.55     | 33 | 2.28| 0.65| Farias et al. 2012|
| Boa Vista    | Forest Island                          | Plots (4 points) 0.64 ha  | 5        | 52 | 1.89-3.16| 0.67-0.87| Santos et al. 2013|
| Boa Vista    | Forest Island                          | Plots (12 points) 2.48 ha | 10       | 112| 3.86| 0.82| Jaramillo 2015   |
| Boa Vista    | Riparian Forest                        | Plots / 0.5 ha            | 10       | 22 | 2.63| 0.57| Present study    |
| Boa Vista    | Buritizal                               | Plots / 0.25 ha           | 10       | 19 | 2.59| 0.88| Present study    |
| Boa Vista    | Forest Island                          | Plots / 0.25 ha           | 10       | 13 | 2.21| 0.86| Present study    |

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Data resources

Data package title: Tree species composition in different habitats of savanna used by indigenous in the Northern Brazilian Amazonia

Resource link: http://www.gbif.org/dataset/80fecd69-bf8f-48ef-9066-ade0f60ef5a0

Alternative identifiers: https://ipt.sibbr.gov.br/sibbr/resource?r=darora_floristic_rr&v=1.12

Number of data sets: 1

Data set name: Tree species composition in different habitats of savanna used by indigenous in the Northern Brazilian Amazonia

Data format: Darwin Core Archive DwC-A

Description: Occurrences of plants in four habitats in Amazonian Savanna in an indigenous community, State of Roraima. Data set consists of the eml.xml, meta_xml and occurrence.txt containing the DwC-Attributes.

| Column label   | Column description                                                                 |
|----------------|------------------------------------------------------------------------------------|
| eventid        | A identifier for the record (record code)                                          |
| institutionCode| Institution that has custody of the object or information about its registration   |
| occurrenceID   | A identifier for the occurrence                                                    |
| basisOfRecord  | The specific nature of the data record                                              |
| collectionCode | The name or acronym of the collection or dataset from which the record is derived   |
| catalogNumbe   | An identifier (preferably unique) for the record within the dataset or collection   |
| recordedBy     | List of names of persons or organizations responsible for the registration of the original occurrence |
| eventDate      | The date or period during which an event occurred                                  |
| habitat        | Description of the habitat in which the event occurred                             |
| continent      | The Continent of the occurrence                                                    |
| country        | The Country of the occurrence                                                      |
| stateProvince  | The State or Province of the occurrence                                            |
| county         | The County of the occurrence                                                       |
| locality       | The location-specific description                                                  |
| decimalLatitude| The geographical latitude in decimal degrees of the geographical center of a location |
| decimalLongitude| The geographical longitude in decimal degrees of the geographical center of a location |
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Author contributions

RLC Oliveira (researcher), HLS Farias (statistic and data analiser), RO Perdiz (plant taxonomist), VV Scudeller (Adviser), RI Barbosa (Co-adviser).

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Supplementary materials

Suppl. material 1: DBS and Heights of individuals in non-forest (typical savanna) and forest habitats (riparian forest, forest island and buritizal)

Authors: Rodrigo Leonardo Costa de Oliveira
Data type: occurrences
Filename: Darora.xlsx - Download file (67.95 kb)

Suppl. material 2: Ethnomap of Darora Community, Boa Vista, Roraima.

Authors: Rodrigo Leonardo Costa de Oliveira
Data type: image
Brief description: This ethnomapa was developemented with the participation of the inhabitants of different ages. In legend: Farm area, "roças" (cultivated areas), road, rivers, lakes, residences, frontiers, community center (malocão).
Filename: Darora ethnomap.jpg - Download file (2.02 MB)