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Influence of edaphic factors on the floristic composition of an area of *cerradão* in the Brazilian central-west

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ABSTRACT

This study describes the influence of edaphic factors on the floristic composition of an area of *cerradão* (woodland savanna) in the city of Campo Grande, located in the Brazilian central-west. In 10 plots (5 × 20 m each), we evaluated all trees with a diameter at breast height ≥ 4.77 cm. Soil samples were analyzed for each plot in order to determine edaphic variables correlated with species composition. We sampled 1180 individuals of 61 species. The evenness index was 0.74, which indicates uneven distribution of species, which was explained by a high abundance of *Qualea parviflora*, *Curatella americana*, *Qualea grandiflora*, *Terminalia argentea* and *Astronium fraxinifolium*. We registered more trees in the smallest diameter class and in the middle layer of the vertical structure. The soil was dystrophic with a clay texture, which explains the higher abundance of species related to dystrophic *cerradão*. However, we also found some trees typical of mesotrophic *cerradão* and deciduous forests, which could be attributable to the presence of patches of fertile soil within the dystrophic *cerradão* or could indicate that those mesotrophic species are tolerant of lower levels of soil nutrients.

Key words: *cerrado*, dystrophic *cerradão*, mesotrophic *cerradão*, phytosociology, soil-plant interaction

Introduction

The *Cerrado* biome of Brazil possesses physiognomies that comprise grassland, savanna and forest formations. Edaphic factors such as effective depth, presence of concretions in the soil profile, proximity of the water table to the surface, drainage, and fertility are among the most important determinants of the floristic composition, structure and productivity of the native vegetation (Haridasan 2000).

Of the forest formations, the woodland known as the *cerradão* is distinct because of its low height and xeromorphic features, corresponding to a "mesophilous sclerophyllous forest", with trees of 8-15 m, understory composed of shrubs and treelets that can reach 3 m, and a sparse herbaceous layer with low species richness. The *cerradão* contains species that co-occur in the *cerrado típico* (a savanna formation that constitutes the most widespread physiognomy of the *cerrado* biome) and in several other types of forests (Ribeiro & Walter 2008).

Haridasan (1992) argued that factors such as water availability in the soil and soil composition might play a role in phytophysiognomic differentiation, providing higher nutrient availability, thus enabling the establishment of vegetation with greater density and height, as in the case of the *cerradão*. The author also argued that such physiognomy could remain in dystrophic soils because of the closed nutrient cycle.

Two types of *cerradão* with floristic and soil differences have been described, one characteristics of mesotrophic soils with higher pH and levels of Ca and Mg and the other of dystrophic soils of lower pH, Ca and Mg (Ratter 1971, Ratter *et al*. 1973, 1977, 1996, 2003, 2006, 2011; Furley & Ratter 1988). In the earlier publications of the series these communities were named after characteristics marker tree species: *Hirtella glandulosa* Spreng and *Emotum nitens* (Benth.) Miers for dystrophic and *Magonia pubescens* St. Hill., and *Callisthene fasciculata* (Spreng) for mesotrophic, but later the terms "dystrophic *cerradão*" and mesotrophic *cerradão*" were used. The soils of dystrophic *cerradão* show pH and minerals similar to these open forms of *cerrado*, but higher clay content, indicating greater retention of water in cases that have been analyzed (Assis *et al*. 2011).

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In keeping with the observations of many of the previously cited authors, Assis *et al.* (2011) found no correlation between soil fertility and *cerradão*. However, those authors described the considerable correlation that dystrophic *cerradão* displays with high levels of clay and microporosity, resulting in greater water retention, thus enabling the occurrence of a more exuberant vegetation (i.e., *cerradão*). Therefore, considering the latest discussions on this subject, it seems that soil texture determines the vegetation structure, whereas soil fertility determines the floristic type of *cerradão* (Ratter 1971; Ratter *et al.* 1973, 1977; Furley & Ratter 1988).

Because studies of soil-plant interaction are useful tools to improve the understanding of the floristic patterns of the *cerrado* biome and to aid in its preservation, in this study, we evaluated the relationship between floristic composition and edaphic variables in the *cerradão* in the municipality of Campo Grande, in the state of Mato Grosso do Sul. We hypothesized that the distribution and dominance of species in the *cerradão* are related to chemical and physical attributes of the soil.

Material and methods

Study site

The study was conducted in an urban *cerrado* fragment of 36.5 hectares, located within the *Reserva Particular do Patrimônio Natural* (RPPN, Private Nature Reserve) operated by the *Universidade Federal de Mato Grosso do Sul* (UFMS, Federal University of Mato Grosso do Sul), in the municipality of Campo Grande (20°30'33.83"S; 54°36'57.07"W). According to the Köppen climate classification system (Köppen 1948), the climate is type Aw (rainy tropical savanna), characterized by a dry period during winter and a rainy period during summer, with an average annual precipitation of 1,532 mm (Embrapa 1985). According to the Brazilian Agency for Agricultural Research (Embrapa 2006), the predominant soil types in the region are dystroferric red latosol and udorthent.

General aspects of the vegetation

Using the phytophysiognomic classification of the *cerrado* biome proposed by Ribeiro & Walter (2008) as a reference, we identified the following formations in the RPPN of the UFMS: *cerrado típico*, gallery forest and *cerradão*.

Sampling

We used the plot method (Mueller-Dombois & Ellenberg 1974). The survey was conducted in one hectare, in ten 50 × 20 m plots, randomly distributed. We included all living woody individuals with a diameter at breast height (DBH) ≥ 4.77 cm. The total height of trees was estimated visually, using a 5 m graduated measuring stick. All botanical material was preserved and later deposited in the Campo Grande-Mato Grosso do Sul Herbarium (code, CGMS). We identified specimens by consulting the literature, by comparing them with specimens deposited in the CGMS Herbarium or by enlisting the aid of specialists. The plant families were listed according to the Angiosperm Phylogeny Group III guidelines (APG III 2009).

Soil collection

The collection of soils for the analysis of fertility was carried out with a probe type auger. In each plot, we collected a sample comprising 20 subsamples, randomly collected at depths of 0 cm to 20 cm. The chemical and physical analyses were conducted in the Soil Fertility Laboratory of the Anhanguera University for the Development of the Pantanal Region, following the methodology described by the Brazilian Agency for Agricultural Research (Embrapa 1998).

Data analysis

We analyzed the following phytosociological parameters (Mueller-Dombois & Ellenberg 1974): basal area, absolute density, relative density, absolute frequency, relative frequency, absolute dominance, relative dominance, cover value, and importance value (IV). We evaluated floristic diversity by calculating the Shannon index (H') and Pielou's evenness index (J'), as described by Brower & Zar (1984). All parameters were estimated with the software Mata Nativa 2 (Cientec 2007).

For the analysis of diametric classes, the individuals were distributed in diameter classes with the ideal class interval (CI=7.1) calculated according to the formulae put forth by Spiegel (1976):

$$CI = A/NC$$
$$NC = 1+3.3 \log N$$

where A is the amplitude of diameters, NC is the number of classes, and N is the number of individuals.

Although there are several criteria for height stratification to estimate the absolute sociological position per species in the plant community, we used three height layers, following the recommendation of Paula *et al.* (2004). *A posteriori*, we applied the D'Agostino-Pearson normality test, according to Zar (1999).

To establish the relationships between plots/species and soil parameters, we performed canonical correspondence analysis (CCA), as described by ter Braak (1988). The CCA requires two matrices, one with the species per plot data and another with the explanatory variables. The highest correlations were found for the following variables: texture (clay), organic matter, phosphorus, potassium, aluminium saturation, base saturation, sum of bases, cation exchange capacity (CEC) and pH.

There are several advantages in the use of the CCA, the greatest of which is the Monte Carlo test, which consists in randomly permuting the lines of the matrix of environmental variables to test the significance of the correlation between the two matrices, identifying the probability that the relationship observed between the two original matrices is correct. The CCA and the Monte Carlo test were processed by the program PC-ORD for Windows, version 5.0 (McCune & Mefford 2006).

Results and discussion

Floristics and structure

We recorded 61 species, belonging to 52 genera, distributed in 31 families (Tab. 1). Of the sampled families, Fabaceae had the highest richness, with 11 species; followed by Vochysiaceae (6 species); Erythroxylaceae (4 species); Annonaceae, Anacardiaceae, and Myrtaceae (3 species each); and Bignoniaceae, Chrysobalanaceae, Combretaceae, Connaraceae, Malpighiaceae, and Malvaceae (2 species each). These families accounted for 68.85% of the species observed at the study site. The remaining 19 families were represented by only one species each.

The most prominent families in this study were the same families found in other *cerradão* areas (Batalha & Mantovani 2001; Salis *et al.* 2006; Silva *et al.* 2008; Souza *et al.* 2008; Araújo *et al*. 2011), especially Fabaceae and Vochysiaceae in areas of dystrophic *cerradão* (Costa & Araújo, 2001; Marimon Júnior & Haridasan, 2005; Araújo *et al.* 2011).

The H' value obtained (3.03) was similar to those reported for other areas of *cerradão* in the state of Mato Grosso do Sul, which have ranged from 2.90 to 3.36 (Salis *et al.* 2006), and lower than those reported for areas of *cerradão* in the southeast (range, 3.38-3.54; Gomes *et al.* 2004; Guimarães *et al.* 2001), northeast (range, 3.31-3.32; Silva *et al.* 2008; Alencar *et al.* 2007) and central-west (range, 3.42-3.84; Andrade *et al.* 2002; Felfili & Silva Junior 1992; Marimon Junior & Haridasan 2005). The J' value obtained (0.74) indicated an unequal distribution of individuals per species. The high abundance of five species, *Qualea parviflora* Mart., *Curatella americana* L. *Qualea grandiflora* Mart., *Terminalia argentea* Mart. and *Anadenanthera peregrina var. falcata* (Benth.) Altschul, collectively accounting for 55.71% of the relative density, contributed to the low evenness observed.

The variation in richness and diversity might be related to factors such as the inclusion criterion for trees, basal area, sample size (Pinheiro & Durigan 2012), soil (Assis *et al.* 2011; Neri *et al.* 2013) and biogeography (Ratter *et al.* 1997). The *cerrado* areas in the Alto Araguaia region in the state of Mato Grosso, the state of Tocantins and the Federal District have a high species richness in comparison to the marginal and disjunct areas of the *cerrado* biome (Ratter *et al.* 1997). However, in marginal areas, floristic elements from adjacent plant formations occur, adding to the richness of the *cerrado* (Ratter *et al.* 2003).

Regarding the vertical structure (Fig. 1), 60.25% of individuals belonged to the middle layer (height, 4.01-7.88 m), 21.69% belonged to the lower layer (0-4 m), and 18.13% belonged to the upper layer (7.89-12 m). According to Ratter (1986), the tallest species in the *cerradão* usually reach 10-12 m, although taller individuals can occur. In the present study, the tallest species were *Andira cuyabensis* Benth., *Bowdichia virgilioides* Kunth, *Callisthene minor* Mart., *Curatella americana*, *Hymenaea stigonocarpa* Mart. ex Hayne, *Lafoensia pacari* A. St.-Hil., *Luehea paniculata* Mart., *Qualea parviflora*, *Matayba guianensis* Aubl., *Stryphnodendron obovatum* Benth., *Tachigali aurea* Tul., and *Terminalia argentea*, with individuals between 10 and 12 m tall. Of the 61 species recorded, 30 had no individuals in the lower layer, suggesting the existence of restrictions to the natural processes of reproduction, dispersal and regeneration (Silva & Soares 1999; Toppa 2004). An important factor that might be related to this condition is the human impact on the areas surrounding the study site. This impact causes the isolation of the area, restricting the flux of pollinators, and is a major negative factor in the regeneration process, considering that most tree species depend on animals for their pollination and dispersal (Reis *et al.* 1999).

The analysis of diametric distribution revealed that most of the individuals belong to the smallest size classes (71.86% for the first two classes) (Fig. 2), and that this community has an inverted "J" pattern, which indicates the regenerative capacity of the community. According to Silva Júnior & Silva (1988), the concentration of individuals in the first two diameter classes might indicate possible past disturbances, natural or anthropic, such as timber harvesting, selective logging, fires, deforestation and herbivory, and might also be explained by the genetic potential of most *cerrado* species for small size.

The absolute density in the *cerradão* was 1,180 $ind.ha^{-1}$. This result was lower than that observed for other areas of dystrophic *cerradão*, such as those in the municipality of Uberlândia, in the state of Minas Gerais (Costa & Araújo 2001), with 2,071 $ind.ha^{-1}$; in the state of Mato Grosso, with 1,884 $ind.ha^{-1}$ (Marimon Junior & Haridasan 2005); and in the Federal District, with 2,231 $ind.ha^{-1}$ (Ribeiro *et al.* 1985). This difference demonstrates the effect of dominant species on the structure, considering that the 10 species with the largest IV accounted for 59.11% of the total density value and covered 74.51% of the basal area (Tab. 2). Such numbers might indicate the presence of a restricted group of species with competitive advantages, high DBH and large number of individuals, thus affecting the previously discussed values of density, diversity and evenness.

The fact that the highest IV was obtained for *Qualea parviflora* corroborates the patterns reported by Ratter *et al.* (2003), in which *Q. parviflora* had the second highest

Table 1. List of the species recorded in the *cerradão* of the Private Nature Reserve operated by the Federal University of Mato Grosso do Sul, in the city of Campo Grande, Brazil.

Family	Scientific name	Herbarium record
Anacardiaceae	*Astronium fraxinifolium* Schott	24898
	Myracrodruon urundeuva Allemão	24897
	Tapirira guianensis Aubl.	24894
Annonaceae	*Annona coriacea* Mart.	24932
	Annona crassiflora Mart.	24931
	Xylopia aromatica (Lam.) Mart.	24900
Araliaceae	*Schefflera morototoni* (Aubl.) Maguire, Steyerm. & Frodin	24880
Asteraceae	*Piptocarpha rotundifolia* (Less.) Baker	24896
Bignoniaceae	*Handroanthus ochraceus* (Cham.) Mattos	24886
	Tabebuia aurea (Manso) Benth. & Hook. f. ex S. Moore	24933
Caryocaraceae	*Caryocar brasiliense* Cambess.	24934
Chrysobalanaceae	*Hirtella hebeclada* Moric. ex DC.	24890
	Licania humilis Cham. & Schltdl.	24891
Clusiaceae	*Kielmeyera coriacea* Mart. & Zucc.	24930
Combretaceae	*Terminalia argentea* Mart.	24879
	Buchenavia tomentosa Eichler	24927
Connaraceae	*Connarus suberosus* Planch.	24893
	Rourea induta Planch.	24929
Dilleniaceae	*Curatella americana* L.	24926
Erythroxylaceae	*Erythroxylum anguifugum* Mart.	24887
	Erythroxylum deciduum A. St.-Hil.	24889
	Erythroxylum suberosum A. St.-Hil.	24888
	Erythroxylum tortuosum Mart.	24889
Fabaceae	*Anadenanthera peregrina var. falcata* (Benth.) Altschul	24905
	Andira cuyabensis Benth.	24902
	Bowdichia virgilioides Kunth	24906
	Copaifera langsdorffii Desf.	24922
	Dimorphandra mollis Benth.	24923
	Dipteryx alata Vogel	24925
	Diptychandra aurantiaca Tul.	24903
	Hymenaea stigonocarpa Mart. ex Hayne	24920
	Leptolobium dasycarpum Vogel	24924
	Stryphnodendron rotundifolium Mart.	24904
	Tachigali aurea Tul.	24921
Lauraceae	*Ocotea minarum* (Nees & Mart.) Mez	24881
Lythraceae	*Lafoensia pacari* A. St.-Hil.	24917
Malpighiaceae	*Byrsonima coccolobifolia* Kunth	24883
	Byrsonima verbascifolia (L.) DC.	24882
Malvaceae	*Eriotheca pubescens* (Mart. & Zucc.) Schott & Endl.	24877
	Luehea paniculata Mart. & Zucc.	24918
Melastomataceae	*Miconia albicans* (Sw.) Triana	24916
Myrtaceae	*Eugenia aurata* O. Berg	24908
	Eugenia egensis DC.	24909
	Myrcia guianensis (Aubl.) DC.	24907

Continues

Table 1. Continuation.

Family	Scientific name	Herbarium record
Nyctaginaceae	*Guapira opposita* (Vell.) Reitz.	24892
Opiliaceae	*Agonandra brasiliensis* Miers ex Benth. & Hook. f.	24895
Primulaceae	*Myrsine guianensis* Aubl. Kuntze	24919
Proteaceae	*Roupala montana* Aubl.	24911
Rubiaceae	*Rudgea viburnoides* (Cham.) Benth.	24884
Rutaceae	*Zanthoxylum rigidum* Humb. & Bonpl. ex Willd.	24899
Salicaceae	*Casearia sylvestris* Sw.	24912
Sapindaceae	*Matayba guianensis* Aubl.	24878
Sapotaceae	*Chrysophyllum marginatum* (Hook. & Arn.) Radlk.	24885
Styracaceae	*Styrax ferrugineus* Nees & Mart.	24915
Verbenaceae	*Aegiphila verticilata* Vell.	24901
Vochysiaceae	*Callisthene minor* Mart.	24874
	Qualea grandiflora Mart.	24910
	Qualea multiflora Mart.	24913
	Qualea parviflora Mart.	24914
	Salvertia convallariodora A. St.-Hil.	24875
	Vochysia thyrsoidea Pohl	24876

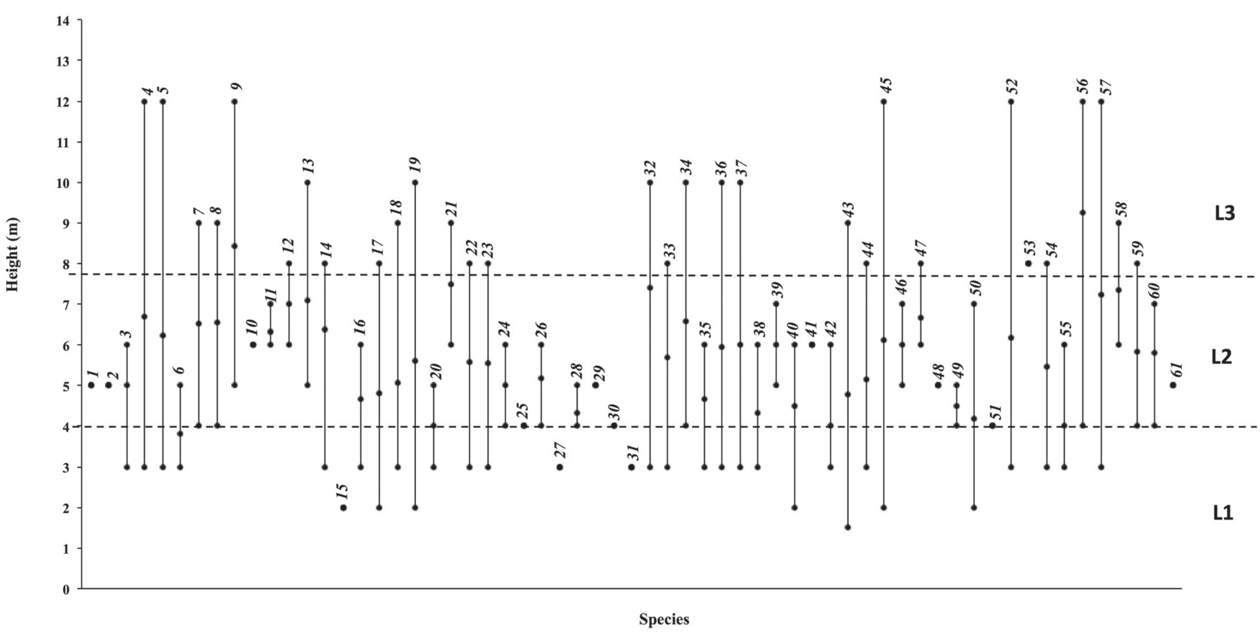

Figure 1. Distribution of the frequency of individuals, by height (m), in the plots in the tree community of an area of *cerradão* in the Private Nature Reserve operated by the Federal University of Mato Grosso do Sul, in the city of Campo Grande, Brazil. Lower layer (L1: 0-4.0 m), middle layer (L2: 4.01-7.88 m), and upper layer (L3: 7.89-12 m) identified by horizontal lines.

1 *L. dasycarpum*; 2 *A. klotzkiana*; 3 *A. brasiliensis*; 4 *A. peregrina*; 5 *A. cuyabensis*; 6 *A. coriaceae*; 7 *A. crassiflora*; 8 *A. fraxinifolium*; 9 *B. virgilioides*; 10 *B. tomentosa*; 11 *B. coccolobifolia*; 12 *B.verbasifolia*; 13 *C. minor*; 14 *C. brasiliense*; 15 *C. sylvestris*; 16 *C. marginatum*; 17 *C. suberosus*; 18 *C. langsdorffii*; 19 *C. americana*; 20 *D. mollis*; 21 *D. alata*; 22 *D. aurantiaca*; 23 *E. pubescens*; 24 *E. anguifugum*; 25 *E. deciduum;* 26 *E. suberosum;* 27 *E. tortuosum;* 28 *E. aurata;* 29 *E. egensis;* 30 *G. opposita.;* 31 *H. hebeclada;* 32 *H. stigonocarpa;* 33 *K. coriacea;* 34 *L. pacari;* 35 *L. humilis;* 36 *L. paniculata;* 37 *M. guianensis;* 38 *M. albicans;* 39 *M. urundeuva;* 40 *M. guianensis;* 41 *O. minarum;* 42 *P. rotundifolia;* 43 *Q. grandiflora;* 44 *Q. multiflora;* 45 *Q. parviflora;* 46 *R. guianensis;* 47 *R. montana;* 48 *R. induta;* 49 *R. viburnoides;* 50 *S. convallariodora;* 51 *S. morototoni;* 52 *S. obovatum;* 53 *S. ferrugineus;* 54 *Tab. aurea;* 55 *H. ochraceus;* 56 *T. aurea;* 57 *T. argentea;* 58 *T. pallida;* 59 *V. thyrsoidea;* 60 *X. aromatica;* 61 *Z. hasslerianum.*

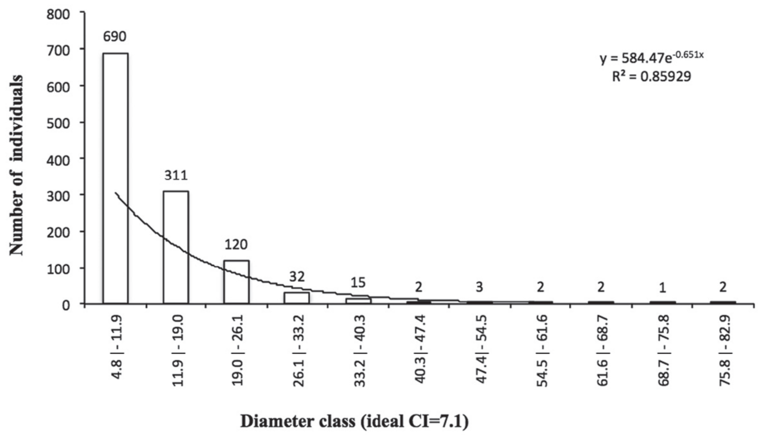

Figure 2. Distribution of the number of individuals by diameter class, with an ideal class interval (CI) of 7.1 cm, in plots within the tree community of an area of *cerradão* in the Private Nature Reserve operated by the Federal University of Mato Grosso do Sul, in the city of Campo Grande, Brazil.

Table 2. Phytosociological parameters of the species recorded for the *cerradão* of the Private Nature Reserve operated by the Federal University of Mato Grosso do Sul, in the city of Campo Grande, Brazil.

Scientific name	N	RD	RF	RDo	CV%	IV%
Qualea parviflora	291	24.66	4.17	24.78	24.72	17.87
Curatella americana	92	7.8	3.75	13.48	10.64	8.34
Qualea grandiflora	127	10.76	4.17	7.93	9.35	7.62
Terminalia argentea	112	9.49	4.17	8.63	9.06	7.43
Anadenanthera peregrina var. falcata	29	2.46	2.5	9.27	5.86	4.74
Astronium fraxinifolium	51	4.32	4.17	2.23	3.28	3.57
Salvertia convallariodora	24	2.03	4.17	1.49	1.76	2.56
Annona crassiflora	21	1.78	2.92	2.75	2.27	2.48
Callisthene minor	37	3.14	0.83	2.99	3.07	2.32
Tabebuia aurea	21	1.78	3.75	1	1.39	2.18
Vochysia thyrsoidea	17	1.44	2.5	1.6	1.52	1.85
Diptychandra aurantiaca	34	2.88	0.83	1.6	2.24	1.77
Xylopia aromatica	32	2.71	1.67	0.78	1.74	1.72
Bowdichia virgilioides	14	1.19	2.08	1.9	1.54	1.72
Matayba guianensis	22	1.86	2.5	0.63	1.25	1.67
Stryphnodendron rotundifolium	12	1.02	2.92	0.9	0.96	1.61
Andira cuyabensis	9	0.76	3.33	0.6	0.68	1.56
Connarus suberosus	17	1.44	2.5	0.66	1.05	1.53
Tachigali aurea	12	1.02	1.67	1.86	1.44	1.52
Lafoensia pacari	16	1.36	1.67	1.49	1.43	1.51
Luehea paniculata	19	1.61	2.08	0.58	1.1	1.42
Eriotheca pubescens	9	0.76	2.92	0.55	0.66	1.41

Continues

Table 2. Continuation.

Scientific name	N	RD	RF	RDo	CV%	IV%
Hymenaea stigonocarpa	5	0.42	0.83	2.94	1.68	1.4
Kielmeyera coriacea	16	1.36	1.67	1.01	1.18	1.34
Copaifera langsdorffii	17	1.44	0.83	1.47	1.46	1.25
Qualea multiflora	13	1.1	2.08	0.46	0.78	1.21
Caryocar brasiliense	8	0.68	2.08	0.83	0.76	1.2
Licania humilis	6	0.51	2.5	0.29	0.4	1.1
Miconia albicans	6	0.51	2.08	0.42	0.47	1.0
Myrcia guianensis	8	0.68	2.08	0.22	0.45	0.99
Erythroxylum suberosum	6	0.51	1.67	0.64	0.57	0.94
Roupala montana	6	0.51	1.25	0.4	0.46	0.72
Piptocarpha rotundifolia	10	0.85	0.83	0.33	0.59	0.67
Dipteryx alata	4	0.34	1.25	0.25	0.3	0.61
Annona coriacea	5	0.42	1.25	0.09	0.25	0.59
Rapanea guianensis	5	0.42	1.25	0.08	0.25	0.59
Myracrodruon urundeuva	4	0.34	1.25	0.06	0.2	0.55
Eugenia aurata	3	0.25	1.25	0.08	0.17	0.53
Chrysophyllum marginatum	3	0.25	1.25	0.06	0.16	0.52
Handroanthus ochraceus	3	0.25	1.25	0.05	0.15	0.52
Erythroxylum tortuosum	3	0.25	1.25	0.04	0.15	0.52
Rudgea viburnoides	2	0.17	0.83	0.44	0.31	0.48
Tapirira guianensis	3	0.25	0.83	0.31	0.28	0.46
Styrax ferrugineus	1	0.08	0.42	0.76	0.42	0.42
Byrsonima coccolobifolia	3	0.25	0.83	0.15	0.2	0.41
Dimorphandra mollis	3	0.25	0.83	0.11	0.18	0.4
Agonandra brasiliensis	3	0.25	0.83	0.05	0.15	0.38
Erythroxylum anguifugum	2	0.17	0.83	0.09	0.13	0.36
Byrsonima verbascifolia	2	0.17	0.42	0.33	0.25	0.3
Eugenia egensis	1	0.08	0.42	0.07	0.08	0.19
Rourea induta	1	0.08	0.42	0.05	0.07	0.18
Hirtella hebeclada	1	0.08	0.42	0.03	0.06	0.18
Buchenavia tomentosa	1	0.08	0.42	0.03	0.06	0.18
Zanthoxylum rigidum	1	0.08	0.42	0.01	0.05	0.17
Aegiphila verticilata	1	0.08	0.42	0.01	0.05	0.17
Casearia sylvestris	1	0.08	0.42	0.02	0.05	0.17
Erythroxylum deciduum	1	0.08	0.42	0.01	0.05	0.17
Guapira opposita	1	0.08	0.42	0.02	0.05	0.17
Leptolobium dasycarpum	1	0.08	0.42	0.02	0.05	0.17

Continues

Table 2. Continuation.

Scientific name	N	RD	RF	RDo	CV%	IV%
Schefflera morototoni	1	0.08	0.42	0.02	0.05	0.17
Ocotea minarum	1	0.08	0.42	0.02	0.05	0.17
Total	1180	100	100	100	100	100

N – number of individuals; RD – relative density; RF – relative frequency; RDo – relative dominance; CV% – cover value (proportional); IV% – importance value (proportional).

frequency (78%) in 376 areas within the *cerrado* biome. The most common species was *Q. grandiflora*, which has a wide distribution in the *cerrado*, occurring in 85% of the areas listed by those same authors (Ratter *et al.* 1996; 2003).

Some of the species recorded at our study site also occur in semi-deciduous forests, although with different IVs (Araújo & Haridasan 1997; Araújo *et al.* 1997): *Matayba guianensis*, *Rudgea viburnoides* (Cham.) Benth., *Tapirira guianensis* Aubl., *Copaifera langsdorffii* Desf., *Casearia sylvestris* Sw., and *Guapira opposita* (Vell.) Reitz. Oliveira-Filho & Ratter (1995) conducted a study of the forest formations of central Brazil and demonstrated the high exchange of species between the *cerradão* and other vegetation types. It is evident that the flora of the *cerradão* has an intermediate nature, with various aspects of savanna, forest and generalist species and therefore no indication of exclusive species.

Some species sampled in this study require additional comments. *Astronium fraxinifolium* Schott (with 51 individuals, IV% 4.74) is a common species in deciduous forests and was classified as slightly mesotrophic by Ratter *et al.* (2011); *Terminalia argentea* Mart. (112 individuals, IV% 7.62) belongs to the same category. In contrast, *Luehea paniculata* (19 individuals, IV% 1.42) was classified as strongly mesotrophic by those same authors, as was *Dipteryx alata* Vog. (4 individuals, IV% 0.61); whereas *Myracrodruon urundeuva* Allemão, frequently referred as the archetype calcicolous species, had 4 individuals and an IV% of 0.55. The occurrence of *Astronium fraxinifolium* and *Terminalia argentea,* which have a weak preference for mesotrophic soils, is not surprising; however, the other species are certainly unexpected. These anomalies have been recorded in other studies (Ratter, personal communication; Araújo *et al.* 2011; Neri *et al.* 2012), and it has been suggested that they occur on mesotrophic soils within dystrophic landscapes.

Edaphic factors

Also in the state of Mato Grosso do Sul, Ratter *et al.* (2003) found a higher frequency of *cerrado* areas on mesotrophic soils: 20 of the 33 areas analyzed. However, considering base saturation as an indicator of soil fertility, base saturation values < 50% being indicative of dystrophic soil (Embrapa 2006), the soil at our study site was dystrophic (base saturation, 9-29%). Aluminum saturation was 27-73%, representing the proportion of aluminum in relation to

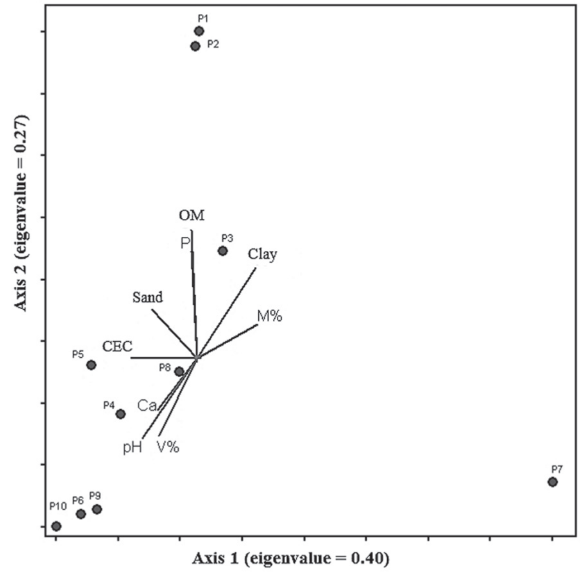

Figure 3. Canonical correspondence analysis of sampled plots and edaphic variables in the *cerradão* of the Private Nature Reserve operated by the Federal University of Mato Grosso do Sul, in the city of Campo Grande, Brazil. OM – organic matter; CEC –cation exchange capacity.

the sum of Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, and Al^{3} in the soil; higher aluminum saturation values indicate soils with less fertility and higher aluminum concentration.

In the CCA, the eigenvalues obtained for axes 1 and 2 were low (0.40 and 0.27; respectively), which implies low floristic turnover between the plots (ter Braak 1995). Axes 1 and 2, respectively, explained 26.8% and 18.1% of the variance ($P < 0.001$ for both), collectively accounting for 44.9% of the accumulated variance (Fig. 3). A considerable proportion (65.1%) was not explained by the predictors or was stochastic in nature (Hubbell, 2001). However, this high level of noise is common in vegetation studies and does not compromise the species-environment relationship (ter Braak 1988). In the diagram of the CCA (Fig. 3), axis 1 was efficient in segregating plots 3 and 7. Those plots had lower CEC values and higher aluminum saturation (Tab. 3), which might explain the differentiation in species composition. The fact that *Qualea parviflora* and *Qualea grandiflora* were the most abundant species in these plots corroborates those results, because species of the family Vochysiaceae are classified as

Table 3. Chemical and physical characteristics of the soil (depth, 0-20 cm) of the 10 plots evaluated in the *cerradão* of the Private Nature Reserve operated by the Federal University of Mato Grosso do Sul, in the city of Campo Grande, Brazil.

Plot	pH	P	K^+	Ca^{2+}	Mg^{2+}	Al^{3+}	$H^+ + Al^{3+}$	SB	CEC	OM	m	V	Clay	Silt	Sand
	H_2O	mg/dm³		cmol$_c$/dm³						mg/dm³	%		g/kg		
1	5.25	2	72	0.7	1.6	0.9	8.25	2.5	10.7	49.2	27	23	525	244	231
2	5.09	2	58	0.5	1.3	1.8	9.74	1.9	11.7	39.1	48	17	544	270	186
3	5.11	1	58	0.3	0.3	2	7.76	0.7	8.5	35.3	73	9	504	298	198
4	5.22	1	58	0.2	1.4	1.4	7.43	1.7	9.2	32.4	44	19	540	274	186
5	5.24	1	58	0.3	1.3	1.5	8.09	1.7	9.8	33.9	46	18	522	304	174
6	5.44	1	87	0.6	2.3	1.5	8.91	3.1	12	33.8	32	26	472	321	207
7	5.18	1	58	0.5	1.2	2	7.43	1.8	9.3	33.1	52	20	526	300	174
8	5.26	2	87	0.6	1.2	1.5	8.25	2.0	10.3	34.9	43	20	506	292	202
9	5.17	1	87	0.9	1.4	1.6	8.91	2.5	11.4	33.2	39	22	470	315	215
10	5.28	1	79	1.6	1.4	1.4	7.92	3.2	11.1	34.6	30	29	479	346	175

SB – sum of bases; CEC – cation exchange capacity; OM – organic matter; m – aluminum saturation; V – base saturation.

tolerant to and obligate accumulators of aluminum (Haridasan 2000). Axis 2 was efficient in segregating plots 6, 9 and 10, with more fertile soils, higher values of CEC and lower aluminum saturation. These three plots had species that co-occur in areas of *cerradão* with mesotrophic soils (Ratter *et al.* 1977), such as *Terminalia argentea*, *Luehea paniculata* and *Astronium fraxinifolium*. This demonstrates that soil fertility is a determinant of species composition in the *cerrado*.

In general, the soil of the plots had a clay texture (Tab. 3). According to Marimon-Junior & Haridasan (2005), clay soils under *cerradão* vegetation have a higher water-retention capacity and are therefore more capable to support the processes of biomass synthesis and maintain higher fertility, because water availability regulates the dynamics of nutrients in the soil, and consequently, their absorption by the plants. Ribeiro (1983), comparing *cerradão* and *cerrado típico*, found differences in the physical characteristics of the soil: that of the *cerradão* had higher porosity and higher water-retention capacity. This water regime, which is more favorable to the community than is that of the *cerrado típico*, might be an important factor restricting the distribution of *cerradão*. It should be noted that many soils in Brazil, although classified as clay soils, behave similarly to sandy soils in terms of CEC. This is explained by the fact that these clays are, predominantly, of low activity (kaolinite, iron and aluminum sesquioxides, etc.), and most latosols under *cerrado* are part of this category (Lopes & Guilherme 1992).

Conclusion

Our findings, together with those of the other studies discussed, support the hypothesis of our study, that there is a relationship between edaphic factors and species distribution in the *cerradão*. The clay soils favored the predominance of tree species, whereas the dystrophic soils, with considerable variation in aluminum saturation, influenced the floristic turnover between the plots.

Although the study site is classified as an area of dystrophic *cerradão*, we recorded species that are characteristic of mesotrophic soils and deciduous forests. The presence of those species might be related to the existence of areas with mesotrophic soils within a dystrophic landscape, as has previously been suggested.

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