VEGETATIONAL AND EDAPHIC ATTRIBUTES IN FOREST FORMATIONS IN THE CERRADO BIOME

Thalles Oliveira Martins[1*], Karoline Nascimento Siqueira[2], Carlos de Melo e Silva-Neto[3], Carolinne de Sousa Fonseca[2], Fábio Venturoli[2], Francine Neves Calil[2]

[1]Universidade Estadual de Goiás, Programa de Pós-Graduação em Recursos Naturais do Cerrado, Anápolis, Goiás, Brasil - thallesflorestal@hotmail.com.
[2]Universidade Federal de Goiás, Departamento de Engenharia Florestal – Escola de Agronomia, Goiânia, Goiás, Brasil
[3]Instituto Federal de Educação, Ciência e Tecnologia de Goiás, IFG, Cidade de Goiás, Goiás, Brasil

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Resumo

Atributos edáficos e vegetacionais em formações florestais no bioma do Cerrado do Brasil. O objetivo deste estudo foi verificar a existência de variações na composição e distribuição das espécies arbóreas devido às características químicas de um solo em uma floresta estacional semidecidual e cerradão. Foram instaladas aleatoriamente 40 parcelas de 400 m² na área, 25 parcelas distribuídas na floresta estacional semidecidual e 15 parcelas distribuídas no cerradão. Os indivíduos arbóreos com circunferência a altura do peito igual ou superior a 15,7cm (DAP ≥ 5 cm) e altura total foram mensurados na floresta estacional semidecídua. No cerradão todos os troncos de uma mesma árvore, assim como as suas bifurcações, a 0,30cm de circunferência do solo (CAS ≥ 5cm), foram medidos separadamente. A riqueza de espécie apresentou uma amplitude de 84 espécies para a floresta estacional semidecidual e 73 espécies para o cerradão. Já a densidade foi de 2227 ind.ha^{-1} para cerradão e 1699 ind.ha^{-1} para floresta estacional semidecidual. Diagramas de espécies e variáveis edáficas por meio da análise de correlação canônica (CCA) mostraram que espécies de floresta estacional semidecidual correlacionaram-se com maior quantidade de nutrientes (K^+ e P^-), saturação por bases (V%), saturação por alumínio (M%), capacidade de troca de cátions em pH 7 (CTC)T e manganês. As espécies de cerradão correlacionaram-se com maior quantidade de zinco (Zn^{2+}), ferro (Fe^{3+}) e pH em H_2O.
Palavras-chave: biodiversidade, nutrientes, florística.

Abstract

The objective of this study was to verify the existence of variations in the distribution of tree and composition species due to the chemical characteristics of the soil in a Semi-deciduous seasonal forest and Cerradão. 40 plots of 400 m² were installed randomly in the area, 25 plots distributed in the semi-deciduous seasonal forest and 15 plots distributed in the cerradão. The trees with circumference at breast height equal to or above 15.7cm (or diameter at breast height DBH ≥ 5cm) were sampled for the species of semi-deciduous seasonal forest. All individuals with a circumference of 0.30 of the soil (CAS) ≥ 5cm were sampled for the species of cerradão. The richness of species presented an amplitude of 84 species for the semi-deciduous seasonal forest and 73 species for the cerradão. The density was 2227 ind.ha^{-1} for cerradão and 1699 ind.ha^{-1} for semi-deciduous seasonal forest. Diagrams of species and edaphic variables by means of canonical correlation analysis (CCA) showed that semi-deciduous seasonal forest species correlated with a higher amount of nutrients (K^+ and P^-), base saturation (V%), saturation by aluminum (M%), cation exchange capacity at pH 7 ((CEC)T), and manganese. The cerradão species correlated with a higher amount of zinc (Zn^{2+}), iron (Fe^{3+}), and pH in H_2O.
Keywords: biodiversity, nutrients, floristic.

INTRODUCTION

The Brazilian Cerrado is considered the world's most biodiverse savannah and a global biodiversity hotspot (MYERS *et al*., 2000), having approximately 160.000 species, including fungi, flora, and fauna. However, more than 40% of the Cerrado biome has already been converted from natural lands to agricultural land because of poor conservation status, which is likely to worsen in the future (SILVA; BATES, 2002, SANO *et al.*, 2010). Cerrado biome is composed mainly of typical vegetation of savanna formation that appear in dystrophic and acid soils, and these soils are usually incapable of sustaining vegetation with a lot of biomass (MARIMON-JUNIOR; HARIDASAN, 2005).

The Cerrado forests are present in all the relief compartments, and the forests that occur along the water courses are called gallery forests, or ciliary forests, and the others are called seasonal forests because they have dynamics linked to climatic seasonality (PEREIRA *et al.*, 2011). Among the forest formations of the Cerrado,

the phytophysiognomy known as "Cerradão" is usually associated with interfluvial areas, in deep and well drained soils (MIGUEL *et al.*, 2016).

Understanding the relationships between floristics and environmental conditions has become a key instrument for conservation ecological and biodiversity studies information on the availability of soil nutrients in natural forests and on the nutritional requirements species of tree associated with the ecology of these native tree species helps to select species used in ecological restoration works (MICHAELIS *et al.*, 2016).

This formation occupies about 1% of the extension of the cerrado biome (MARIMON-JUNIOR; HARIDASAN, 2005), being this phytophysiognomy has a continuous canopy and tree cover that can reach up to 70%, with average tree height ranging from 8 to 15 (RIBEIRO; WALTER, 2008). In this study, we observed the presence of low-density epiphytes. The semideciduous seasonal forests occupy, approximately 15% of the Cerrado area (ca. 300,000 km²), and are among the most degraded and fragmented phytophysiognomies of this phytogeographic domain (PEREIRA *et al.*, 2011) and this total is equivalent to 35% estimated by (GÓES-FILHO; BRAGA, 1991), for the seasonal forests, in Brazil, based on the surveys of the Radam-Brazil Project.

However, it is that the soils where they are in ecosystems are of low fertility, dependent on the variability of existing soils, relief conditions and climatic interactions, thus affecting the mineral nutrition of the trees (JOHN *et al.*, 2007). The nutrient uptake capacity controlled by the nutritional status of the plant, which is linked with a plant genetic basis, is a nutrient resource in the soil, and also available in water (PALARDY, 2008). The plant and environment interactions are complex and specific for each phytophysiognomy of the present study, which initiates the study, are a prominent factor for the ecosystem. Looking for the nutritional information of the energy species and also as characteristics of the soil ecosystems, helpers in an attempt to defend the ecological causes of the environments, which suffer great anthropogenic disturbances.

The aim of this study was to verify the influence of soil chemical variables and their relationship with the arboreal community of a semi-deciduous seasonal Forest and cerradão in Biome Cerrado. This objective was completed by testing the hypotheses that accounts for differences in structure, diversity, and composition of flora that are influenced by edaphic conditions.

MATERIAL AND METHODS

The study was conducted in the legal reserve of the Capivara farm, in the National Center for Research on Rice and Beans - CNPAF unit of Embrapa, with approximately 335 hectares, located in the municipality of Santo Antônio de Goiás, Goiás, Brasil whose geographical coordinates are latitude 16°30'28.63"S, and longitude 49°17'10.37"W, with an altitude of 823 meters above sea level. The regional climate is characterized as tropical savanna climate (Aw), with rainy summers and dry winters (ALVARES *et al.*, 2014).

The forest inventory is composed of forty random sample units, having dimensions of 20mx20m (400m²). 25 plots were plotted in the semi-deciduous seasonal forest and 15 plots in the cerradão, totaling 1.6 ha of sample area. The trees with circumference at breast height equal to or above 15.7cm (or diameter at breast height DBH ≥ 5cm) were sampled for the species of semi-deciduous seasonal forest. All individuals with a circumference of 0.30 of the soil (CAS) ≥ 5cm were sampled for the species of cerradão. The total heights of all trees within the plots were obtained through an electronic clinometer. This was adopted by the angiosperm classification system of Angiosperm Phylogeny Group IV (APG IV, 2016).

The phytosociological parameters were calculated according to Mueller-Dombois and Ellenberg (2002) using Excel worksheet. Therefore, Absolute Sociological Position (PSAi) and Relative Sociological Position (PSRi) parameters were used according to Finol (1971) and the diversity indexes of Shannon-Wiener (H') and Pielou index (J') (Brower; Zar 1984) foram realizados com o sofware PAST.

In order to analyze the soil variables, soil samples were taken from each plot at each of the following points: in the soil layers (0-20cm depth), in the subsurface layer (30-50cm depth), at the four vertices, and at the center. They were then mixed and homogenized. Soil fertility analyses were carried out in the laboratory of Agro-environmental Analysis at the National Rice and Bean Research Center, according to Embrapa's procedure, obtaining pH in H_2O, P^-, K^+, Ca^{2+}, Mg^{2+}, Al^{3+}, potential acidity ($H^+ + Al^{3+}$), cation exchange capacity (CEC) at pH 7.0 (T), effective cation exchange capacity (t), base saturation index (V), sum of bases (SB), and organic matter (OM).

The matrix of abundance of the species was constructed for identifying patterns of distribution of the species as a function of the edaphic variables. Species with a density greater than ten individuals were used in the sample, totaling 49 species. Soil parameters pH in H_2O, Ca^{2+}, Mg^{2+}, Al^{3+}, $H^+ + Al^{3+}$, P^-, K^+, Cu^{2+}, Zn^{2+}, Fe^{3+}, Mn^{2+}, base addition, effective cation exchange capacity, cation exchange capacity at pH 7.0, base saturation, and aluminum saturation, made up the other matrix.

The canonical correspondence analysis (CCA) was used with the objective of identifying patterns of distribution for the species that reflected the environmental variations between the two phytophysiognomies (TER BRAAK,

1987). This technique analyzes the data of the species matrix together with data from the environmental variables matrix and produces diagrams that indicate the direction and magnitude of the changes of each variable in the ordering space.

RESULTS

In the semi-deciduous seasonal forest were sampled 1699 individuals, belonging to 84 species, 73 genera, and 42 botanical families (table 1). The families with showed high richness were Fabaceae (13), followed by Apocynaceae (4) and Myrtaceae (4). The tree density was 1699 ind.ha^{-1}, and the basal area was 39.0 m².ha^{-1}. The species with the highest values of importance (IVI), in decreasing order were: *Hymenaea courbaril* L. (7.38%), *Ixora brevifolia* Benth. (7.06%), *Aspidosperma polyneuron* Müll.Arg. (6.59%), *Aspidosperma discolor* A. DC. (6.45%), Dead Tress (6.0%), *Nectandra cuspidata* Nees (4.48%), *Micropholis venulosa* (Mart. & Eichler) Pierre (4.31%), *Tapirira guianensis* Aubl. (4.03%), *Emmotum nitens* (Benth.) Miers (3.15%), Schefflera morototoni (Aubl.) Maguire, Steyerm. & Frodin (3.0%), *Copaifera langsdorffii* Desf. (2.61%), *Callisthene major* Mart. (2.60%), *Miconia cuspidata* Naudin (2.33%). These 12 species represented 54% of total importance value index (IVI), 51.9% of relative density, 42.5% of relative frequency, and 67.3% of relative dominance. The Shannon diversity index was 3.55 nats.ind^{-1}, and the Pielou index (J') was 0.83.

Table 1. Phytosociological and structural information on the fragments of the semi-deciduous seasonal forest plots at the national center for research of rice and beans, in Santo Antônio de Goiás, Goiás, Brazil.
Tabela 1. Fitossociologia e informações estruturais no fragmento das parcelas na floresta estacional semidecidua no Centro Nacional de Pesquisa em Arroz e Feijão, em Santo Antônio de Goiás, Goiás, Brasil.

Species (FE´s)	**Vertical structure**		**Horizontal structure**	
	PSAi*	PSRi**	NI*	IV**
Hymenaea courbaril L.	32.8	3.6	67.0	7.3
Ixora brevifolia Benth.	131.0	14.3	230.0	7.0
Aspidosperma polyneuron Müll.Arg.	51.9	5.7	104.0	6.5
Aspidosperma discolor A.DC.	31.7	3.5	67.0	6.4
Dead trees	53.4	5.8	138.0	6.0
Nectandra cuspidata Nees	49.8	5.5	99.0	4.4
Micropholis venulosa (Mart)	65.2	7.1	106.0	4.3
Tapirira guianensis Aubl.	27.3	3.0	57.0	4.0
Emmotum nitens (Benth.) Miers	35.0	3.8	61.0	3.1
Schefflera morototoni (Aubl.)	6.2	0.7	22.0	3.0
Copaifera langsdorffii Desf.	16.5	1.8	34.0	2.6
Callisthene major Mart.	18.9	2.1	35.0	2.6
Miconia cuspidata Naudin	29.3	3.2	56.0	2.3
Hirtella glandulosa Spreng.	27.2	3.0	46.0	2.2
Protium heptaphyllum (Aubl.)	24.2	2.6	41.0	1.9
Myracrodruon urundeuva Allemão	20.9	2.3	35.0	1.8
Cheiloclinium cognatum (Miers)	22.2	2.4	35.0	1.6
Ocotea aciphylla (Nees & Mart.)	14.9	1.6	25.0	1.6
Inga vera subsp. Affinis (DC.)	15.2	1.7	27.0	1.5
Apuleia leiocarpa (Vogel)	3.8	0.4	12.0	1.5
Other species	236.50	25	402	5.9
Total	914.9	100	1699	100
Number of species		84		
Total basal area (m^2 ha^{-1})		39,1		
Shannon Diversity Index (H')		3,55		
Pielou Equability Index (J)		0,83		

*Absolute Sociological Position (PSAi); **Relative Sociological Position (PSRi); *NI = number of individuals per hectare; **IV = Importance Value (%).
* Posição Sociológica Absoluta (PSAi); ** Posição Sociológica Relativa (PSRi); * NI = número de individuos por hectare; ** IV = Valor de importancia (%).

In the cerradão a total of 1.336 individuals belonging to 73 tree species, distributed in 58 genera and 34 botanical families were sampled in cerradão. Fabaceae was the most abundant family with 14 species and 13 genera, followed by the family Vochysiaceae with seven species and three genera. Apocynaceae presented five species and two genera, Anacardiaceae presented three species and three genera, Rubiaceae presented three species and three genera, Sapotaceae presented three species and two genera, and Annonaceae presented two species and two genera.

The density was 2227 trees per hectare and basal area (absolute dominance) was 30.37 m^2/ha^{-1}. The species with the highest values of importance value in percentage (IVI%) were *Emmotum nitens* (Benth.) Miers (9.8%), *Tachigali subvelutina* (Benth.) Oliveira-Filho (8.5%), *Hirtella glandulosa* Spreng. (7.9%), *Tapirira guianensis* Aubl. (5.5%), *Xylopia aromatica* (Lam.) Mart. (5.6%), *Callisthene major* Mart. (5.8%), *Virola sebifera* Aubl. (5.5%), *Alibertia edulis* (Rich.) A.Rich. (3.4%), *Qualea grandiflora* Mart. (2.2%), *Ouratea hexasperma* (A.St.-Hil.) Baill. (3.1%), *Syagrus flexuosa* (Mart.) Becc. (2.0%), *Kielmeyera coriacea* Mart. & Zucc. (2.4%). These twelve species represented 58.7% of the total IVI, 61.74% of the total density, and 71.85% of the relative dominance. The Shannon diversity index was 3.35 $nats.ind^{-1}$ and the Pielou (J') equability was 0.77, which suggests high species diversity with relative uniformity in the size of the respective populations. The structural data of the study plots (Table 2) show that the areas exhibit high floristic diversity, given the high values of the Shannon Diversity and Pielou Equitability Indices.

Table 2. Phytosociological and structural information on the fragments of the cerradão plots at the national center for research of rice and beans, in Santo Antônio de Goiás, Goiás, Brasil.

Tabela 2. Fitossociologia e informações estruturais no fragmento das parcelas do cerradão no Centro Nacional de Pesquisa em Arroz e Feijão, em Santo Antônio de Goiás, Goiás, Brasil.

Species (CE)	**Vertical structure**		**Horizontal structure**	
	PSAi*	**PSRi****	**NI***	**IV****
Emmotum nitens (Benth.) Miers	69.7	10.6	218.3	10.5
Tachigali subvelutina (Benth.)	51.2	7.7	190.0	9.7
Dead trees	66.3	10.0	241.6	8.2
Hirtella glandulosa Spreng.	51.8	7.8	175.0	7.2
Tapirira guianensis Aubl.	30.8	4.6	123.3	6.4
Xylopia aromatica (Lam.) Mart.	39.3	5.9	125.0	4.9
Callisthene major Mart.	41.2	6.2	126.6	4.3
Virola sebifera Aubl.	43.4	6.6	121.6	4.0
Alibertia edulis (Rich.) A.Rich.	24.6	3.7	76.6	2.7
Qualea grandiflora Mart.	16.8	2.5	50.0	2.4
Ouratea hexasperma (A. St.-Hil.)	5.7	0.8	70.0	2.1
Syagrus flexuosa (Mart.) Becc.	4.7	0.7	45.0	2.0
Kielmeyera coriacea Mart. & Zucce	9.5	1.4	53.3	2.0
Roupala montana Aubl.	15.6	2.3	45.0	1.9
Matayba guianensis Aubl.	10.2	1.5	41.6	1.9
Bowdichia virgilioides Kunth.	10.8	1.6	30.0	1.6
Magonia pubescens A.St.-Hil.	12.5	1.9	36.6	1.6
Qualea parviflora Mart.	9.8	1.5	30.0	1.4
Vochysia rufa Mart.	8.0	1.2	21.6	1.1
Copaifera langsdorffii Desf.	8.7	1.3	26.6	1.1
Other species	116.4	4.09	378	4.26
Total	**657.7**	**100**	**2227**	**100**
Number of species		73,0		
Total basal area ($m^2.ha^{-1}$)		30,3		
Shannon Diversity Index (H')		3,35		
Pielou Equability Index (J)		0,77		

*Absolute Sociological Position (PSAi); **Relative Sociological Position (PSRi); *NI = number of individuals per hectare; **IV = Importance Value (%).

* Posição Sociológica Absoluta (PSAi); ** Posição Sociológica Relativa (PSRi); * NI = número de individuos por hectare; ** IV = Valor de importancia (%).

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In the canonical correlation analysis (CCA) of the edaphic variables of the superficial layer (0-20cm) (Figure 2), species, and edaphic variables, the eigenvalues were 0.44 for the first ordering axis and 0.06 for the second. This indicated the existence of strong gradients with ecological significance (>0.3) between species and environmental variables on the first axis. These axes accounted for 24.9% and 28.5% of the cumulative variance of the species, suggesting the existence of interference that was not explained by the variables included in the analysis.

The correlation coefficients of the edaphic variables with the two first axes of the CCA indicate that the variables most strongly correlated with the first ordering axis were the pH in H_2O (0.82), CEC(T) (-0.70), Mn^{2+} (-0.69), $H^{+}+Al^{3+}$ (-0.62), K^{+} (-0.32). The variables most correlated with the second axis were Fe^{3+} (-0.63), K^{+} (0.43), and Zn^{2+} (-0.40). The weighted correlations also showed strong interrelations between the eight edaphic variables, highlighting the negative correlations between pH in H_2O and $H^{+}+Al^{3+}$ (-0.63), pH in H_2O and CEC (T) (-0.57), pH in H_2O and Mn^{2+} (-0.49), Fe^{3+} and Mn^{2+} (-0.46), Fe^{3+} and CEC(T) (-0.33); and positive correlations $H^{+}+Al^{3+}$ and CTC(T) (0.90), P^{-} and CEC(T) (0.33), K^{+} and Mn^{2+} (0.61), K^{+} and CEC(T) (0.40), Zn^{2+} and Fe^{3+} (0.47), Mn^{2+} and CEC(T) (0.59).

The species management by the CCA led to the distinction of environmental-species sets for the forest formation analyzed in this study. On the negative side, the first axis of ordering included the semi-deciduous seasonal forest species, which are correlated with a higher potential acidity ($H^{+}+Al^{3+}$), greater CEC(T), and contents of Mn^{2+}, P^{-}, and K^{+}. The inverse trends are on the positive side of this axis with the group of CE species in this analysis that present a relation with a higher pH in H_2O, and contents of Zn^{2+} and Fe^{3+}.

On the positive side, the second axis of the cluster has the semi-deciduous seasonal forest species that correlate with a higher cation exchange capacity at pH 7 CEC (T), higher levels of K^{+}, P^{-} and Mn^{2+}, and negative with $H^{+}+Al^{3+}$. Inversely the CE species had a pH in H_2O higher than that of FE and higher levels of Zn^{2+} and Fe^{3+}.

The ordering of the species with the edaphic variables revealed the complexity of the two phytophysiognomies and confirmed the distinction between floristic and environmental groups. The species (*R. montana*), (*K. coriaceae*), (*M. pubescens*), (*Q. parviflora*), (*O. hexasperma*), (*S. flexuosa*), (*M. acutifolium*), (*X. aromatica*), were only present or were more abundant in the phytophysiognomy of the cerradão. They were correlated on the positive side of the two axes with the pH in H_2O.

These were the sampled species that were only present or were more abundant in the phytophysiology of the cerradão: (*V. rufa)*, (*T. subvelutina*), (*B. virgilioides*), (*Q. grandiflora*), (*V. sebifera*), (*P. emarginatus)*, (*V. haenkeana*), and (*D. burchellii*), which are located on the positive side of axis 1 and negative on axis 2, in addition to being correlated with higher iron contents (Fe^{2+}) and zinc (Zn^{2+}).

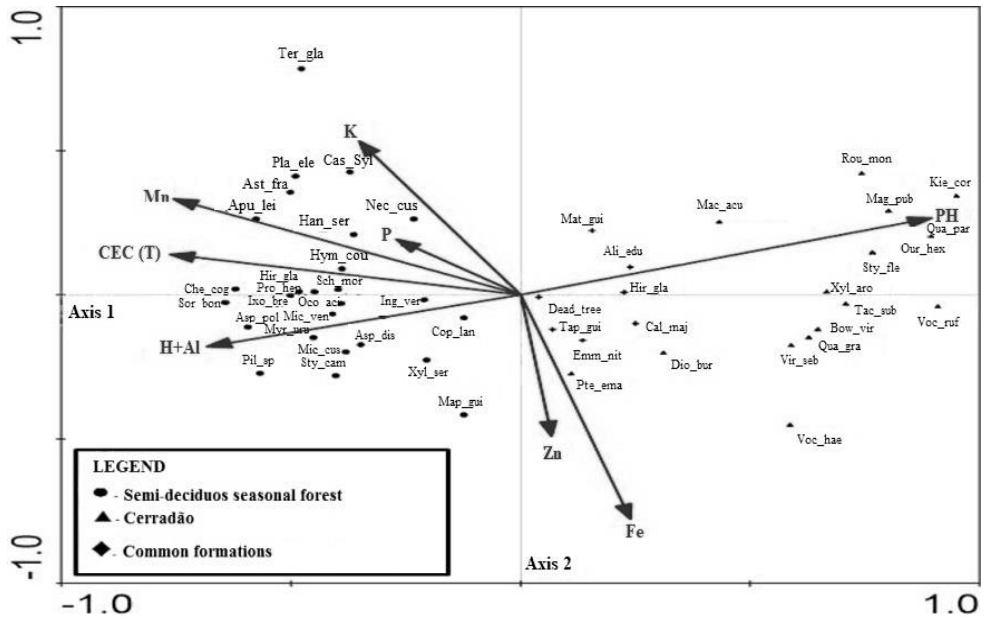

Figure 1. Ordering diagram produced by the canonical correlation analysis for the superficial layer (0-20cm), showing the distribution in the first two axes of the Semi-deciduous seasonal forest and cerradão plots with abundance of the species and the edaphic variables at the National Center for Research of Rice and Beans, in Santo Antônio de Goiás, Goiás, Brazil.

Figura 1. Diagrama de ordenação produzido pela análise de correlação canônica para a camada superficial (0-20cm), mostrando a distribuição nos primeiros dois eixos nas parcelas de floresta estacional semidecidua e cerradão com a abundância de espécies e variáveis edáficas no Centro Nacional de Pesquisa de Arroz e Feijão, em Santo Antônio de Goiás, Goiás, Brasil.

The species *T. glabrescens, C. sylvestris, P. elegans, A. fraxinifolium, A. leiocarpa, H. serratifolius, N. cuspidata, H. courbaril, H. gracilipes, S. morototoni, P. heptaphyllum, C. cognatum*, species that were exclusive or more abundant in the semi-deciduous seasonal forest plots. They are also correlated with higher levels of potassium (K^+), manganese (Mn^{2+}), phosphorus (P^-), and a higher cation exchange capacity at pH 7.

On the negative side of the two axes, the species: *I. brevifolia, A. polyneuron, A. discolor, M. venulosa, I. vera, O. aciphylla, M. urundeuva, S. bonplandii, Pilocarpus sp., C. langsdorffii, M. cuspidata, S. camporum, X. sericea*, and *Maprounea guianensis* Aubl., were exclusive, or more abundant, in the plots of Semi-deciduous seasonal forest with higher levels of potassium (K^+), phosphorus (P^-), manganese (Mn^{2+}), and cation exchange capacity at pH 7.

The ordering of species data with edaphic variables in the subsurface layer (30-50 cm) by canonical correlation analysis (CCA) showed eigenvalues of the order of 0.42 for the first ordering axis and of 0.05 for the second axis. This showed that the first axis suggests a larger environmental gradient with changes between species and samples. These axes accounted for only 24.2% and 27.1% of the cumulative variance of the species, indicating a large amount of difference not explained by the soil variables included in the analysis.

The Monte Carlo permutation test revealed significant correlations between species abundance and environmental variables (P = 0.0001 for the first axis), corroborating the rate of variation explained by such variables. This indicated the significance of the correlations analyzed and the existence of differences between the two studied phytophysiomies (Semi-deciduous seasonal forest and Cerradão).

The correlation coefficients of the environmental variables with the first two axes of the CCA (figure 3) indicate that the variables most strongly correlated with the first ordering axis were pH in H_2O (0.81), H^++Al^{3+} (-0.58), K^+ (-0.59), Mn^{2+} (-0.70), and CEC(T) (-0.67). Those that are most correlated with the second axis outside were K^+ (-0.59) and V% (0.69).

The weighted correlations also showed strong interrelationships among the six variables, especially the negative correlations between pH in H_2O and H^++Al^{3+} (-0.70), K^+ and pH in H_2O (-0.48), Mn^{2+} and pH in H_2O (-0.48), and CEC (T) in pH and H_2O (-0.57). The positive correlations were between H^++Al^{3+} and CEC (T) (0.81), K^+ and Mn^{2+} (0.74), K^+ and CEC (T) (0.59), K^+ and V% (0.71), Mn^{2+} and CEC (T) (0.66), Mn^{2+} and V% (0.79), and V% and CEC (T) (0.60).

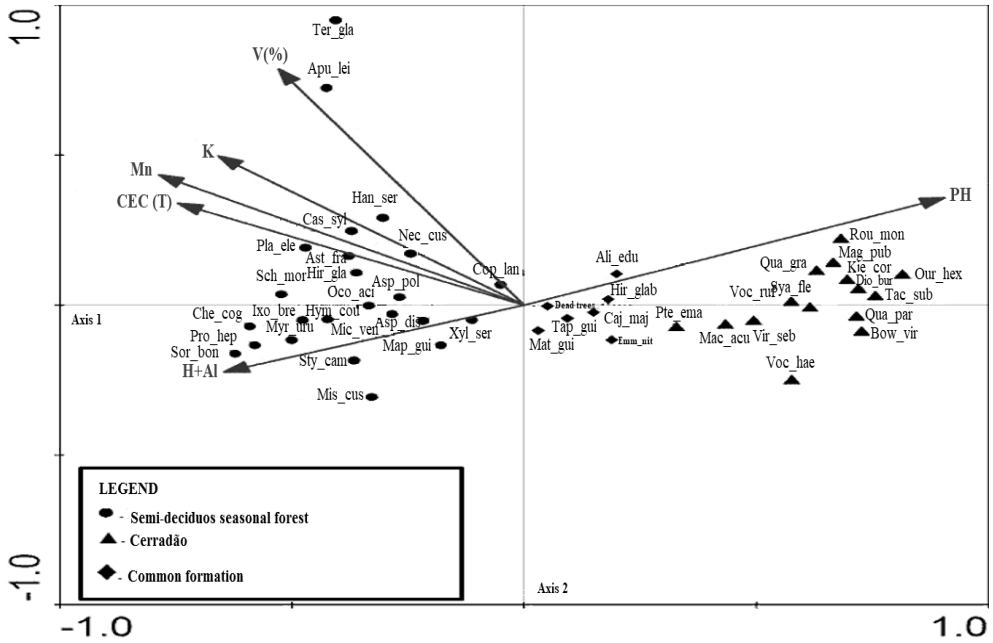

Figure 2. Ordering diagram produced by the canonical variate analysis, in the superficial layer (30-50cm) showing the distribution in the first two axes of the semi-deciduous seasonal forest and cerradão plots with abundance of species and edaphic variables in the National Rice and Bean Research Center, in Santo Antônio de Goiás, Goiás, Brazil.

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Figura 2. Diagrama de ordenação produzido pela análise de correlação canônica para a camada superficial (30-50cm), mostrando a distribuição nos primeiros dois eixos nas parcelas de floresta estacional semidecidua e cerradão com a abundância de espécies e variáveis edáficas no Centro Nacional de Pesquisa de Arroz e Feijão, em Santo Antônio de Goiás, Goiás, Brasil.

As can be seen in figure 3, the ordering of the species led to the distinction of two floristic-environment sets in the samples considered. On the negative side, the first axis of ordination grouped the species that are correlated with a higher saturation of bases (V%), higher levels of potassium (K^+), manganese (Mn^{2+}), cation exchange capacity at pH 7 (CEC T), potential acidity (H^++Al^{3+}), and individuals belonging to the Semi-deciduous seasonal forest. On the positive side, some species belonging to the cerradão correlated with the pH in H_2O.

The second grouping of the cerradão species on the positive side correlated with pH in H_2O. Most of the semi-deciduous seasonal forest species correlated with higher base saturation (V%), higher potassium (K^+), manganese (Mn^{2+}), cation exchange capacity at pH 7 (CEC T), and the negative side at potential acidity (H^++Al^{3+}) grouped with some species of Semi-deciduous seasonal forest.

The ordering of the species with the edaphic variables revealed the complexity of the two phytophysiognomies and confirmed the distinction between floristic and environmental groups. In the ordering diagram produced by the CCA (Figure 3), species: *R. montana*, *K. coriacea*, *M. pubescens*, *Q. grandiflora*, *O. hexasperma*, *S. flexuosa*, *V. rufa*, *D. burchellii*, *T. subvelutina*, which are present and abundant in the Cerradão area, are on the positive side of the two axes and strongly correlated with the pH variable in H_2O.

Individuals of the species *Xylopia aromatica* (Lam.) Mart., *Bowdichia virgilioides* Kunth, *Machaerium acutifolium* Vogel, *Virola sebifera* Aubl., *Pterodon emarginatus* Vogel, *Vochysia haenkeana* Mart and *Qualea parviflora* Mart. that were found to be more abundant in Cerradão phytophysiognomy and also located on the positive side of the first axis and negative side of the second axis, are not strongly correlated with the variables analyzed in this layer of soil.

The most common species sampled in the Semi-deciduous seasonal forest: *Terminalia glabrescens* Mart., *Apuleia leiocarpa* (Vogel) J.F.Macbr., *Handroanthus serratifolius* (Vahl) S.Grose, *Casearia sylvestris* Sw., *Platypodium elegans* Vogel, *Nectandra cuspidata* Nees, *Astronium fraxinifolium* Schott, *Hirtella gracilipes* (Hook.f.) Prance, *Schefflera morototoni Aubl.*, *Hymenaea courbaril L.*, *Pilocarpus sp*, *Copaifera langsdorffii* Desf., *Aspidosperma polyneuron* Müll.Arg grouped both with base saturation (V%), potassium (K^+), manganese (Mn^{2+}), and cation exchange capacity at pH 7 (CEC T) respectively, on the first axis on the negative side.

Individuals occurring widely in the Semi-deciduous seasonal forest, such as: *Ixora brevifolia* Benth., *Aspidosperma discolor* A.DC., *Micropholis venulosa* (Mart. & Eichler) Pierre, *Inga vera* Willd., *Cheiloclinium cognatum* (Miers) A.C.Sm., *Ocotea aciphylla* (Nees & Mart.) Mez, *Myracrodruon urundeuva* Allemão, *Sorocea bonplandii* (Baill.), *Protium heptaphyllum* (Aubl.) Marchand, *Miconia cuspidata* Naudin, *Styrax camporum* Pohl, *Xylopia sericea* A.St.-Hil., *Maprounea guianensis* Aubl, are grouped on the negative side of the two axes with the variable soil potential acidity (H^++Al^{3+}).

DISCUSSION

The total number of species sampled in the Semi-deciduous seasonal forest (84) was equivalent to the number of tree species listed by Haidar *et al.* 2013. In the referenced study of seasonal forests and ecotone areas in the state of Tocantins, they reported a wide variation (33 to 243 species). Pereira *et al.* (2016) also observed a total of 97 species in a study about the effect of fire on the structure of a semi-deciduous seasonal forest in the southern center of the state of Goiás.

The species sampled also corroborate the work of Haidar *et al.* (2005) in Semi-deciduous seasonal forests in the state of Goiás: *Aegiphila sellowiana* Cham, *Cardiopetalum calophyllum* Schltdl, *Cheiloclinium cognatum* (Miers) A.C.Sm, *Emmotum nitens* (Benth.) Miers, *Hirtella gracilipes* (Hook.f.) Prance, *Hirtella glandulosa* Spreng., *Inga vera* Willd., *Myracrodruon urundeuva* Allemão, *Protium heptaphyllum* (Aubl.) Marchand, *Tapirira guianensis* Aubl.

The absolute density 1.699 ind.ha^{-1} and the basal area of 39.0m².ha^{-1}, in a study of seasonal forests and ecotone areas in the state of Tocantins, Haidar *et al.* (2013) observed densities ranging from 486 to 1179 ind.ha^{-1}, while the basal area ranged from 14.04 to 37.49 m².ha^{-1} in a compilation of data from 22 areas (samples) by means of the inventory of 477 parcels of 400 m². The alpha diversity calculated through the Shannon index was high. In the present study, it was (H'=3.55 nats.ind^{-1}). The equability of the Pielou index for (J') of 0.83 expresses higher variation observed by Ferreira *et al.* (2017) of 0.67 for Cerrado strictu sensu, 0.81 for Riparian forest, 0.82 for the Cerradão and 0.75 for Decidous forest sampled in the Paracatu River basin, MG.

In the cerradão, the diversity of the 73 species sampled is less than that observed by Miguel *et al.* (2016) in the area of the cerradão in Palmas, Tocantins, where 82 species were found. The species of the genus *Qualea* spp., did not present marked dominance in this study, but in the literature, it is among the taxa that express the highest percentage of tree biomass and wide distribution in Brazilian savannas (OTONI *et al.*, 2013).

The alpha diversity calculated through the Shannon index was high. In the present study, it was H'=3.35 nats.ind^{-1}, which is within the range of values observed by Salis *et al.* (2006) that observed 2.90 to 3.36 for areas of the Cerradão in the state of Mato Grosso do Sul. The Pielou equability (J') of 0.77 also indicated an unequal distribution of individuals by species, indicating a high abundance of five species: *E. nitens, T. subvelutina, H. glandulosa, T. guianensis, X. aromatica*.

The ordering diagram produced by CCA correlated with the species cited in the results with the soil that had the highest amount of nutrients and aluminum saturation (m%), which is in accordance with other studies of distribution of species in FE´s (TEIXEIRA; ASSIS, 2009). The cerradão species mentioned in the results are correlated with low natural fertility with higher levels of iron (Fe^{3+}) and zinc (Zn^{2+}) (RODRIGUES, 2013). According to Assis *et al.* (2011), the soils of the dystrophic cerradão present pH and minerals similar to savanna formations of the Cerrado biome, notably higher clay content and, thus, indicating a higher retention of water. These patterns are different from those observed in this study as the cerradão has lesser amounts of bases (Ca^{2+}, Mg^{2+}, K^{+}) and presented pH in H_2O at an average of 5.5, which is considered good.

In accordance to Otoni *et al.* (2013), analyses on phytosociological structure and environmental relationships in a remnant of the cerradão in Curvelo, Minas Gerais, the variables that presented the greatest internal correlation with the axes of order produced by the CCA were calcium (Ca^{2+}) and phosphorous (P^{-}) in the 0 to 20cm layer, as well as the potassium (K^{+}) and aluminum saturation (m%) in the 20 to 40 cm layer of soil. Although the soil of the plots presented low fertility because base saturation (V%) was lower than 50% (dystrophic), there were high values of organic matter observed, as well as high values of aluminum (Al^{3+}) and acidity. However, we reinforce the need to understand the vegetation patterns of the Cerrado on a macroecological scale, seeking to gather specific studies for an overview of the Biome, but respecting important localities such as soil, relief, climate and watershed unit. This understanding on a macro scale may contribute to local conservation strategies that affect the conversion of the entire biome.

CONCLUSION

- The two contiguous forest formations differ in relation to soil fertility, species composition, diversity, and structure, forming different group between the two phytophysiognomies.
- In the Semideciduous Seasonal Forest, the index's diversity, richness, and abundance of species were superior to the Cerradão.
- The hypothesis that the two forest formations of the Cerrado Biome, which are established in an environment that has common characteristics and also present variations in the composition and distribution of species abundances, is partially related to the differentiation in the edaphic variables.

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