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Effect of a protected area on the tree structure of the Cerrado

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A B S T R A C T

The Cerrado Biome has been increasingly affected by the advance of agribusiness, and conservation units have served as alternatives for the preservation of species. The objective of this work was to characterize the structuring of the Cerrado vegetation by comparing inside and outside the conservation unit of the Silvânia National Forest. 50 plots were demarcated, 15 (50 m x 20 m = 1000 m²) of which were inside and 35 1 (0 m x 10 m = 100 m²) outside the conservation unit. Litter biomass and soil fertility were quantified. In this study was found a richness of 172 species, 51 families and 118 genera. In Cerrado inside (CSR_IN) abundance is 0.137 ind.ha^{-1} and Cerrado outside (CSR_OUT) 0.214 ind.ha^{-1}. The CSR_IN richness is 0.033 ind.ha^{-1} and CSR_OUT 0.115 ind.ha^{-1}. Already the abundance and richness of Seasonal Forest areas inside and outside the conservation unit were similar. Cerrado areas showed the most acidy soil and smaller fertility and litter, not differing in relation to the conservation unit. Currently, the Silvânia NF is almost an isolated fragment, even presenting aspects of richness and abundance of trees of the same size or even smaller than areas outside the unit itself.

Keywords: brazilian savanna, forest structure, native species, soil, species richness

Efeito de uma área protegida na estrutura arbórea do Cerrado

R E S U M O

O Bioma Cerrado tem sido cada vez mais afetado pelo avanço do agronegócio, e as unidades de conservação (UC) têm servido como alternativas para a preservação das espécies. O objetivo deste trabalho foi caracterizar a estrutura da vegetação do Cerrado comparando áreas dentro e fora da UC Floresta Nacional da Silvânia. Foram demarcadas 50 parcelas, sendo 15 (50 m x 20 m = 1000 m²) dentro e 351 (0 m x 10 m = 100 m²) fora da unidade de conservação. A biomassa da serapilheira e a fertilidade do solo também foram quantificadas. Neste estudo foi encontrada uma riqueza de 172 espécies, 51 famílias e 118 gêneros. No Cerrado interno (CSR_IN) a abundância é de 0,137 ind.ha^{-1} e no Cerrado externo (CSR_OUT) 0,214 ind.ha^{-1}. A riqueza de CSR_IN é 0,033 ind.ha^{-1} e CSR_OUT 0,115 ind.ha^{-1}. Já a abundância e riqueza de áreas de Floresta Estacional dentro e fora da unidade de conservação foram semelhantes. As áreas de cerrado apresentaram os solos mais ácidos e com menor fertilidade e serapilheira, não diferindo em relação à unidade de conservação. Atualmente, a Floresta Nacional de Silvânia é quase um fragmento isolado, mesmo apresentando aspectos de riqueza e abundância de árvores do mesmo porte ou até menores do que áreas externas à própria unidade.

Palavras-chave: savana brasileira, estrutura florestal, espécies nativas, solo, riqueza de espécies.

Introduction

The high biodiversity and quantity of endemic species in the biome, in addition to its destruction, has made Cerrado to be a global hotspot for the conservation of biodiversity (Ferreira et al., 2017). It has more than 6,600 species of plants, of which about 40% of tree species are endemic (Ibram, 2018). Even with such important roles, the Cerrado has not received the deserved attention with regard to an adequate conservation policy. The advance of agriculture in the second half of the 20th century consolidated the Cerrado as an agricultural frontier with the installation of large monocultural systems, and these have accelerated the process of landscape degradation, as well as the extinction of several species (Santos et al., 2021a;).

According to 2018 and 2019 data from the National Institute for Space Research (INPE), 6483.4km2 were devastated in the Cerrado, including about 517 km2 in Conservation Units

(CU). In the previous year, there was deforestation of 449.7 km2 of CUs, that is, an increase of 15% (INPE, 2019). The biome has about 8% of its territory legally protected by CUs, and less than 3% of these are fully protected conservation units (MMA, 2020; Santos et al., 2020). In Goiás, the Cerrado stands out for its rich biodiversity and numerous endemic species (Zappi et al., 2015; Martins et al., 2021). More than 82% of the remaining Cerrado areas in Goiás are smaller than 1 ha, indicating the high degree of biome fragmentation. The Federal and State CUs within Goiás total 1,986,035.475ha, which corresponds to only 5.84% of protected areas in Goiás. One of these units is the Silvânia National Forest (NF), and it pertains to the municipality of Goiás, located in the eastern region of the state, 88 Km from the capital Goiânia (MMA, 2020).

Despite all these reasons, the Silvania NF still lacks studies on the importance of protecting and conserving (rational and sustainable use) the ecosystems that exist there, reinforcing the importance of NF environmental valuation. The forest inventory provides necessary subsidies for identifying tree flora characteristics, which are fundamental for development of a plan for use of its natural potential, protection and conservation of the environment, and serve as a basis for studies in different areas of the knowledge (Santos et al., 2021b). With this, we hypothesize that the composition and structure of the Cerrado vegetation will be different within the Silvânia National Forest conservation unit in relation to the surroundings. It is expected that both in composition and vegetation structure, the characteristics within the conservation unit show the greater conservation of this area.

Thus, in view of the above, the objective of this work was to characterize the structuring of the Cerrado vegetation in the Silvânia National Forest conservation unit and surroundings, in addition to comparing its soil attributes.

Methods

Study area

The study was conducted in the National Forest of Silvânia and in adjacent areas located in the municipality of Silvânia, GO. There was approximately 486.37 ha, whose geographical coordinates are: Latitude 16º38'30.0” S - Longitude 48º39'02.5” W with an altitude of 877 m above sea level. According to the Köppen classification, the regional climate is Aw, and it is characterized by two well-defined seasons: one hot and rainy from October to April; and the other cold and dry from May to September. Soils in the interior of the NF are predominantly of the type Acrossic Red Oxisol with distinct portions of Dystrophic Oxisol. In the municipality of Silvânia, Red-Yellow Oxisols, Red Oxisols, and restricted areas of Plintossolos predominate, all of these highly weathered soils and with clay contents are typically higher than 80% (Embrapa, 2007).

Forest inventory

For plots within the conservation unit, considered permanent plots, the dimensions were 50m x 20m (1000m²), and there was a total of 15 plots. In the remaining plots (35 plots) the 10m x 10m (100m²) dimensions were used. In the Semideciduous Seasonal Forest plots (and other forest plots of the Cerrado), arboreal individuals with diameter at breast height equal to or greater than 5 cm (DBH $\geq$ 5 cm) and total height were identified with their respective scientific names and measured with a tape measure (Martins et al., 2016; 2019). In the Cerrado (and other Cerrado plots), all the branches a single tree, as well as their bifurcations at 30cm and circumference at ground (CGH $\geq$ 15.7cm), were measured separately. Individuals with multiple stems were included when the sum of the squares roots of the CGH followed the inclusion criterion and counted as a unique individual, according to Otoni et al. (2013). Later, CGH was transformed into DBH = CGH / π.

The total heights of all trees within the plots were obtained using a Haglof electronic clinometer, stretching the 20m long measuring tape to measure the distance between the operator of the clinometer and the base of the tree in order to adjust the device and measure the height (Martins et al., 2019). To avoid the edge effect on the plots, the adopted strategy was to walk at least 30m inward to reduce this sampling error. All tree individuals inserted in the plots were identified in the field either through the collection and drying of botanical material for identification with the help of specialized literature (Silva Júnior, 2005; Kuhlmann, 2012) or by comparison with botanical materials deposited in herbariums in the state of Goiás.

Litter

With the aid of a 25cm x 25cm (0.0625m²) wooden frame that was randomly launched in the study areas, according to the methodology of Martins et al. (2021), all dead organic matter above the ground was considered to be litter. In cases where the litter was partly inside and partly outside the frame, only the part that was inside the borders was collected. In the laboratory, the samples were dried in a circulation and air renewal oven at 70ºC for approximately 72 hours until reaching constant weight. After the litter drying, samples of the material from each individual collection were weighed with a digital scale (0.1g) (Martins et al., 2021).

Soil quality indicators

For component analysis, five samples were collected from the superficial soil layers (0-20 cm deep) in the plots using a shovel, derived from both the four corners and the center and also mixed and homogenized to form a composite sample. Each sample contained about 500g of soil, which was collected and packed in a sealed plastic bag and sent to the soil laboratory. In the laboratory, physical and chemical analyses were performed following the methods described by Embrapa (2018).

Phytophysiognomies characterization

The frequency distribution between the diameter and height classes were calculated and represented by histograms for the horizontal and vertical characterizations of the sampled plots. The width of the diameter classes was defined at 5 cm and the height classes was defined at 2 m for comparison purposes. These parameter ranges follow the definitions of other authors (according Miguel et al., 2016, Pereira et al., 2016).

The phytophysiognomies nomenclature was established according to Ribeiro and Walter (2008). For statistical purposes, the data were grouped into two large groups: 1) Cerrado stricto sensu and Cerradão; 2) Seasonal Forest and Gallery / Riparian Forest. Groupings were chosen based on similarity of species, savanna and forest formations, and it was necessary since some sampling points presented little material for evaluation, given fewer replicates of them in the environment.

Statistical analysis

The Shapiro-Wilk and Levene test ($p > 0.05$) was used to verify the normality of the data and homogeneity of the variances for the litter, richness, and abundance data adjusted to m², and this accounted for differencess in the plot sizes and diameter at breast height (DBH) – Height both inside and outside the conservation unit. Statistical significance was assessed by the non-parametric Kruskal-Wallis e U Mann-Whitney tests when the analyses did not meet the assumptions of normality, as well to compare the litter, richness, abundance, DBH – Height data sets both inside and outside the conservation unit. The results were considered statistically significant when values of $p \leq 0.05$ were obtained.

To produce an environmental ordering of the plots based on the soil chemical parameters, a principal component analysis (PCA) was performed. For the construction of the diagram, the plots of each phytophysiognomy were used to check the correspondence with soil parameters (pH, Ca2+, Mg2+, Al3++ H++ P+ Al3+, K+), cation exchange capacity at pH 7.0, clay, silt, sand, and litter.

Results

Floristic composition

A total of 50 plots were inventoried, in which four distinct types of phytophysiognomies were found: Cerrado stricto sensu, Cerradão, Estacional Forest and Mata Ciliar, each with 24, 08, 11, and 07 plots, respectively. As shown in (Table 1), 3010 individuals were cataloged, observing an average of 60 individuals per plot. Among these individuals, there was a richness of 173 species in 51 families and 118 genera.

The families Fabaceae and Vochysiaceae were the most abundant with 352 and 392 individuals each, representing 24.7% of the total sample. This was followed by the families Rubiaceae (155), Calophyllaceae (143) Anacardiaceae (139), Proteaceae (130), Sapindaceae (124), Malpighiaceae (120), Bignoniaceae (113), and Annonaceae (111). The genera with the highest species richness were Aspidosperma (six) and Byrsonima (five), and the genera Miconia, Ocotea, Qualea, and Xylopia presented four species for each.

Table 1. Studies of water infiltration in the Cerrado biome.

Families/Speccies	**N**	**%**
Anacardiaceae	**139**	**4.6%**
Anacardium humile A.St.-Hil.	5	0.2%
Anacardium othonianum Rizzini	8	0.3%
Astronium fraxinifolium Schott	5	0.2%
Lithraea molleoides (Vell.) Engl.	38	1.3%
Myracrodruon urundeuva Allemão	9	0.3%
Tapirira guianensis Aubl.	74	2.5%

Annonaceae	**111**	**3.7%**
Annona coriacea Mart.	12	0.4%
Cardiopetalum calophyllum Schltdl.	27	0.9%
Rollinia sylvatica (A.St.-Hil.) Mart.	7	0.2%
Xylopia aromatica (Lam.) Mart.	36	1.2%
Xylopia brasiliensis Spreng.	8	0.3%
Xylopia emarginata Mart.	4	0.1%
Xylopia sericea A.St.-Hil.	17	0.6%
Apocynaceae	**92**	**3.1%**
Aspidosperma cylindrocarpon Müll.Arg.	14	0.5%
Aspidosperma discolor A.DC.	3	0.1%
Aspidosperma macrocarpum Mart.	32	1.1%
Aspidosperma polyneuron Müll.Arg.	12	0.4%
Aspidosperma subincanum Mart.	9	0.3%
Aspidosperma tomentosum Mart.	7	0.2%
Balfourodendron riedelianum	2	0.1%
Hancornia speciosa Gomes	4	0.1%
Himatanthus obovatus (Müll. Arg.) Woodson	5	0.2%
Rauvolfia sellowii Müll. Arg.	4	0.1%
Araliaceae	**44**	**1.5%**
Schefflera macrocarpa (Cham. & Schltdl.) Frodin	11	0.4%
Schefflera morototoni (Aubl.) Maguire. Steyerm. & Frodin	18	0.6%
Dendropanax cuneatus (DC.) Decne. & Planch.	15	0.5%
Asteraceae	**37**	**1.2%**
Eremanthus glomerulatus Less.	13	0.4%
Piptocarpha rotundifolia (Less.) Baker	24	0.8%
Bignoniaceae	**113**	**3.8%**
Cybistax antisyphilitica (Mart.) Mart.	4	0.1%
Handroanthus ochraceus (Cham.) Mattos	2	0.1%
*Handroanthus roseo-albus (*Ridl.) Mattos	5	0.2%
Tabebuia aurea (Silva Manso) Benth. & Hook.f. ex S.Moore	25	0.8%
Tabebuia caraiba (Mart.) Bureau	77	2.6%
Burseraceae	**10**	**0.3%**
Protium heptaphyllum (Aubl.) Marchand	10	0.3%
Calophyllaceae	**143**	**4.8%**
Calophyllum brasiliense Cambess.	1	0.0%
Kielmeyera coriacea Mart. & Zucc.	8	0.3%
Kielmeyera rubriflora Cambess.	4	0.1%
Kielmeyera speciosa A.St.-Hil.	130	4.3%
Cannabaceae	**3**	**0.1%**
Celtis iguanaea (Jacq.) Sarg.	3	0.1%
Caryocaraceae	**20**	**0.7%**
Caryocar brasiliense Cambess.	20	0.7%
Celastraceae	**30**	**1.0%**
Cheiloclinium cognatum (Miers) A.C.Sm.	1	0.0%
Plenckia populnea Reissek	29	1.0%
Chrysobalanaceae	**55**	**1.8%**
Hirtella glandulosa Spreng.	8	0.3%
Hirtella gracilipes (Hook.f.) Prance	29	1.0%
Hirtella martiana Hook.f.	18	0.6%
Clusiaceae	**2**	**0.1%**
Vismia guianensis (Aubl.) Choisy	2	0.1%
Combretaceae	**12**	**0.4%**

Terminalia glabrescens Mart.	11	0.4%
Buchenavia tomentosa Eichler	1	0.0%
Connaraceae	**19**	**0.6%**
Connarus suberosus Planch.	16	0.5%
Rourea induta Planch.	3	0.1%
Cunoniaceae	**3**	**0.1%**
Lamanonia ternata Vell.	3	0.1%
Dilleniaceae	**30**	**1.0%**
Curatella americana L.	12	0.4%
Davilla elliptica A.St.-Hil.	18	0.6%
Ebenaceae	**44**	**1.5%**
Diospyros burchellii Hiern	44	1.5%
Erythroxylaceae	**50**	**1.7%**
Erythroxylum suberosum A.St.-Hil.	50	1.7%
Euphorbiaceae	**7**	**0.2%**
Mabea fistulifera Mart.	1	0.0%
Maprounea guianensis Aubl.	6	0.2%
Fabaceae	**352**	**11.7%**
Acosmium dasycarpum (Vogel) Yakovlev	60	2.0%
Anadenanthera colubrina (Vell.) Brenan	34	1.1%
Anadenanthera falcata (Benth.) Speg.	3	0.1%
Anadenanthera macrocarpa (Benth.) Brenan	6	0.2%
Andira cujabensis Benth.	2	0.1%
Bauhinia longifolia (Bong.) Steud.	22	0.7%
Bowdichia virgilioides Kunth	1	0.0%
Copaifera langsdorffii Desf.	30	1.0%
Dalbergia miscolobium Benth.	4	0.1%
Dimorphandra mollis Benth.	34	1.1%
Enterolobium gummiferum (Mart.) J.F.Macbr.	13	0.4%
Hymenaea courbaril L.	3	0.1%
Hymenaea stigonocarpa Mart.	6	0.2%
Inga cylindrica (Vell.) Mart.	4	0.1%
Inga marginata Willd.	6	0.2%
Inga uruguensis Hook. & Arn.	1	0.0%
Leptolobium dasycarpum Vogel	7	0.2%
Lonchocarpus cultratus (Vell.) A.M.G.Azevedo & H.C.Lima	6	0.2%
Machaerium brasiliense Vogel	2	0.1%
Machaerium hirtum (Vell.) Stellfeld	2	0.1%
Machaerium opacum Vogel.	42	1.4%
Plathymenia reticulata Benth.	5	0.2%
Platypodium elegans Vogel	28	0.9%
Pterodon emarginatus Vogel	4	0.1%
Stryphnodendron adstringens (Mart.) Coville	4	0.1%
Tachigali paniculata Aubl.	21	0.7%
Vatairea macrocarpa (Benth.) Ducke	2	0.1%
Flacourtiaceae	**25**	**0.8%**
Casearia sylvestris Sw.	25	0.8%
Lacistemataceae	**1**	**0.0%**
Lacistema hasslerianum Chodat	1	0.0%
Lamiaceae	**21**	**0.7%**
Aegiphila sellowiana Cham.	7	0.2%
Vitex montevidensis Cham.	14	0.5%
Lauraceae	**29**	**1.0%**

Nectandra cuspidata Nees	10	0.3%
Nectandra lanceolata Nees &Mart.	1	0.0%
Ocotea odorifera (Vell.) Rohwer	7	0.2%
Ocotea porosa (Nees & Mart.) Barroso	4	0.1%
Ocotea spixiana (Nees) Mez	6	0.2%
Ocotea velloziana (Meisn.) Mez	1	0.0%
Lecythidaceae	**8**	**0.3%**
Cariniana estrellensis (Raddi) Kuntze	8	0.3%
Loganiaceae	**1**	**0.0%**
Strychnos pseudoquina A.St.-Hil.	1	0.0%
Lythraceae	**21**	**0.7%**
Lafoensia pacari A.St.-Hil.	11	0.4%
Physocalymma scaberrimum Pohl	10	0.3%
Malpighiaceae	**120**	**4.0%**
Byrsonima coccolobifolia Kunth	22	0.7%
Byrsonima crassifolia (L.) Kunth	3	0.1%
Byrsonima lancifolia A.Juss.	8	0.3%
Byrsonima pachyphylla A.Juss.	47	1.6%
Byrsonima verbascifolia (L.) DC.	40	1.3%
Malvaceae	**72**	**2.4%**
Aguaí Luehea candicans Mart. & Zucc.	1	0.0%
Apeiba tibourbou Aubl.	2	0.1%
Eriotheca pubescens (Mart. & Zucc.) Schott & Endl.	14	0.5%
Guazuma ulmifolia Lam.	5	0.2%
Luehea candicans Mart. & Zucc.	26	0.9%
Luehea divaricata Mart. & Zucc.	8	0.3%
Luehea grandiflora Mart. & Zucc.	1	0.0%
Pseudobombax tomentosum (Mart.) A.Robyns	12	0.4%
Sterculia striata A.St.-Hil. & Naudin	3	0.1%
Melastomataceae	**108**	**3.6%**
Miconia albicans (Sw.)Triana	17	0.6%
Miconia burchellii Triana	33	1.1%
Miconia cuspidata Naudin	7	0.2%
Miconia ferruginata DC.	36	1.2%
Mouriri elliptica Mart.	3	0.1%
Mouriri pusa Gardner	1	0.0%
Tibouchina candolleana (Mart. ex DC.) Cogn.	11	0.4%
Meliaceae	**108**	**3.6%**
Guarea guidonia (L.) Sleumer	37	1.2%
Guarea kunthiana A. Juss.	20	0.7%
Trichilia pallida Sw.	51	1.7%
Metteniusaceae	**67**	**2.2%**
Emmotum nitens (Benth.) Miers	67	2.2%
Moraceae	**4**	**0.1%**
Brosimum gaudichaudii Trécul	2	0.1%
Sorocea bonplandii (Baill.) W.C.Burger *et al.*	2	0.1%
Myristicaceae	**34**	**1.1%**
Virola sebifera Aubl.	34	1.1%
Myrsinaceae	**4**	**0.1%**
Cybianthus detergens Mart.	4	0.1%
Myrtaceae	**93**	**3.1%**
Eugenia dysenterica (Mart.) DC.	3	0.1%
Myrcia fallax (Rich.) DC.	3	0.1%

Myrcia fenzliana O. Berg	43	1.4%
Myrcia splendens (Sw.) DC.	5	0.2%
Psidium araca Raddi	10	0.3%
Psidium cattleianum	1	0.0%
Psidium sartorianum (O.Berg) Nied.	28	0.9%
Nyctaginaceae	**30**	**1.0%**
Guapira hirsuta (Choisy) Lundell	6	0.2%
Guapira noxia (Netto) Lundell	19	0.6%
Neea theifera Oerst.	5	0.2%
Ochnaceae	**39**	**1.3%**
Ouratea castaneaefolia (DC.) Engl.	1	0.0%
Ouratea hexasperma (A.St.-Hil.) Baill.	38	1.3%
Opiliaceae	**5**	**0.2%**
Agonandra excelsa Griseb.	5	0.2%
Piperaceae	**4**	**0.1%**
Piper arboreum Aubl.	4	0.1%
Primulaceae	**8**	**0.3%**
Myrsine coriacea (Sw.) R.Br. ex Roem. & Schult.	8	0.3%
Proteaceae	**130**	**4.3%**
Roupala brasiliensis Klotzsch	113	3.8%
Roupala montana Aubl.	17	0.6%
Rubiaceae	**155**	**5.1%**
Cordiera edulis (Rich.) Kuntze	58	1.9%
Cordiera sessilis (Vell.) Kuntze	23	0.8%
Guettarda viburnoides Cham. & Schltdl.	7	0.2%
Ixora gardneriana Benth.	30	1.0%
Palicourea rigida H. B. & Kunth	4	0.1%
Randia armata (Sw.) DC.	7	0.2%
Rudgea viburnoides (Cham.) Benth.	20	0.7%
Tocoyena formosa (Cham. & Schltdl.) K.Schum.	6	0.2%
Rutaceae	**5**	**0.2%**
Zanthoxylum rhoifolium Lam.	5	0.2%
Sapindaceae	**124**	**4.1%**
Cupania vernalis Cambess.	26	0.9%
Dilodendron bipinnatum Radlk.	1	0.0%
Matayba elaeagnoides Radlk.	2	0.1%
Matayba guianensis Aubl.	95	3.2%
Sapotaceae	**15**	**0.5%**
Chrysophyllum marginatum (Hook. & Arn.) Radlk.	8	0.3%
Pouteria ramiflora (Mart.) Radlk.	4	0.1%
Pouteria torta (Mart.) Radlk.	3	0.1%
Siparunaceae	**30**	**1.0%**
Siparuna guianensis Aubl.	30	1.0%
Solanaceae	**4**	**0.1%**
Solanum lycocarpum A.St.-Hil.	4	0.1%
Styracaceae	**37**	**1.2%**
Styrax camporum Pohl	3	0.1%
Styrax ferrugineus Nees & Mart.	34	1.1%
Vochysiaceae	**392**	**13.0%**
Callisthene major Mart.	107	3.6%
Qualea dichotoma (Mart.) Warm.	6	0.2%
Qualea grandiflora Mart.	123	4.1%
Qualea multiflora Mart.	10	0.3%

Qualea parviflora Mart.	100	3.3%
Salvertia convallariodora A.St.-Hil.	19	0.6%
Vochysia elliptica Mart.	20	0.7%
Vochysia haenkeana Mart.	2	0.1%
Vochysia rufa Mart.	5	0.2%
Total	**3010**	**100.0%**

Abundance

As shown in (Figure 1), the phytophysiognomy CSR_OUT (Cerrado stricto sensu - Outside) presented the largest number of tree individuals with an abundance of 0. 2145ind.ha-1. When analyzing the two Cerrado areas, a statistically significant difference was observed in the CSR_IN abundance with an average of 0.137 ind.ha-1 when compared with CSR_OUT that presented an average of 0.214 ind.ha-1.

When comparing the abundance of species in the Seasonal Forest areas inside and outside the conservation unit, it was found that there was no statistically significant difference between the areas that presented an average of 0.122 and 0.123 ind.ha-1, respectively. On the other hand, it was observed that the CSR_OUT presented about 1.3 times the abundance with respect to the seasonal forest when analyzing the areas outside the conservation unit. The number of tree individuals in CSR_OUT was about 1.7 times greater than in FLOR_OUT and 1.5 times greater than CSR_IN.

Litter

As shown in (Figure 1), FLOR_IN phytophysiognomy had the highest litter accumulation per plot, presenting a weight of 498.8g. In comparison, FLOR_OUT presented 164g, CSR_IN presented 144g, and CRS_OUT presented 104g. When analyzing the Cerrado and Floresta areas, both inside and outside, it was observed that there is no significant difference between them. However, there was a significant difference between the areas of FLOR_IN and CSR_OUT in grams of material, noting FLOR_IN was about 2.4 times higher.

DBH-Height

As shown in (Figure 1), the phytophysiognomy FLOR_OUT had the highest indexes of maximum DBH with an average of 136cm and was followed by CSR_OUT with an average of 80cm, FLOR_IN with an average of 41cm, and CSR_IN with an average of 32cm. When comparing the areas of CSR_IN and CSR_OUT, there was a significant difference between them, and the areas of CSR_OUT had values about twice as high as CSR_IN. For the areas of Forest FLOR_OUT and FLOR_IN, FLOR_OUT had values 3 times higher than FLOR_IN, presenting a statistical difference. Both phytophysiognomies CSR_OUT and FLOR_OUT and CSR_IN and FLOR_OUT also presented a significant difference, observing a difference of two and five times greater for each pair, respectively.

As shown in (Figure 1), phytophysiognomy FLOR_IN had the highest maximum height indexes with an average of 15.3m, followed by FLOR_OUT with 12m, CSR_IN with 8.9m, and CSR_OUT with 5.6m. When comparing the areas of CSR_IN and CSR_OUT, there were no significant differences. Among phytophysiognomies, FLOR_IN had forest plot areas about 3 times higher than CSR_OUT, presenting a significant difference. The FLOR_OUT and CSR_OUT areas also showed a significant difference, and the forest areas were about twice higher for the former.

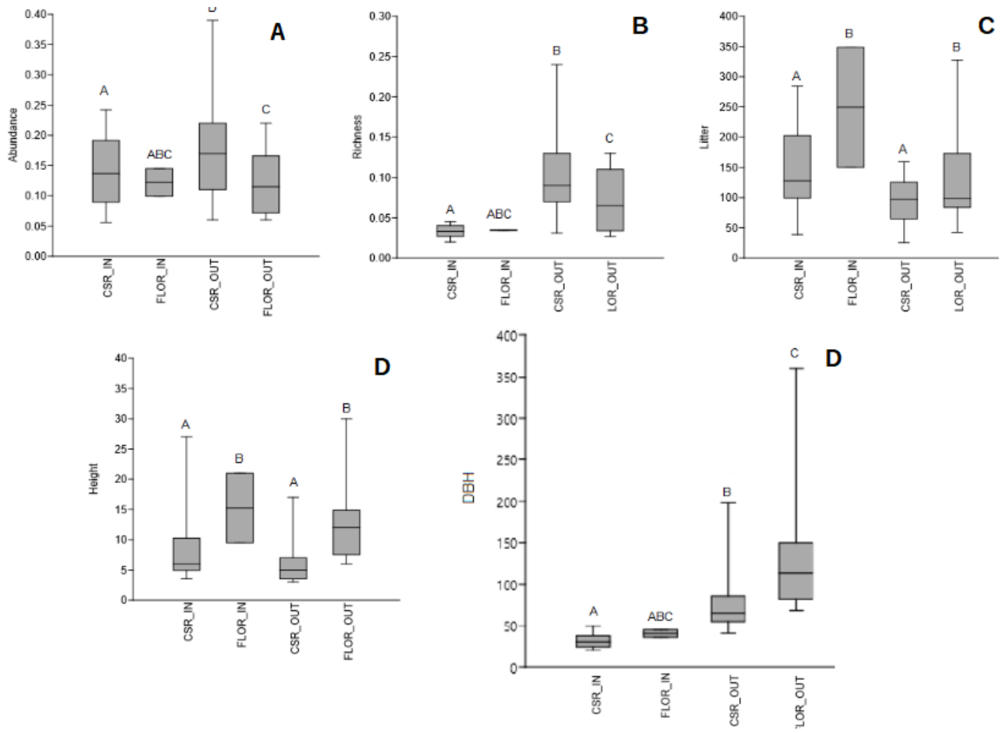

Figure 1. Box-plots with mean, quartiles, maximum, and minimum of the Abundance (A), Richness(B), Litter(C), Heigh(D) DBH(E) and t variable that indicate statistically significant differences by the Mann-Whitney U test when p <0.05. CSR_IN (Cerrado stricto sensu-Inside); CSR_OUT (Cerrado stricto sensu-Outside); FLOR_IN (Seasonal Semideciduous Forest-Inside); FLOR_OUT (Seasonal Semideciduous Forest-Outside). Treatments with the same letters did not differ significantly by the Mann-Whitney U test.

Richness

As shown in (Figure 2), phytophysiognomy CSR_OUT had the highest number of tree species per plot, presenting a richness of 0.115 ind.ha-1. When analyzing the two Cerrado areas, a statistically significant difference was observed for the CSR_IN richness with an average of 0.033 ind.ha-1 when compared to CSR_OUT, which had an average of 0.115 ind.ha-1.When comparing the species richness of the Seasonal Forest areas inside and outside the conservation unit, it was found that there was no statistically significant difference between the areas, which presented an average of 0.0345 ind.ha-1 and 0.053 ind.ha-1, respectively. On the other hand, areas outside the conservation unit presented greater species richness of CSR_OUT when compared to the seasonal forest areas. The number of tree individuals in CSR_OUT was twice that in FLOR_OUT and about three times more than in CSR_IN.

Diametric and Altimetric Distribution.

For the FLOR_IN areas, they were concentrated in the diameter classes of 0-5-10-15, and this corresponds to a total of 89% of the individuals. For FLOR_OUT, they were concentrated in the diameter classes of 0-20-40, corresponding to a total of 97%, and the largest classes in which they presented few individuals corresponded with less than 1%. For the areas of CSR_ D, they were concentrated in the diameter classes of 0-5-10-15, and this corresponds to a total of 89% of the individuals. For CSR_OUT, they were concentrated in the diameter classes of 0-7.5-15, corresponding to 91% of individuals, and the other classes in which they presented few individuals corresponded to less than 1% (Figure 2).

As shown in the figure above (Figure 3), it was observed that most of the individuals are grouped in the first two classes of height 0-5-10 for the areas of FLOR_IN and FLOR_OUT, with 94% and 92%, respectively. In other words, the smallest altimetric classes showed higher densities of individuals, indicating a possible young population entering the equilibrium phase, and the largest classes in which they presented few individuals corresponded to less than 1%. In the Cerrado areas, individuals are grouped in the first three altimetric classes with CSR_IN classes of 0-5-10 with 97% of individuals and CSR_OUT 2-4-6 with 89% of individuals.

Principal Component Analysis

The results of the principal component analysis (PCA) plots for the soil samples indicated the formation of two main components, which together explain 64% of the variance in the soil surface layer (0-20cm). The first main component presented an eigenvalue of 1.81, representing 44.5% of the total variance. The second most representative component presented an eigenvalue of 1.42, representing 19.5% of the total variance. The most significant nutrients in the soil in component one were Ca^{2+}, Mg^{2+}, and K^+, also noting that the V (%) and pH have significant eigenvalues and have a positive correlation with a most of the variables. In the second component, Al^{3+}, clay, silt, and sand were the most representative.

As shown in Figure 3, the distribution of the plots and the edaphic variables vectors for the first two components of the PCA indicated that $H^+ + Al^{3+}$, silt, clay, and Al^{3+} showed a high positive correlation with each other and are negatively correlated with the pH variables (in H_2O), P^-, Sand and Litter (g). The variables consistent with the fertility of the Mg^{2+}, Ca^{2+}, K^+, V, and OM soils showed a high positive correlation with each other

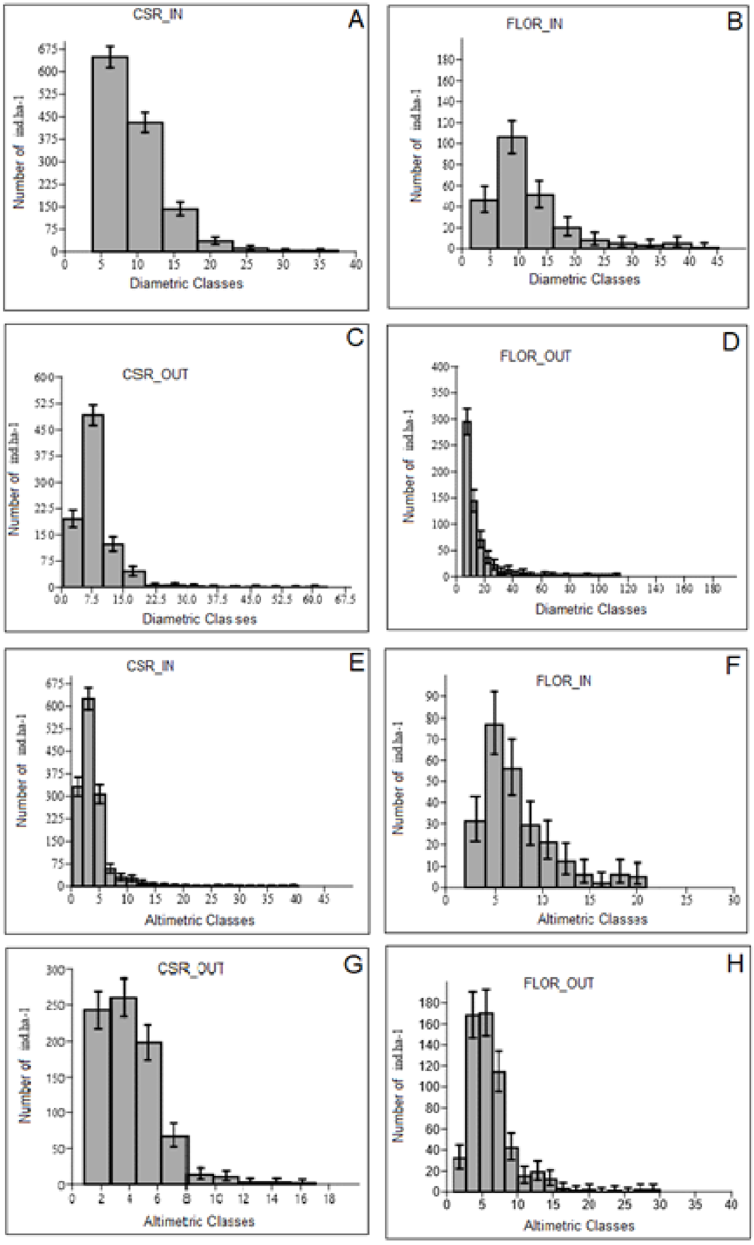

Figure 2. Distribution of the diametric classes (A, B.C, D) altimetric classes (E, F, G, H) and standard deviation of the tree individuals of the inside and outside Forest areas and Cerrado inside and outside the Silvânia National Forest – GO.

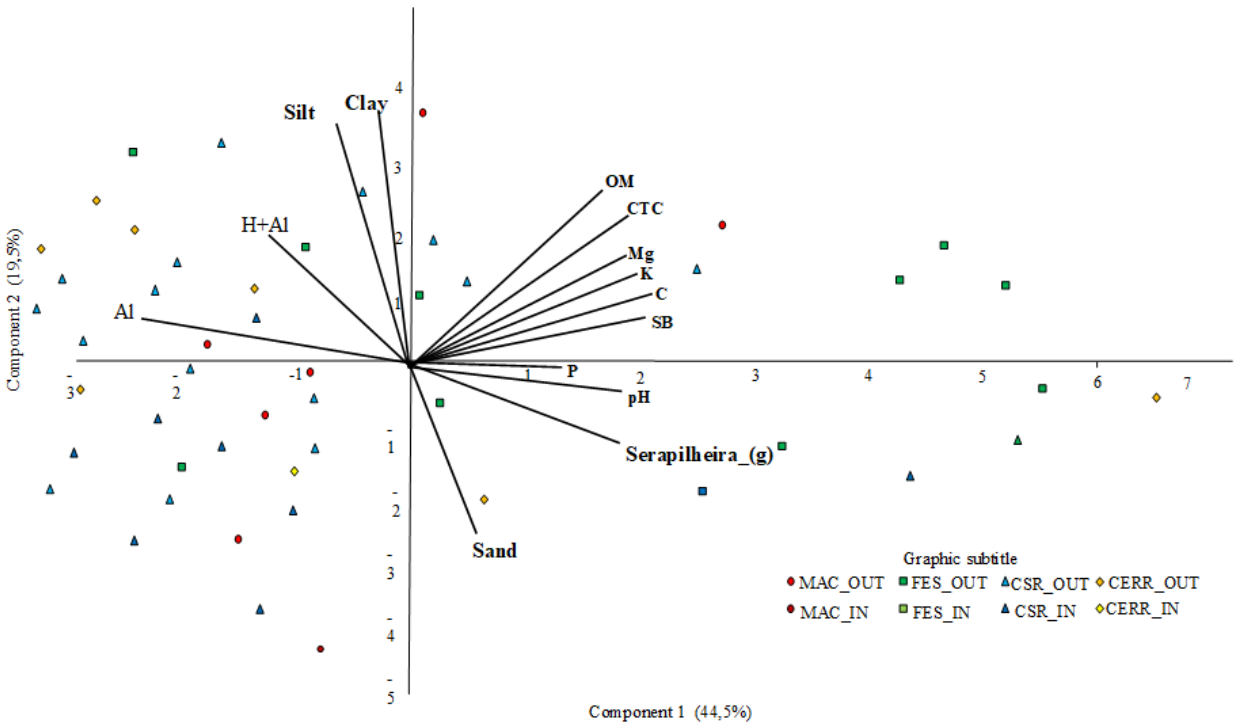

Figure 3. Ordering diagram produced by principal component analysis (PCA) showing the distribution of plots (MAC_OUT) Mata Ciliar - Outside; (MAC_IN) Mata Ciliar - Inside; (FES_OUT) Seasonal Semideciduous Forest - Outside; (FES_IN) Seasonal Semideciduous Forest - Inside; (CSR_OUT) Cerrado Sentido Restrito - Out; (CSR_IN) Cerrado Sensido Restrito - Inside; (CERR_OUT) Cerradão - Outside and (CERR_IN) Cerradão Within the depth (0-20 cm) of NF - National Forest in Silvânia, Goiás, in the first two ordering axes, according to the edaphic variables. Where: pH = hydrogen potential (in H2O); Ca2+ = Calcium; Mg2+ = Magnesium; Al3+ = Aluminum; H+ = Hydrogen; P- = Phosphorus; K+ = Potassium; OM = organic matter; V = Sum of bases; CEC (T) = Cation exchange capacity at pH 7; V (%) = Base saturation.

The first component showed a positive correlation with: Ca2+, Mg2+, K+, CEC (T) BS, and a negative correlation with: Al3+, H++Al3+, clay, and silt. The second component was negatively correlated with pH in H2O, P-, BS, and sand. These two components divided the plots with phytophysiognomies based on soil fertility, while the Seasonal Semideciduous Forest plots (CSR_OUT38, CSR_OUT39, CSR_OUT40, MAC_OUT19, MAC_OUT43, FES_OUT 17, FES_OUT 18, FES_OUT 23, FES_OUT 29) were associated with greater natural fertility, presenting higher levels of Mg2+, Ca2+ , and K+, CEC (T), and OM, as well as a greater sum of bases (V).

The plots of (CSR_IN08, CSR_OUT 15 CERR_OUT 25, FES_IN02, FES_OUT13, FES_OUT16) were correlated with pH in H2O and Sand. The plots (FES_OUT14, FES_OUT28, MAC_OUT19, CSR_OUT20, CSR_OUT22, CSR_OUT24, CERR_OUT31, CERR_OUT32, and CERR_OUT35) were correlated with the potential acidity H++Al3+, clay, silt, and Al3+.

The plots (MAC_IN05, MAC_OUT21, MAC_OUT37, CSR_IN01, CSR_IN04, CSR_IN06, CSR_IN07 CSR_IN09, CSR_IN10, CSR_IN11, CSR_OUT12, CSR_OUT30, CSR_IN34, and CERR_IN03) are negatively correlated with the variables consistent with the soil fertility, Mg2+, Ca2+, K+, V, and OM and with the accumulation of litter. The plots of MAC-D 05, MAC_OUT19, and MAC_OUT21 were close to those of the Cerrado, due to the degradation index of the environments where they are located.

Discussion

In this work, the Cerrado of Goiás was distributed into forest and savanna vegetation plots for determination of the forest richness. Despite investigating the forest richness, the effectiveness of the conservation unit to protect these areas is low, since greater species richness has been found in areas outside the Silvânia NF. The areas of CSR_OUT (Cerrado stricto sensu-Outside) and FLOR_OUT (Seasonal Semideciduous Forest-Outside) had a higher number of individuals per m², indicating that the external plots have better preservation sites than within the conservation unit. Either way, the NF is still relevant, as it maintains vegetation characteristics more resembling of the original with respect to vegetation structure. In other words, the Silvânia NF has suffered a high degree of external influence, making conservation and preservation of its plant species difficult. In addition to the diversity, the altimetric and diametric structure can be excellent descriptors of the community structure, since they are directly linked to the allocation and availability of nutrients in the communities (Poorter et al., 2016; Martins et al., 2021).

The families described in the samplings are common and representative of the Cerrado stricto sensu, and they are also able to be found in the vast plant formations of this biome. The richest families were Fabaceae and Vochysiaceae followed by Rubiaceae, Calophyllaceae, Anacardiaceae, Proteaceae, Sapindaceae, Malpighiaceae, Bignoniaceae, and Annonaceae. Fabaceae is a family that stands out not only in the Cerrado, but also in other forest formations, both for its richness and other characteristics of importance. The genera with the greatest species richness were Aspidosperma, Byrsonima and the Miconia, Ocotea, Qualea and Xylopia genera. The richest genera found in the evaluated plots are common and well distributed in Cerrado stricto sensu areas in Central Brazil, and this occurrence corroborates other previous studies (Souza et al., 2017; Vasconcelos et al., 2020).

As also observed in this study, Savanna formations, as well as species more common in savanna formations, tend to occur in more acidic and aluminum-rich soils. Forest formations and more frequent species in these environments tend to occur in soils that are richer in organic matter. Savanna formations are more open environments, tend to produce less litter, and their decomposition is different from forest environments. Although less understood as an environmental process, the decomposition of litter can somehow reflect the change in the function of vegetation (Costa et al., 2019; Martins et al., 2020), and in this case, the Silvânia NF has less litter in comparison to vegetation outside the unit, requiring further study.

Another important aspect for understanding vegetation formations is its by diametric and altimetric structuring. In this context, it was observed that more than 90% of the cataloged individuals (for the two vegetation formations, inside and outside the Silvânia NF) fall into the smallest diametric classes and presented a higher density of individuals (Figure 3). This indicated that most populations could be in the initial phase of establishment (Souza et al., 2012; Ferreira et al., 2017).

The largest concentration of individuals in the largest diameter classes is characteristic of a stock community in tropical forests with different ages and compositions of species. It is also a well-known expected pattern for forest formations in the Cerrado (Venturoli et al., 2015). The inverted "J" pattern, containing most of the individuals in the first diameter classes and the smallest representation in the larger classes, proves a positive balance between recruitment and mortality, characterizing the forest as self-regenerating. Some anomalies can also be observed in the diametric distribution of the trees, also indicating conservation. For example, the forest formation inside the NF and in the Cerrado outside the NF presents a particular class before the inverted J curve, which may indicate some recent event (last three years) in those areas.

The areas within the Conservation Unit indicate a higher stage of conservation than the external areas, based on the presence of individuals up to 40m high. Outside the NF, the smaller classes indicated a low degree of preservation with individuals that are still young in the stabilization process and also subject to constant fires. Thus, future studies are also recommended to understand the successional dynamics in the Cerrado (Silva-Neto et al., 2016).

Although the Cerrado vegetation seems to be well understood in several studies, its biogeographic patterns are poorly understood. The creation of conservation units in the Cerrado must consider a number of factors, when aiming to maximize conservation of the preserved remnants. Currently, the Silvânia NF is almost an isolated fragment, even presenting aspects of richness and abundance of trees of the same size or even smaller than areas outside the unit itself. Thus, understanding vegetation and soil can contribute to the creation of models for the conservation of forest ecosystems, which can improve the use of the regional natural resources and conservation of biodiversity.

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