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Influence of Soil Type and Rocky Outcrops on the Species Distribution in a Woody Plant Community at Brazilian Semiarid

José Cícero de Moura[1], Maria Amanda Nobre Lisboa[2], Brenda Luana Muniz Gonçalves[2], Gabriel Venâncio Cruz[2], Eduardo S. S. Tavares Barreto[2], Antonio Ivanildo Pinho[2], Marcos Aurélio Figueiredo dos Santos[3], Luciana da Silva Cordeiro[3], Ana Cleide Alcântara Morais Mendonça[3], Maria Arlene Pessoa da Silva[1,3], Luiz Marivando Barros[1,2], Toshik Iarley da Silva[4], Leonardo Silvestre Gomes Rocha[5], Marcos Antônio Drumond[6] & João Tavares Calixto Júnior[1,2]

[1] Master's Program in Biological Diversity and Natural Resources, Regional University of Cariri, Crato, Ceará State, Brazil

[2] Laboratory of Studies of the Regional Flora of the Cariri (LEFLORE), Regional University of Cariri, Crato, Ceará State, Brazil

[3] Herbarium Caririense Dárdano de Andrade-Lima (HCDAL), Regional University of Cariri, Crato, Ceará State, Brazil

[4] Doctoral Program in Phytotechnichs, Federal University of Viçosa, Viçosa, Minas Gerais State, Brazil

[5] Department of Animal Biology, Federal Rural University of Rio de Janeiro, Rio de Janeiro, Brazil

[6] Brazilian Agricultural Research Corporation (EMBRAPA Semiárido), Petrolina, Pernambuco State, Brazil

Correspondence: João Tavares Calixto Júnior, Laboratory of Studies of the Regional Flora of the Cariri (LEFLORE), Regional University of Cariri, Crato, Ceará State, Brazil. Tel: 55-88-3102-1213. E-mail: joao.calixto@urca.br

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Abstract

Cerrado is a biome that holds many phytophysiognomies, influenced by the edaphic factors, where the type of substrate is strongly related to the established vegetation. This study aims to verify on how soil physicochemical properties, as well as the presence of rocky outcrops, influence the species distribution of woody plants in a Cerrado fragment located in deep soils and tabular relief at Serra do Boqueirão (289 m elev.) Lavras da Mangabeira municipality (6º72′24″ S; 38º97′73″ W), Northeastern Brazil. Every individual with a DNS ≥ 3 cm in 12 sampling units with an area of 12 × 30 m (0.432 ha) was sampled. PAST v. 3.23 software was used in the Main Component analyses. The physical and chemical analyses of the soil were made with samples collected at 0-20 cm and 20-40 cm depths. Differences in diversity, hierarchy and dominance volume of woody plant populations were found between sites with or without the presence of rocky outcrops. The soil has a tendency for water erosion and the aluminum saturation reached values of concentration of 7.9 $cmol_c\ dm^{-3}$, with a pH value between 4.1-4.2 in rocky environments. The obtained results suggest that *Q. parviflora* and *A. occidentale* probably have some kind of resistance to the toxicity of aluminum in soil with a pH value below 5.0.

Keywords: rocky outcrops, woody plant community, Brazilian semiarid, vegetal ecology, cluster analyses

1. Introduction

Brazilian Cerrado is the world's richest savanna in terms of biodiversity (Silveira, 2010), with 11,000 species of native plants are already cataloged (Klink & Machado, 2005). It ranges through an estimated area of 2,036,448 Km^2, exclusively in Brazil (IBGE, 2018), covering 23% of the national territory (Ribeiro & Walter, 2008; Mota et al., 2014). Cerrado *sensu stricto* is found in high elevation reliefs, mainly in deep and well-drained soils, having an herbaceous layer dominated by grasses and a woody layer with diverse heights, varying mainly from three to five meters (Felfili & Fagg, 2007).

Ribeiro and Walter (2008) determined 11 phytophysiognomic types for the Cerrado biome, distributed between forest, savanic and prairie formations, with Cerrado *sensu stricto* having the largest territorial extension, occupying ca. 70% of the biome (Felfili et al., 2013; Mota et al., 2014). This pattern promotes a greater diversity of subtypes, as landscapes with typic dense and thin vegetation over deep soils and rocky landscapes with shallow soils and rocky outcrops conditioning the presence of bushes and arboreal vegetation (Ribeiro & Walter, 2008; Mota et al., 2014).

Some of the main influencing factors on the vegetation types of Cerrado are largely related to the edaphic conditions, especially the following: water depth, drainage, actual soil profile depth and texture, as well as the percentage of exposed rocks (Haridasan, 2000; Abreu et al., 2012). These factors influence Cerrado phytophysiognomies as much as anthropic action does (Pivello & Coutinho, 1996; Neri et al., 2007).

The Cerrado soil chemical composition is mostly dystrophic, with low pH, low available calcium and magnesium concentrations and high exchangeable aluminum concentration (Lopes & Cox, 1977; Neri et al., 2007). Depending on concentration level, some metals, such as aluminum, cause soil toxicity, influencing the growth of some native plant species and acting as one of the limiting factors for the growth of some plant species of the Cerrado dominion (Balbino-Miguel et al., 2010).

Abreu et al. (2012) suggest that comparative studies on woody vegetation and rocky outcrops in typical Cerrado sites can aid on the evaluation of the effects of edaphic conditions in their floristic and structural compositions.

For the execution of biodiversity conservation projects and sustainable managing plans, the knowledge of the vegetation, its limitations and resilience on the area of interest is necessary (Ferraz et al., 2013).

Castro (1994) warned about the lack of knowledge on the floristic heritage of Cerrado, which can negatively influence the supply of genetic variability for the future technological generations, and the high phytodiversity and compartimentalized architecture of the Cerrado biome difficults extrapolation of the results achieved by quantitative floristic surveys.

The few Cerrado regions on Southern Ceará state are restrict to enclaves of small sedimentary reliefs, first identified by Figueiredo and Fernandes (1987), located at Lavras de Mangabeira, Aurora, Granjeiro, Várzea Alegre, Farias Brito, Cedro and Jucás municipalities and over the Chapada do Araripe (Figueiredo, 1997; Moro et al., 2011; Nepomuceno et al., 2016). Little is known on the diversity of fauna/flora, structure and conservation status of those Cerrado fragments.

In face of the demand for scientific knowledge on this biome and looking forward to support recover and preservation actions on it, this study aims to analyze on how the physicochemical composition of the soil, as well as the presence of rocky outcrops influence the patterns of floristic distribution and phytophysiognomic structure of woody species in that fragment of Cerrado *strictu senso* located in the crystalline Caatinga, Brazilian Semiarid.

2. Methods

2.1 Area of Study

Serra do Boqueirão is located at the municipality of Lavras da Mangabeira (6º72′24″ S; 38º97′73″ W) (Figure 1), at an elevation from 282 to 401 m above sea level. This municipality belongs to the semiarid portion of Northeastern Brazil, officialy regionalized as Lavras da Mangabeira microregion and Southern-Central Ceará mesoregion (IBGE, 2010). The local site on study lies near the Lavras da Mangabeira sedimentary basin, a set of three small basins covering circa 60.27 km^2 in a private property, surprisingly well-preserved, without any agropecuary activity. The climate is defined as Warm Tropical Semiarid (Aw), according to the Köppen classification, with two well-defined seasons (dry winters and humid summers), despite the transitory nature of the semiarid climate on Northeastern Brazil (BSh). The average annual pluviosity is 908.9 mm (FUNCEME, 2019), the rain season being from January to April. The average annual temperature is 26.8 ºC (INPE, 2019).

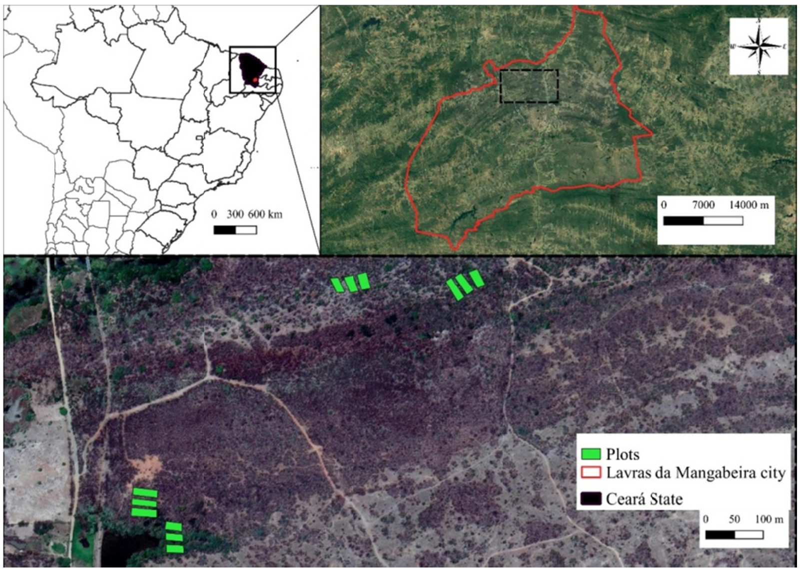

Figure 1. Geographical location of Serra do Boqueirão, Lavras da Mangabeira, Southern Ceará, Brazil

The relief consists on desiccated structural crystal surfaces, with elongated dales and interfluvia. The interfluvia are in an advanced desiccation process, with narrow horizontal surfaces, having parallel grooves in their strands, usually following the fractures (Figueiredo & Fernandes, 1987). The region is part of the Salgado river basin, with the open bushy Caatinga and dense bushy Caatinga as dominant vegetation. Soil types vary between Argisoil, Luvisoil e Neosoil (IPECE, 2019). This region has rocky outcrops even in higher elevations.

2.2 Data Collection and Treatment

The sampling of arboreous-arbustive vegetation was conducted by a forest inventory based on the parcel method (Mueller-Dombois & Ellemberg, 1974). Twelve sampling units (360 m^2—12 × 30 m) were lauched within the distance of 100m, six of them in a site with no rocky outcrops (Environment I) and the remaining six in a site with rocky outcrops (Environment II), in a higher elevation area, totalizing an area of 0.432 ha. Each individual with a DNS (30 cm height from soil diameter) ≥ 3 cm was registered. DNS was measured with a dendrometric t-bevel, and total height (HT) was estimated using a telescopic graduate rod (Ferraz et al., 2013). In case of existence of resprout, the one of greater diameter and within the inclusion criterions was measured, and the remaining were included, as suggested by Rodal (1992). For the inclusion of the remaining resprouts the following formula was used below proposed by Mota et al. (2014):

$$DNSf = \sqrt{DNS_1^2 + DNS_2^2 + \ldots + DNS_n^2} \quad (1)$$

To obtain the phytosociological parameter of Absolute Dominance (DA), the *software* Fitopac 2.1.2 (Shepherd, 2010) was used.

The botanical determination of the specimens was based in floral and vegetative morphological characters and with the use of botanical collections, by comparison of collected exsiccates with determined material at Herbário Caririense Dárdano de Andrade-Lima, Universidade Regional do Cariri (HCDAL-URCA) and Herbário Prisco Bezerra, Universidade Federal do Ceará (EAC-UFC), in addition to expert and literature consulting. Family-level classification follows the system of Angiosperm Phylogeny Group IV-APG IV 2016 and the spelling of taxa was checked at the data banks of Missouri Botanical Garden (2008) and Flora do Brasil 2020 (Brasil, 2019).

The rock cover evaluation followed the criterions of Mota et al. (2014), adapted in all parcels to the Braun-Blanquet value scale (Mueller-Dombois & Ellenberg, 1974). The grades were given to the outcrops by the same observer and varied from zero to four, depending on the frequency of the outcrop in each parcel, being zero for absence; one: 1-25% of occurrence in the parcel; two: 26-50% of occurrence in the parcel; three: 51-75% and four: 76-100%. The value of the grade given to each parcel was used as a categoric variable in the multivariate analysis matrix (Mota et al., 2014). The parcels with a grade ≥ 3 were classified as a rocky outcrop landscape (Environment II).

In the soil analysis, samples were collected from two different areas (Environments I and II), at the depths of 0-20 and 0-40 cm, (Drumond & Calixto-Junior, 2018) and taken to the Water and Plant Lab, EMBRAPA Semiárido (Petrolina, Pernambuco State) to obtain the physical and chemical values and attributes of the soil.

To evaluate the relationship between soil chemical attributes and floristic diversity at Environments I and II, a Principal Component Analysis (PCA), using the software PAST v.3.23 (Hammer et al., 2001) was made. This is an indirect sorting technique, originally descript by Pearson (1901) and introduced in vegetation studies by Órloci (1966). The components generated in PCA are sets of independent, uncorrelated variables, with normal distribution. In the generated component matrix, each sampling unit (parcel) has a value for each species and for each environmental variable. Each individual (species) has a value for each component, and receive together the name of component values, which vary in importance, being of interest to show the most significative and/or main (Filfili et al., 2013).

3. Results

3.1 Diversity on Environments I and II

In the presence/absence of rocky outcrop analysis, parcels were sorted in two environments: Environment I (without rocky outcrops) with sampling units 1, 2, 6, 7, 8 and 9; and environment II (with rocky outcrops) with sampling units 3, 4, 5, 10, 11 and 12.

The phytosociological survey encountered 906 individuals distributed in 46 species, 43 genera and 22 botanical families. In environment I, 45 species were registered, and in environment II, there were 31 species.

The most representative families in environment I (Table 1) were: Fabaceae (10 spp.), Bignoneaceae (4 spp.), Malvaceae (4 spp.), Rubiaceae and Salicaceae, both with three species. In environment II, family Fabaceae had 5 species; Bignoneaceae (3), Rubiaceae, Salicaceae, Vochysiaceae and Anacardiaceae had 2 species, pointing to a significative reduction of species richness in comparison with environment I.

In relation to the number of individuals, 559 (61.6%) of the 906 measured specimens were sampled at environment I and 347 (38.4%) at environment II. The species with highest absolute dominance values were: *Anacardium occidentale* (3.01); *Hymenaea stignocarpa* (1.29); *Qualea parviflora* (1.04) *Callisthene fasciculata* (0.66) and *Annona leptopetala* (0.66).

3.2 Multivariate Analysis (PCA)

The PCA analysis for the distribution of species between the two environments related *H. stigonocarpa* (Fabaceae), *A. leptopetala* (Annonaceae); *C. fasciculata* (Vochysiaceae), *Guettarda virbunoides* and *Psdium mysinites* as the ones obtaining the most significative values for Environment I axis (Figure 2). The analysis also demonstrated that *Astronium fraxilifoium* (Anacardiaceae), *Dalbergia cearenses* (Fabaceae) and *Handroanthus impetiginosus* (Bignoniaceae) are the species with more similar values between the two main component axes, suggesting that these species are more homogeneously distributed between the two environments. *Q. parviflora* (Vochysiaceae) and *A. occidentale* (Anacardiaceae) had the most representative values for the Environment II axis, pointing that these species dominate environments where there are rocky outcrops.

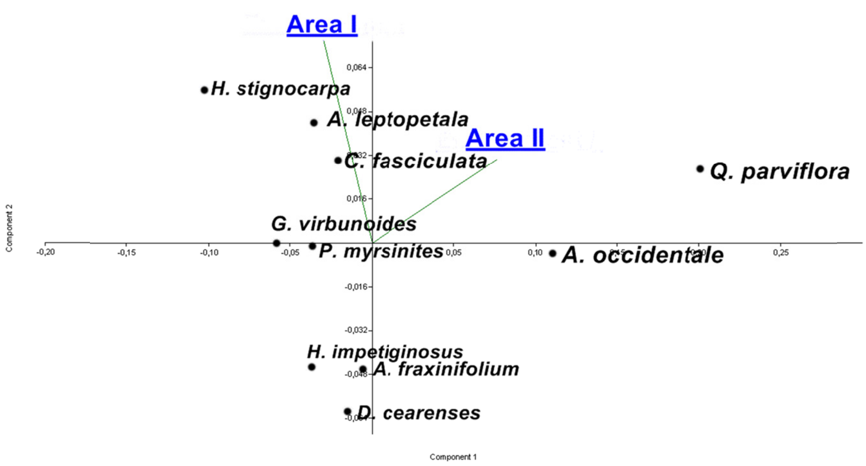

Figure 2. Ordering diagram of Principal component analysis (PCA) of 10 most representative species on two substrate tpes of a Cerrado fragment at Serra do Boqueirão, Lavras da Mangabeira, Ceará, Brazil

Table 1. Floristic composition of a Cerrado *Sensu stricto*, Serra do Boqueirão, Lavras da Mangabeira, Ceará, Brazil

Family	Species	Common name	Area I	Area II	AD
Anacardiaceae	*Anacardium occidentale* var. microcarpum	Cajuí	10	61	3.01
	Astronium fraxinifolium Schott	Gonçalo-Alves	12	18	0.42
Annonaceae	*Annona leptopetala* (R.E.Fr.) H.Rainer	Bananinha	65	20	0.42
Apocynaceae	*Aspidosperma cuspa* (Kunth) S.F.Blake	Pereiro-branco	20	9	0.10
	Aspidosperma pyrifolium var. molle (Mart.) Müll.Arg.	Pereiro-preto	5	7	0.06
Bignoniaceae	*Cuspidaria argentea* (Wawra) Sandwith	Cipó-rosa	5	14	0.08
	Handroanthus impetiginosus (Mart. ex DC.) Mattos	Ipê-roxo	19	8	0.28
	Tabebuia aurea (Silva Manso) Benth & Hook.f. ex S. Moore	Craibeira	6	9	0.21
	Jacaranda caroba (Vell.) DC.	Caroba-bocade-sapo	6	Aus.	0.06
Bixaceae	*Cochlospermum vitifolium* (Willd.) Spreng.	Pacoté	4	1	0.09
Burseraceae	*Commiphora leptophloeos* (Mart.) J.B.Gillett	Umburana-de-cambão	2	1	0.04
Cactaceae	*Cereus jamacaru* DC.	Mandacaru	1	4	0.10
Combretaceae	*Combretum glaucocarpum* Mart.	Sipaúba	4	1	0.12
	Combretum leprosum Mart.	Mofumbo	4	Aus.	0.02
Dilleniaceae	*Curatella americana* L.	Lixeira	6	5	0.38
Euphorbiaceae	*Croton jacobinensis* Baill.	Marmeleiro	5	Aus.	0.02
Fabaceae	*Dahlstedria araripensis* (Benth.)	Angelim	6	9	0.66
	Amburana cearensis (Allemão) A.C.Sm.	Umburana-de-cheiro	5	1	0.05
	Dalbergia cearenses Ducke	Violete	6	13	0.45
	Plathymenia reticulata Benth.	Pau-amarelo	16	10	0.39
	Luetzelburgia auriculata (Allemão) Ducke	Pau-mocó	Aus.	1	0.07
	Hymenaea stigonocarpa Mart. ex Hayne	Jatobá-de-veado	85	Aus.	1.29
	Bauhinia sp.	Pata-de-vaca	5	Aus.	0.02
	Libidibia ferrea (Mart. ex Tul.) L.P.Queiroz	Pau-ferro	4	Aus.	0.03
	Machaerium acutifolium Vogel	Coração-de-negro	7	Aus.	0.17
	Mimosa tenuiflora (Willd.) Poir.	Jurema-preta	2	Aus.	0.00
	Vatairea macrocarpa (Benth.) Ducke	Amargoso	2	Aus.	0.01
Lythraceae	*Lafoensia vandelliana* Cham. & Schldt. Subsp. vandelliana	Romã-brava	20	1	0.08
Malpighiaceae	*Byrsonima gardneriana* A. Juss.	Murici	11	1	0.06
Malvaceae	*Helicteres macropetala* A. St.-Hil.	Saca-rolha	2	Aus.	0.01
	Luehea candicans Mart. & Zucc.	Açoita-cavalo1	8	Aus.	0.04
	Luehea paniculata Mart. & Zucc.	Açoita-cavalo2	3	1	0.06
	Pseudobombax marginatum (A.St.-Hil., Juss. & Cambess.) A.Robyns	Embiratanha	2	Aus.	0.01
Moraceae	*Brosimun gaudichaudii* Trécul	Inharé	18	2	0.39
Myrtaceae	*Psidium myrsinites* DC.	Araçá-bravo	42	14	0.24
Olacaceae	*Ximenia americana* L.	Ameixa	5	2	0.02
Rubiaceae	*Coutarea hexandra* (Jacq.) K.Schum.	Quína-Quina	2	Aus.	0.00
	Guettarda viburnoides Cham. & Schltdl.	Veludo-branco	47	7	0.60
	Tocoyena formosa (Cham. & Schltdl.) K.Schum.	Jenipapo	3	1	0.01
Rutaceae	*Zanthoxylum* sp.	Laranjinha	2	4	
Salicaceae	*Laetia* sp.	Pau-piranha	4	1	
	Prockia crucis P. Browne ex L.	Farinha-seca	1	Aus.	
	Xylosma ciliatifolia (Clos) Eichler	Espinho-de-judeu	3	2	
Simaroubaceae	*Simarouba amara* Aubl.	Pau-Paraíba	8	Aus.	0.02
Vochysiaceae	*Qualea parviflora* Mart.	Pau-terra	7	94	1.04
	Callisthene fasciculata Mart.	Carvoeiro	55	23	0.66

Note. Area I = Environment without rocky outcrops; Area II = Environment with rocky outcrops; AD = Absolute dominance e Aus. = Absent species for this environment.

3.3 Physical/Chemical Aspects of the Soil

The kind of substrate in which the plant community grows, according to the classification of IPECE (2019) for the 1st cathegoric level are variations of Neosoil and Luvisoils. Granulometric tests, according to textural classification triangle (Lemos & Santos, 1984) (Figure 3) demonstrate a sandy soil with variations between the classes "franco-arenoso" and "areia franca" for environment I and just "areia franca" for environment II.

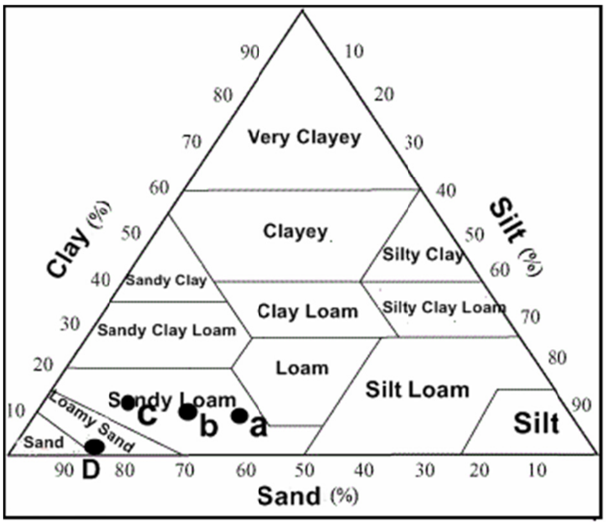

Figure 3: Soil textural classification triangle of a Cerrado *Sensu stricto* fragment at Serra do Boqueirão, Lavras da Mangabeira, Ceará, Brazil. Adapted from Lemos and Santos (1984)

Note. a = soil sample taken at depths of 0-20 cm and b = samples taken at depths of 0-40 cm in a rocky outcrop environment; c = samples taken at depths of 0-20 cm and D = samples taken at depths of 0-40 in environments without rocky outcrops.

The results obtained for porosity (Table 2) are over 50% in both substrates, in wich this value (51.47%) was reached at the 0-20 cm level for environment I and for environment II porosity is even higher, varying from 53.82 to 54.77% also the 0-20 cm level.

Table 2. Analytical result—soil physics of a Cerrado *Sensu stricto* fragment located at Serra do Boqueirão, Lavras da Mangabeira, Southern Ceará, Brazil. Carried out by Soil, water and plant analysis laboratory, Taniguchi (2018)

Substrate	Soil density (Kg/dm^3)	Porosity (%)
Area I (0-20 cm)	1.316	51.47
Area I (20-40 cm)	1.392	47.45
Area II (0-20 cm)	1.166	54.77
Area II (20-40 cm)	1.223	53.82

Regarding chemical attributes, PCA (Figure 4) showed a high concentration of Aluminum (Al) (1.00 $cmol_c$ dm^{-3}—0-20 cm/1.15 $cmol_c$ dm^{-3}—20-40 cm) and higher acidity (pH: 4.2—0-20 cm/4.1—20-40 cm) for environment II (Table 3). The values for the potassium concentration (K); Sodium (Na), Calcium (Ca) and Magnesium (Mg) were also recorded in larger amounts in the rocky substrate, however, in low concentration for both study sites. Aluminum saturation reached high levels in the deepest horizons of soil in environment II (7.9 $cmol_c$ dm^{-3}—20-40 cm).

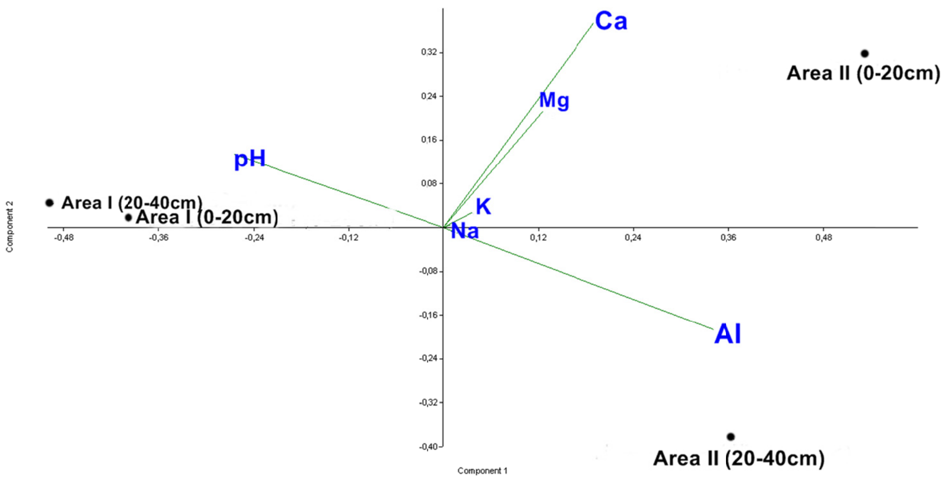

Figure 4. Multivariate Principal Component Analysis (PCA) of soil chemical attributes in a Cerrado *Sensu stricto* fragment at Serra do Boqueirão, Lavras da Mangabeira, Ceará, Brazil

Note. Environment I = substrates without rock outcrops; Environment II = substrates with rocky outcrops; Al = aluminum; K = Potassium; Na = Sodium; Ca = Calcium and Mg = Magnesium.

Table 3. Chemical soil analysis of a Cerrado *senso stricto* fragment at Serra do Boqueirão, Lavras da Mangabeira, Southern Ceará, Brazil. Soil, water and plant analysis laboratory, Taniguchi (2018)

Substrate	pH	K	Na	Ca	Mg	Al	Al + H
		$cmol_c\,dm^{-3}$					
Area I (0-20 cm)	4.6	0.16	0.10	0.5	0.45	0.45	2.4
Area I (20-40 cm)	4.7	0.20	0.10	0.5	0.40	0.40	1.4
Area II (0-20 cm)	4.2	0.27	0.12	1.1	0.60	1.00	7.4
Area II (20-40 cm)	4.1	0.22	0.11	0.5	0.25	1.15	7.9

4. Discussion

Until then, a reduction both in diversity and volume of woody vegetation can be observed, at environments where there are rocky outcrops, in comparison with environments without them. Studies conducted by Mota et al. (2014) at Parque Estadual do Biribiri (PEB), Diamantina, Minas Gerais State (Southeastern Brazil), reinforce that the presence of rocky outcrops inside some parcels influence the differerentiation of floristic composition. Moura et al. (2010) evidence the good species richness for a rocky Cerrado *sensu stricto* area at Parque Estadual dos Pireneus, Goiás State (Mid-west Brazil), in deep and well-drained latosoils. Similar studies conducted by Amaral et al. (2006), Felfili and Fagg (2007), Felfili et al. (2007), Miranda et al. (2007), Moura et al. (2007) and Pinto et al. (2009) corroborate this tendency, suggesting that other factors, besides the presence of rock, may also influence the floristic composition of the studied environments.

The PCA analysis also pointed to a strong dependence for *H. stignocarpa* and *Q. parviflora*, while evidenced a notorious dominance of both species in their respective substrates, what is confirmed by the numeric factor, all the 85 individuals of *H. stignocarpa* were registered only at environment I and *Q. parviflora* demonstrated the same numerical tendency, for of the 101 individuals registered, 94 (93%) are at environment II. *A. occidentale* seems to vie the dominance with *Q. parviflora* in the rocky substrate, whilst *C. fasciculata* demonstrates good competitiveness in environment I. The presence of *A. leptopetala* in the vie for dominance in environment I suggests that the Caatinga vegetation may be invading the Cerrado fragment.

The evidence for these hierarchical variations between woody species populations in different kinds of substrates demonstrated in this study can be explained by Ricklefs (2010), who states that plants, by exploiting resources punctually and having a sessile life habit, have the abiotic factors as the main selective pressures to evolution, thus limiting species distribution.

Gomes et al. (2011) point that *A. occidentale* and *Q. parviflora* were important for the vegetation structure in deep soils of typical Cerrado and shallow soils with rocky outcrops at Parque Municipal do Bacaba, Nova

Xavantina, Mato Grosso state (Mid-west Brazil). Lemos et al. (2013), in similar studies in a Cerrado *sensu stricto* area in Tocantins state (Mid-west Brazil) suggest that *A. occidentale* and *Q. parviflora* seem not to be influenced by different kinds of substrates. Ratter et al. (2003) point that taxa of the genus *Qualea* are well-adapted to different substrates, and thus are widely distributed by the Cerrado biome.

Those facts do not corroborate this study, for as demonstrated, *A. occidentale* and *Q. parviflora* significantly lose their representativeness in number of individuals in environments where rocky outcrops are absent, reinforcing the hypothesis that the presence of rocky outcrops is not the only determinant factor that may be influencing the distribution and competitiveness dynamics of the studied plant communities.

There were little variations in soil density between the two environments. Environment I demonstrated a slightly higher density in comparison to environment II, but the density value did not surpass 1.39 Kg/dm^3. Skopp (2002) and Donagemma et al. (2016) understand that sandy soil density varies from 1.4 to 1.9 g cm^{-3}, what reflects the occurrence of a greater clustering in sandy materials; in this case, the value of 1.85 g cm^{-3} is critical for root development.

Converting the maximum value in this study to the values evaluated by Skopp (2002) and Donagemma et al. (2016), the maximum of 1.3 g cm^{-3} was obtained, whic suggests that soil density is not a limitant factor to the development of the woody species of Serra do Boqueirão.

Donagemma et al. (2016) confirm that Quartzarenics Neossolos stand out in the Brazilian System of Soil Classification (SiBCS), having sandy texture in all horizons, reaching 1.50m from the surface or reaching the lithic bed, covering ca. 15% of the Cerrado area in Brazil.

Tognon (1991) defends that soil porosity interferes in aeration, water conduction and retention, resistance to penetration and ramification of roots, and consequently in the utilization of available water and nutrients. Pessoa-de-Souza et al. (2015), in studies conducted with Quartzarenics Neossolos corroborate the obtained results, where the total porosity volume did not reach 50%, and by the way evidenced a kind of orthic Neossolo Quartzarênico, for not offering resistance to water percolation, thus allowing a higher physical-hydric dynamics of the terrain, which also contributes to a susceptibility to water erosion due to the high level of porosity.

Balbino-Miguel et al. (2010) declared that in soils with pH below 5.0, the high concentration of available aluminum (Al) is one of the factors that cause major toxicity problems, which is a limiting factor to plant growth, since the presence of Al reduces root growth and development, as well as decreases nutrient absorption. Haridasan (2000), Salvador et al. (2000), Echart and CavallI-Molina (2001), and Gomes et al. (2011) corroborated these same trends and help us explain the loss of richness and dominance volume in the environment II.

Abreu et al. (2012) confirm a high aluminum saturation associated with environment with characteristics of sandy soils and observe that the physico-chemical analyses of the soil better explain the structural and floristic differences of the vegetation.

However, *Q. parviflora* and *A. occidentale* do not seem to be limited in relation to the aluminum concentration in the mentioned environment, indicating a type of tolerance to this element, judging by the fact that the PCA in consonance with the absolute dominance values, demonstrated that these species have a larger domain established in substrates with high aluminum saturation and acid pH.

Haridasan (2000) points out that several species of family Vochysiaceae are aluminum accumulators a trait which, therefore, gives them an adaptive advantage in environments with the presence of exchangeable aluminum.

Mota et al. (2014), following the same trend of the results obtained in this study, confirmed this hypothesis and indicated that Vochysiaceae and Fabaceae are the most representative families of the Brazilian Cerrado and that, nevertheless Fabaceae, despite having the nitrogen fixation capacity as one of its adaptive advantages for this domain, seems to be more influenced by rocky outcrops than Vochysiaceae.

The resistance of *A. occidentale* found in the present study may be a reflection of gene mutations, which conferred adaptive success through the limiting factors of the environment. Echart and Cavalli-Molina (2001) explain that Al tolerance can be controlled in different ways, from a single dominant gene to a complex one with additive effect genes acting on different biochemical pathways. In genetic studies conducted by EMBRAPA (2018) in *A. occidentale* seedlings, aluminum tolerance was pointed out in two distinct genotypes (CCP 06 and BRS 275), in which no symptoms of toxicity were present in presence of this element within 60 days of application.

Neri et al. (2007) confirm that most of Cerrado soil has acid pH and low concentration of available calcium and magnesium, with high concentration of exchangeable aluminum, which corroborates the characteristics of most of the soil of the studied area. It suggests that the chemical attributes of the soil associated with high all concentration may be the decisive factors for the establishment of common Cerrado species in the middle of Caatinga of Serra do Boqueirão, since Cerrado species are more adapted to inhabit substrates under these conditions.

5. Conclusions

The species *Anacardium occidentale*, *Hymenaea stigonocarpa* and *Qualea parviflora* were dominant in the Cerrado environment under study.

There were differences in diversity, hierarchy and dominance of arboreous plant populations between environments with and without the presence of rocky outcrops.

The physical characteristics of the soil suggest that the Cerrado fragment is susceptible to water erosion due to the high level of porosity.

Aluminum in consonance with the rocky outcrops, act as limiting abiotic factor for the establishment and development of woody species in the Cerrado fragment. *Q. parviflora* and *A. occidentale* have some kind of tolerance to aluminum toxicity in environments with pH below 5.0.

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