Diversity and indicator species in the cerrado biome, Brazil

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Abstract

The Cerrado biome has high species richness, endemism and spatial heterogeneity. Knowing the main characteristics and peculiarities of the flora is essential to adequately protect the species richness of the Cerrado. Therefore, the objective of this study was to analyze the species richness, alpha diversity and beta diversity of four vegetation types in the Paracatu River Basin (15°30'/19°30'S and 45°10'/47°30'W), Paracatu-MG. The four vegetation types cerrado (*stricto sensu*, "cerradão" or Savannah woodland, deciduous seasonal forest and riparian forest) were sampled following the Manual for Monitoring Permanent Plots of the Cerrado and Pantanal Biomes. *Alpha* diversity was assessed using the Simpson (Ds') and Shannon & Wiener (H') indexes, and *beta* diversity using the Sørensen and Jaccard similarity indexes. The "cerradão" vegetation type had the highest number of species (106) and highest *alpha* diversity (3.83nats.ind^{-1}). The cerrado *stricto sensu* had the lowest species richness (54 species) and *alpha* diversity value (2.65 nats. ind $^{-1}$). *Beta* diversity was high (low Jaccard and Sørensen similarity) except between cerrado *stricto sensu* and "cerradão". The initial hypothesis of this study was rejected, because although the phytophysiognomies are located on the same land system, the *beta* diversity is high, except for the cerrado *stricto sensu* and "cerradão", which had similar diversity.

Keywords: *alpha* and *beta* diversity, "cerrado *stricto sensu*", "cerradão", deciduous forest, riparian forest.

Introduction

The Cerrado biome has high species richness, endemism, spatial heterogeneity (Machado et al., 2008) and is currently considered the most species rich Savannah in the world (Myers et al., 2000), with more than 11 thousand species of vascular plants (Mendonça et al., 2008). Species richness is linked to the different vegetation types, which range from grasslands to forests (Machado et al., 2004). Knowing the main characteristics and the environmental integrity of the flora is essential to adequately plan and carry out the conservation of the Cerrado Biome. Biological characteristics and environmental integrity may be estimated using diversity indexes as well as by comparing areas. *Alpha* diversity indexes are based on the proportion of species abundance and are the most used in ecology, although species abundance models describe diversity more fully. Therefore, both uniformity (measured as equitability) and species richness are considered (Barros, 2007).

Alpha diversity values enable the comparison of different communities in regards to diversity and richness. However,

similarity of species composition is disregarded. *Beta* diversity is used as an environmental heterogeneity measure so that regions with low pairwise similarity have high *beta* diversity. *Beta* diversity is also assessed comparing species composition among different communities (Magurran, 2004). Studies evaluating *beta* diversity for the Cerrado region are few and punctual (Felfili et al., 2004; Ferreira, 2006; Haidar et al., 2013). In tropical regions, similar studies focus on rainforests (Condit et al., 2002; Tuomisto et al., 2003; Davidar et al., 2007; Arroyo-Rodríguez et al., 2013).

The species distribution in the Cerrado is correlated to edaphic characteristics, primarily chemical characteristics such as natural fertility (Martins et al., 2016). Cochrane et al., (1985), reported 25 physiographic regions and 70 different land systems in Central Brazil with recurrent climate, landscape and soil patterns. The sites studied are located within the same land system, so species overlap is believed to be high among the vegetation types. Therefore, the hypothesis of this study was that, the overlap in plant species

in basins located on the same land system is high, hence the low beta diversity in the region. The objective of this study was to analyze species richness and the *alpha* and *beta* diversities of the four vegetation types in the Paracatu River Basin (Paracatu-MG) and to perform a species indicator analysis for each of the studied vegetation types.

Results and Discussion

Richness and Alfa diversity

The Cerradão had 106 plant species, 1.376 ind.ha^{-1}, a basal area of 24.22 m^2.ha^{-1}, and the highest species richness, density and basal area, followed by the deciduous forest, riparian forest and Cerrado *stricto sensu* (Table 1). The smallest trees, associated with Cerrado *stricto sensu* (savanna formation), had lower basal areas. The cerradão was sampled with a different inclusion criteria from that used for other forest formations, which promoted the greater density and basal area values.

The riparian forest had the lowest density (560 ind.ha^{-1}) in this study and in studies carried out in other areas, for example, 723 ind.ha^{-1} in riparian forest of Carinhanha River basin (state of Bahia, Brazil; Gomes et al., 2014), 2.306 ind.ha^{-1} in the Taquari-Antas River basin (state of Rio Grande do Sul, Brazil; Teixeira *et al.*, 2014), 3.788 ind.ha^{-1} in gallery forests of Acampamento (Distrito Federal, Brazil; Guarino and Walter, 2005), 3445 ind ha^{-1} in the riparian forest of the Gurguéia River (state of Piauí, Brazil; Silva et al., 2015), and 1.475 ind.ha^{-1} in flooding areas of the Canjerana Park (Distrito Federal, Brazil; Dietzsch et al., 2006). The low plant density observed in the riparian forest evaluated is apparently related to annual perturbations, such as natural floods that soak the soil increase superficial runoff, carrying organic matter, seeds, and seedlings and saplings of local species into the waterbody. Cattle from within the studied fragments trample younger individuals (e.g., plant saplings) hindering the development of most plants. Cattle trampling leads to a reduction in the number of individuals that will make up the canopy layer of the riparian forest.

A high number of rare species was recorded in all vegetation types. Rare species tend to occur in higher frequencies in tropical forests (Hartshorn, 1980; ter Steege et al., 2013), where ecological dominance is common (Odum, 2004). Approximately ¼ - ⅓ of the tropical species are sampled in low densities (Hartshon, 1980). In addition, most phytosociological studies have reported few species contributing to the total density (percent contribution) in different savanna or tropical forest formations (Felfili et al., 2007; Pinto et al., 2007; Medeiros and Walter, 2012; Giácomo et al., 2013).

Ecological dominance occurs mostly in sites with extremely high or low resource availability in tropical environments (Ashton, 1990). Overall, few species adjust to extreme conditions, such as flooding events in the Cerrado *stricto sensu* and in the riparian forest. Such extreme conditions provide optimal colonization opportunities for better-adapted species, given the low interspecific competition. This explains the high dominance of *Curatella americana* and *Byrsonima crassifolia* in cerrado *stricto sensu* on Fluvisol (Ferreira et al., 2010), and the dominance of *Acacia polyphylla* in the riparian forest of the Paracatu River (Medeiros, in press).

The deciduous forest had a higher number and proportion of rare species in regards to total richness. However, some species rare in the deciduous forest are sampled in higher densities in other vegetation types (e.g., cerrado *stricto sensu*), namely *Curatella americana, Dimorphandra mollis, Eugenia dysenterica, Leptolobium dasycarpum, Magonia pubescens* and *Tabebuia aurea* (Ratter et al., 2003; Bridgewater et al., 2004). Therefore, the surrounding vegetation (in this case the cerrado *stricto sensu*) influences the floristic composition of the deciduous forest analyzed.

Many of the species collected in the cerrado *stricto sensu* were rare species. Most of these rare species (e.g., *Alibertia edulis, Bowdichia virgilioides, Callisthene fasciculata, Myrcia rostrata, Qualea grandiflora* and *Siparuna guianensis*) are abundant in other areas of the Cerrado *stricto sensu*, where the soil has good drainage conditions (Balduino et al., 2005; Saporetti Júnior et al., 2003; Fonseca and Silva Júnior, 2004; Teixeira et al., 2004; Neri et al., 2007; Finger and Finger, 2015). The anoxia caused by the flooding period may, in a way, restrict the establishment of larger populations of species usually more abundant in other areas where the soils have a good drainage.

The floristic composition recorded in the Paracatu River basin are within the limits detected in other sites for the riparian forest and cerradão (Carvalho et al., 1996, Pereira-Silva et al., 2004, Barttilani et al., 2005, Lacerda et al., 2005 e, Souza et al., 2008). However, the Cerrado *stricto sensu* had the 3rd smallest floristic richness when compared with the other 29 areas in Central Brazil (Ferreira *et al.,* 2010) and the smallest among the four vegetation types studied.

The deciduous seasonal forest showed high richness when compared with other areas in other regions of the country (Santos et al., 2007; Bianchin and Bellé, 2013). The studied deciduous forest has many species typical of the Cerrado *stricto sensu* vegetation type. Therefore, many species were included in the deciduous forest sampling, leading to a high diversity when compared to other deciduous seasonal forests. The low species richness (54) observed for the Cerrado *stricto sensu* may be associated with the environmental control carried out by anoxia. Few species are able to survive anoxia. Therefore, it limits the number of species able to become established in the environment. However, the estimates made by the first and second order *jackknife* were high, indicating that the area has an increasing potential for richness (Fig 1).

The riparian forest sample best approached the asymptote. The other areas showed a tendency of having a larger number of species, due to the high number of rare species. The Shannon and Wiener (*H'*), and Simpson (*Ds'*) diversity indexes and Pielou's evenness (*J'*) quantified local biodiversity and reflected community structures in regards to the relative abundance of the different species that make up richness of the different vegetation types.

Overall, the high *alpha* diversity reported for the cerradão, riparian forest and deciduous forest vegetation types, indicated some heterogeneity and a lower ecological dominance. The Cerrado *stricto sensu* had low diversity and evenness values which indicate high ecological dominance. The species *Curatella americana* contributed to near 33.6% of all individuals. This result may be partially explained by the anoxia condition observed especially in the rainy season, caused by the poor soil drainage conditions.

Beta diversity

Beta diversity among the sampled vegetation types was overall high (Table 2 - B) as the Jaccard and Sørensen indexes indicated low floristic and structural similarity among the vegetation types, except when Cerrado *stricto sensu* was compared with cerradão.

Table 1. Structure, floristic richness and *alpha* diversity for four vegetation types sampled in the Paracatu River basin, MG.

|	Plant types			
	Cerrado *stricto sensu*	Riparian forest	cerradão	Deciduous forest
Sampling:				
Number of plots (N)	10 (20 × 50)	100 (10 × 10)	10 (20 × 50)	25 (20 × 20)
Inclusion criterion (IC)	$Bd_{30} \geq 5cm$	$DBH \geq 5cm$	$Bd_{b30} \geq 5cm$	$DBH \geq 5cm$
Number of species (S)	54	56	106	76
Number of individuals (Ni) ha^{-1}	697	560	1376	1046
Basal area (BA) m^2.ha^{-1}	6.41	20.32	24.22	21.76
Rare species:				
Number of rare species:	13	10	21	22
Percentage of rare individuals	1.87	1.79	1.60	2.01
Percentage of rare species	24.07	17.86	20.75	27.63
Species diversity:				
Shannon & Wienner index (*H'*)	2.65	3.26	3.83	3.25
Simpson Index (*Ds'*)	0.84	0.93	0.96	0.92
Pielou evenness(*J'*)	0.67	0.81	0.82	0.75
1st order *jackknife* estimator	76.5	68.9	133.9	106.8
1st order *jackknife* estimator	88.0	74.8	140.0	121.8
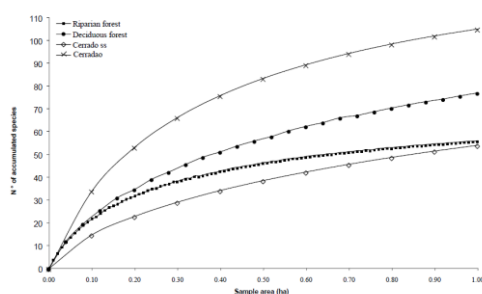
Fig 1. Cumulative number of species per area sampled for four vegetation types in the Middle Paracatu River, MG.

Table 2. (A) Common species; (B) Jaccard similarity index (left side), Sørensen similarity index (right side); (C) Comparison of the Shannon-Wiener diversity indexes using Hutcheson's *t* test for the four vegetation types sampled in the Paracatu River basin, MG.

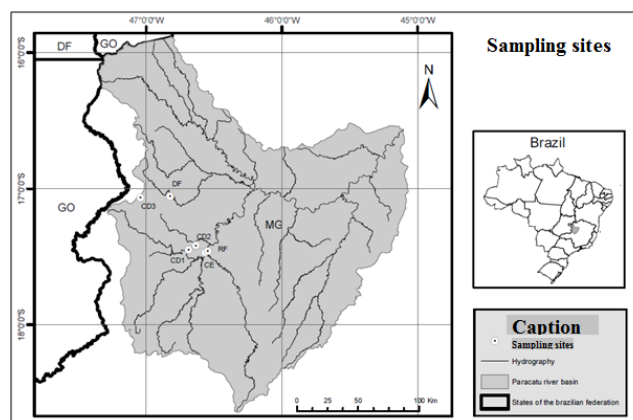| (A)	Cerrado *ss*	Riparian forest	cerradão	Deciduous forest
Cerrado *stricto sensu*		-	-	-
Riparian forest	10		-	-
cerradão	41	10		-
Deciduous forest	16	14	18	
(B)				
Cerrado *stricto sensu*	-	18.18	51.57	24.43
Riparian forest	10.00	-	12.42	21.05
cerradão	34.75	6.62	-	19.78
Deciduous forest	13.91	11.76	10.98	-
(C)				
Cerrado *stricto sensu*	-	-	-	-
Riparian forest	7.25 ***	-	-	-
cerradão	-16.93 ***	-9,69 ***	-	-
Deciduous forest	-7.67 ***	0.11 (ns)	11.14 ***	-

$p \leq 0.001$ ***= significant; ns = non-significan
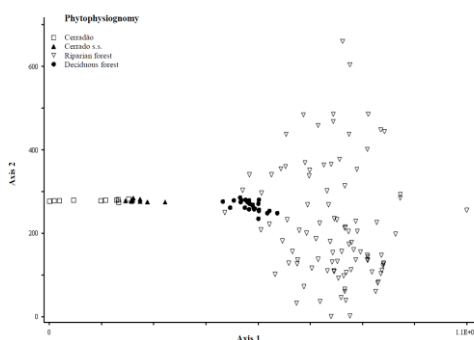
Fig 2. Detrended Correspondence analysis (DCA) for tree density in plots of four vegetation types (Cerrado *stricto sensu*, cerradão, riparian forest and deciduous seasonal deciduous forest) sampled in the Paracatu River basin, MG.

Table 3. Indicator Species Analysis with significance level below 0.001% (*** $P< 0.001$), of four vegetation types and the respective abundance. OIV= Observed indicator value (%), EIV = expected indicator value (mean, standard deviation and significance).

| Vegetation type | OIV | EIV | | |
Species		Mean	SD	*P*
Cerrado *stricto sensu*				
Byrsonima crassifolia	99.1	8.0	4.62	***
Curatella americana	92.1	9.4	5.01	***
Zanthoxylum riedelianum	88.4	7.5	4.24	***
Eugenia dysenterica	65.5	9.3	5.28	***
Tachigali aurea	50.0	5.8	3.73	***
Riparian forest				
Acacia polyphylla	48.0	16.5	5.81	**
cerradão				
Qualea grandiflora	99.1	7.8	4.64	***
Copaifera langsdorffii	93.9	10.0	5.14	***
Emmotum nitens	90.0	7.4	4.13	***
Qualea parviflora	82.3	7.7	4.57	***
Cordiera macrophylla	80.0	7.0	4.08	***
Tachigali subvelutina	80.0	6.9	3.97	***
Simarouba versicolor	80.0	7.1	4.41	***
Platypodium elegans	70.0	6.7	3.97	***
Bowdichia virgilioides	65.9	7.0	4.36	***
Qualea multiflora	64.6	7.4	4.51	***
Xylopia aromatica	63.2	8.0	4.15	***
Machaerium acutifolium	58.3	7.4	4.6	***
Myrcia rostrata	57.0	6.6	4.45	***
Astronium fraxinifolium	54.7	12.5	5.91	***
Aspidosperma tomentosum	50.0	5.9	3.85	***
Deciduous forest				
Aspidosperma pyrifolium	92.0	11.2	5.46	***
Anadenanthera colubrina	88.0	10.8	5.25	***
Myracrodruon urundeuva	73.5	14.3	6.06	***
Handroanthus impetiginosus	59.7	9.3	5.07	***
Coutarea hexandra	52.0	8.5	4.58	***

*** $P< 0.001$.

Fig 3. Sampling sites for each vegetation type. CE: Cerrado *stricto sensu*, RF: riparian forest, CD1, CD2 e CD3: cerradão area and DF: deciduous forest.

Table 4. The geographical and environmental information for the four plant communities sampled in the middle section of Rio Paracatu-MG, Brazil. Areas: Cerrado *stricto sensu* (CE), cerradão (CD), deciduous forest (DF), riparian forest (RF), soil base saturation (V).

Areas	Latitude (S)	Longitude (W)	Altitude (m)	Area (ha)	Soil class[*]	V (%)	Texture
CE	17°28'12.43"	46°33'51.99"	520	22.3	F	14.1	loam, clay
CD1	17°27'0.26"	46°41'17.03"	572	45	RO	8	loam, clay, sand
CD2	17°25'3.73"	46°37'49.64"	564	221.6	RO	10	loam, clay, sand
CD3	17° 3'50.01"	47° 2'22.84"	950	104.5	RO	7.3	loam, clay, sand
DF	17° 3' 16.6"	46° 49' 23.5"	720	473	L	-	-
RF	17°27'31.47"	46°32'47.35"	525	29.3		71	loam, clay

*Soil class prevailing in each vegetation type. F: Fluvisol; LV: Red Oxisol and L: Leptosol.

The cerradão formation is characterized by species typical of the Cerrado *stricto sensu* and of the neighboring forest formations, particularly of the semi-deciduous dry and non-flooding gallery forests (Ribeiro and Walter, 2008; Walter et al., 2015). Thus, the physiognomic identity of the cerradão is considered similar to that of forests, however with a different floristic structure once it does not comprise exclusive species. The cerradão and Cerrado *stricto sensu* formations were more similar to each other in Paracatu (Table 2-A).

The four communities had only five species in common: *Astronium fraxinifolium*, *Casearia sylvestris*, *Copaifera langsdorffii*, *Dilodendron bipinnatum* and *Myracrodruon urundeuva*, of which only *Astronium fraxinifolium* and *Casearia sylvestris* are indexed in the list of species that are widely distributed in the Cerrado Biome (Ratter et al., 2003). This result shows the uniqueness of the vegetation types studied in the referred river basin and their importance for Cerrado conservation. Felfili et al. (2004), analyzed the similarity between the Pratinha, Veadeiros and São Francisco physiographic units, and identified the Paracatu region as a priority area for conservation. The Paracatu region was identified for having low similarity values with the other sites studied.

Sixteen species occurred in at least three of the four vegetation types. Bridgewater et al. (2004), evaluated *beta* diversity patterns for the Cerrado in Distrito Federal and recorded 14 species in all 13 areas, while 94 species (of 236) occurred in 50% or more sites. The Cerrado is indeed very heterogeneous in regards to species composition (see Felfili and Silva junior, 1993 and Ratter et al., 2003).

Areas with high *beta* diversity values must hold large Conservation Units, to protect most of the regional flora variation (Felfili and Felfili, 2001). The Paracatu river basin has 11 Conservation Units, mostly small Environmental Protection Areas (APAs; Área de Proteção Ambiental) and Private Natural Heritage Reserve (RPPNs; Reserva Particular do Patrimônio Natural) (IGAM, 2006). Small sizes limit the protection potential of these units. Therefore, knowledge on the floristic heterogeneity of Cerrado is very important to subsidize making decisions such as how and where to create conservation units (Felfili and Silva-Júnior, 1993).

The DCA based on population density clearly distinguishes the four communities along environmental gradients. The first ordination axis (eigenvalue = 0.90) arranged the plot into two groups: Cerrado *stricto sensu* and cerradão, and dry and riparian forests (however more dispersed). The second axis (eigenvalue= 0.62) showed a wide variation among the riparian forest plots (Figure 2). The total variance in the analysis was 18.83%.

The high eigenvalues for the DCA axes 1 and 2 indicate a long gradient of species distribution (eigenvalue < 0.50). This pattern revealed a species preference for a vegetation type. The DCA has an important feature where the axes are scaled in *beta* diversity units (Palmer, 2005). In other words, the units or standard deviations for the species are the degree of species input and output along the gradient. Therefore, the analyzing the position of plots on the ordination axes shows the beta diversity of the sampled transects (Kent and Coker, 1992).

The first DCA axis separated the cerradão and Cerrado *stricto sensu* from the deciduous seasonal forest and the riparian forest. This result confirmed the results of the analysis of similarity between areas where cerradão and Cerrado *stricto sensu* had the highest species overlap and consequently the lower *beta* diversity.

The riparian forest was floristically more similar to the deciduous forest. The largest difference among these communities is in the riparian forest association with the watercourse and its structures. The 560 ind.ha^{-1} in the riparian forest reached 20.32 m^2.ha^{-1} of basal area, while the 1.046 ind.ha^{-1} in the deciduous forest reached a basal area of only 21.76 m^2.ha^{-1}. The riparian forest had large more spaced trees. The annual flood cycles in the riparian forest restrains the number of species by selecting species resistant to anoxia, and by washing away seeds, saplings and organic matter deposited during the dry season. Species resistant to anoxia must have a refined seed dispersal strategy from the end of the rainy period to the beginning of the dry period, for the germination and initial growth to occur in rates that enable saplings to resist the next flood (Ribeiro and Walter, 2008).

The riparian forest exhibited high variation among plots in the second axis. The riparian forests often have large plant diversity due to the high environmental heterogeneity consequent of topography variations, formation age, soil characteristics and groundwater volume variation (Rodrigues and Leitão Filho, 2000). Such riparian heterogeneity occurs even at a short distance, as for the riparian forest of the Paracatu River, where flooded and dry habitats alternate in the same landscape leading to a large internal variability.

The indicator species analysis revealed 11 indicator species for the Cerrado *stricto sensu*, one for the riparian forest (*Acacia polyphylla*), 64 for cerradão and 25 (of which nine were not identified to the species level) for the deciduous forest. Indicator species are species that represent environmental and biological conditions (Rolstad et al., 2002). Table 3 shows the indicator species with significance level lower than 0.001% (*** *P< 0.001*).

The species *Byrsonima crassifolia, Curatella americana, Eugenia dysenterica, Tachigali aurea* and *Zanthoxylum riedelianum* had high observed indicator values (OIV values) in the Cerrado *stricto sensu*. *Curatella americana* and *Zanthoxylum riedelianum* were recorded with high OIVvalues in a fragment of floodplain forest in the municipality of Lagoa da Confusão-TO (Brito, 2005). These two species, along with *Tachigali aurea*, are considered tolerant to short periods of flooding (Ferreira Júnior, 2009). Such remark concurs with the indication values obtained for the referred species (high OIV), once the periodic flooding does not hinder the establishment of its populations in the flooded Cerrado *stricto sensu*.

Only the species *Acacia polyphylla* was considered an indicator (OIV = 48%) in the riparian forest. *Celtis iguanaea* and *Triplaris gardneriana* are considered typical of riparian forests (Walter et al., 2015), occurred in the floristic survey and were not identified as indicators in the analysis. The species *Celtis iguanaea* was appointed indicator of the deciduous forest in Paracatu, for having the highest abundance and frequencies in deciduous forest plots.

The 64 indicator species of the cerradão represent 60.4% of the species sampled in this vegetation type. The species *Aspidosperma tomentosum, Astronium fraxinifolium, Bowdichia virgilioides, Copaifera langsdorffii, Cordiera macrophylla, Emmotum nitens, Machaerium acutifolium, Myrcia rostrata, Platypodium elegans, Qualea grandiflora, Qualea multiflora, Qualea parviflora, Tachigali subvelutina, Simarouba versicolor* and *Xylopia aromatica*, had high OIV. The species *Qualea grandiflora* are common to the cerradão and Cerrado *stricto sensu*, the species *Copaifera langsdorffii, Emmotum nitens*, *Hirtella glandulosa* and *Siphoneugena densiflora* to the dystrophic cerradão, and *Callisthene fasciculate* and *Platypodium elegans* to the mesotrophic cerradão (Ribeiro and Walter et al. 2008).

The cerradão had the highest number of indicator species among the studied vegetation types, possibly because it has

the least adverse conditions for species establishment in flooded environments. Therefore, 34% of the 64 species considered indicators in the cerradão are typical of the Cerrado *stricto sensu*, and 13% of the 64 species, are typical of non-flooded gallery forests (Walter et al., 2015).

The indicator species analysis highlighted 25 indicator species for the deciduous forest, of which nine were unidentified taxa. Apart from the nine unidentified species, the ones with the highest OIV values were: *Anadenanthera colubrina, Aspidosperma pyrifolium, Coutarea hexandra, Myracrodruon urundeuva* and *Handroanthus impetiginosus*, all commonly found in the seasonal forests of the Cerrado and Pantanal domains and in the arboreal Caatinga (Carvalho, 2009). The afore mentioned species indicate mesotrophic soils (Carvalho et al., 2005), and are thus indicators of the deciduous seasonal forest.

Materials and Methods

Study site

The region studied is located in the middle section of the Paracatu River basin, sub-basin of the São Francisco River (17°28'12.43"; 46°33'51.99'') The Paracatu River is one of the largest and most important tributaries of the São Francisco River. The climate in this region is megathermic rainy, type AW (Köppen, 1936). It is a typical rainy tropical climate with high temperatures and rains from October to April, when 93% of total annual precipitation is reached. The average precipitation in the river basin is 1.340mm and the average annual temperatures range from 21° to 24° C (IGAM, 2006).

The main vegetation types reported within the river basin are Cerrado and Cerrado field (campo Cerrado) (IGAM, 2006). The cerradão are more common in the Southern range of the basin. The grasslands occur mostly on plateau tops and slopes, and the deciduous forests occur in the western portion of the basin. Floodplains occur mainly in valleys of large rivers and palm swamps (veredas) in depressions and valleys surrounding and following headwaters. The Paracatu river basin still has 56.33% of its natural vegetation cover and 43.08% (17,701.19 km^2) of its remaining area is used for pasture, agriculture and reforestation purposes (IGAM, 2006).

Sampling and description of the sampling areas

This study comprises four vegetation types: Cerrado *stricto sensu*, "cerradão" (savannah woodland), deciduous seasonal forest and riparian forest. One hectare was sampled in each physiognomy, following the method described in the Manual for Monitoring of Permanent Plots for the Cerrado and Pantanal Biomes (Felfili *et al.*, 2005).

The Cerrado *stricto sensu* extends for 22.3 ha, and is located on alluvial land surrounding the riparian forest of the Paracatu River. Small Cerrado patches are inserted in a grassland matrix, leading to a local scale mosaic within the alluvial Cerrado. The vegetation is flooded in the rainy season (October - April). Ten 20 x 50 m plots (1000 m^2) were randomly selected in the patches of Cerrado *stricto sensu* for sampling. All individuals with $Bd_{30cm} \geq 5$ cm were measured and the phytosociological parameters of the area are published in Ferreira et al. (2010).

The cerradão was sampled in three segments with 45, 221.6 and 104.5 ha patches, respectively. The cerradão was sampled following the same procedures as for the Cerrado *stricto sensu*. The floristic composition of the area is described in Solórzano et al. (2012). The deciduous seasonal forest covers an area of 473 ha, includes several Legal Reserves of different properties and is embedded in large chain of mountains, surrounded by rocky outcrops. The selected deciduous forest fragment was separated into three segments, and each segment was divided into bands, perpendicular to the elevation gradient. Each band of 20m width was subdivided into 20 x 20m plots (25 plots), so bands could be randomly selected. All woody individuals with DBH ≥ 5 were measured in the 25 plots that amounted to 1 hectare.

The riparian forest sampled is 23.9 ha large and is located on the left bank of the Paracatu River, 2 km after converging with the La Plata River. Nine transects 100 meters away from each other and perpendiculars to river were used to sample the riparian forest. Each transect was divided in continuous 10 x10m (100m^2) plots, with length varying with forest width. All woody individuals in a hectare with DAP ≥5cm were measured.

Palm trees, lianas and overall non-woody plants were not sampled in either vegetation types. The nomenclature used for the species list followed the Angiosperm Phylogeny Group classification system (APG IV, 2016). The botanical material was identified in the field, by comparison with specimens of the herbaria of the University of Brasilia (Universidade de Brasília; UB) and of the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística; IBGE). The collected material was sent to specialists when necessary. The fertile exsiccates were stored in the UB and IBGE herbaria. Table1 shows the geographical and environmental information for the four vegetation types analyzed, and Figure 1 shows the sampling sites for each vegetation type.

Vegetation analysis

Richness and *Alfa* diversity

The four vegetation types were evaluated in regard to species richness, Simpson's diversity (*Ds'*), Shannon-Wiener diversity (H') and Pielou evenness (J') (Brower and Zar 1984). Sampling effort curves were plotted using means and 95% confidence intervals of the cumulative number of species to compare species richness among communities. Accumulation curves were plotted as described in Mccune and Mefford (1999).

First and second order jackknife estimators were also calculated. These estimators determine the maximum species richness reached considering sample heterogeneity (Heltsche and Forrester, 1983; Palmer, 2005). A Hutcheson's t test (Zar, 1996) was used to compare *H'* values obtained for the communities. Therefore, pairwise comparisons of four vegetation types were carried. Species with one specimen per hectare were considered rare (Martins, 1991; Kageyama and Gandara, 1993) for species richness discussions.

Indicator Species

The indicator species analysis (Dufrêne and Legendre, 1997) was used to determine a species habitat preference, in the four communities studied. This method combines species abundance information into groups of sample units, with the frequency in which the species occur within the groups.

The indicator values were obtained for every species of each physiognomic type. Then, a Monte Carlo procedure was applied to assess the difference between the indicator value and chance. This method combines the degree of specificity of a given species to an ecological status, e.g., habitat type and its fidelity within the status (Mcgeoch et al., 2002).

Therefore, it is possible to obtain indicator values that measure the association between species and vegetation types, and vary from zero (no indication) to 100 (maximum indication). Therefore, species are considered habitat indicators when a Monte Carlo test between the observed indicator value (OIV) and the expected indicator value (EIV) is significant (Dufrêne and Legendre, 1997). The analysis was carried out in the software PC-ORD for Windows version 4.14 (McCune and Mefford, 1999).

Beta diversity

Beta diversity values comprise differences in species composition and abundance among the fragments, and were obtained analyzing the similarity among communities through the Sørensen (qualitative) and Jaccard (quantitative) indexes (Kent and Coker, 1992; Mueller-Dombois and Ellenberg, 2002). Therefore, higher *beta* diversities are obtained when the similarity among the vegetation types is the smallest. The analyses were performed in the software CANOCO 4.5 (Ter Braak and Smilauer, 2002).
The Detrended Correspondence Analysis (DCA) was used evaluate the floristic pattern plots in the different vegetation types sampled. The DCA yields an ordination diagram in which the areas are plotted following among-site similarity (Hill and Gauch, 1980).

Conclusion

The cerradão had the highest species richness and *alpha* diversity, while the lowest richness and diversity were recorded for the Cerrado *stricto sensu*. The initial hypothesis of this study was rejected, because although the phytophysiognomies are located on the same land system, the *beta* diversity is high, except for the Cerrado stricto sensu and cerradão, which had similar diversity. The indicator species analysis highlighted 11 indicator species for the Cerrado *stricto sensu*, one for the riparian forest (*Acacia polyphylla*), 64 for the cerradão and 25 (of which nine were not identified in the species level) for the deciduous forest.

Acknowledgments

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