SCIENTIA FORESTALIS

ISSN 2318-1222 (online)

ORIGINAL ARTICLE

Phytosociology, diversity and floristic similarity of a Cerrado fragment on Southern Ceará state, Brazilian Semiarid

Fitossociologia, diversidade e similaridade florística de um fragmento de Cerrado no Sul do Ceará, Semiárido Brasileiro

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How to cite: Calixto Júnior, J. T., Moura, J. C., Lisboa, M. A. N., Cruz, G. V., Gonçalves, B. L. M., Barreto, E. S. S. T., Barros, L. M., Drumond, M. A., Mendonça, A. C. A. M., Rocha, L. S. G., Silva, M. A. P., Cordeiro, L. S. (2021). Phytosociology, diversity and floristic similarity of a Cerrado fragment on Southern Ceará state, Brazilian Semiarid. *Scientia Forestalis*, *49*(130), e3459. https://doi.org/10.18671/scifor.v49n130.01

Abstract

There is a lack of studies on phytosociology of Cerrado fragments within the Caatinga biome, located in the Southern region of Ceará State, associated to the Brazilian Crystalline Shield geological formation. Thus, contributing to the diagnosis and knowledge of this plant community, a survey on the general flora and especially the structure of arboreal vegetation was made. Every individual with SND ≥ 3cm (total height), within 12 parcels with 12x30 m (0.432 ha) of area was sampled. The floristic similarity was calculated by the Jaccard index, in comparison with ten other Brazilian Cerrado areas. Fourty-six species distributed in 22 families were found, comprising a total of 906 individuals, with AD=2,097.22 ind.ha^{-1}. The highest abundance was found within families Fabaceae (20.31%) and Vochysiaceae (19.98%). *Qualea parviflora, Annona leptopetala, Hymenaea stignocarpa* and *Callisthene fasciculata* had the highest IVI index species. The calculated biodiversity indexes were: alpha diversity of Shannon (*H'*) = 3.8 and equitability of Pielou (*J'*) = 0.83. The results obtained show the area as a vegetation relict, under threat due to the penetration of Caatinga species, climatic changes, insufficient conservation efforts and fast anthropic deforestation. As a result, this relict area tends to shrink to a fragment much smaller than it was in the past.

Keywords: Cerrado spots; Lavras da Mangabeira; Serra do Boqueirão.

Resumo

No Sul do Ceará há carência de estudos de fitossociologia em fragmentos de Cerrado em meio à Caatinga do cristalino. Assim, visando contribuir para o reconhecimento e diagnóstico dessa vegetação, realizou-se levantamento da flora e estrutura da vegetação arbórea em mancha localizada em solos profundos e relevo tabular na Serra do Boqueirão (289 m Alt.), em Lavras da Mangabeira (6°72'24" S e 38°97'73" W). Em 12 parcelas de 12x30m (0,432 ha) foram inventariados todos os indivíduos com DNS ≥ 3cm, observando-se altura total. Para observar a similaridade florística comparou-se, pelo método de Jaccard, outras 10 áreas de Cerrado em diferentes regiões do País. Foram encontradas 46 espécies distribuídas em 22 famílias, num total de 906 indivíduos, com DA=2.097,22 ind.ha^{-1}. As famílias Fabaceae (20,31%) e Vochysiaceae (19,98%) apresentaram maior número de indivíduos. *Qualea parviflora, Annona leptopetala, Hymenaea stignocarpa, Callisthene fasciculata* e *Anacardium occidentale* foram as espécies de maior IVI. O

Financial support: Cearense Foundation for Support for Scientific and Technological Development (FUNCAP) -BP3-0139-00197.01.00/18; National Council for Scientific and Technological Development (CNPq) and the Regional University of Cariri (URCA).
Conflict of interest: Nothing to declare.
Correspondig author: joaojrbio@gmail.com
Received: 30 August 2019.
Accepted: 22 January 2020.
Editor: Paulo Henrique Müller Silva.

índice de Shannon (*H'*) para a diversidade alfa foi 3,18, a equabilidade de Pielou (*J'*) foi 0,83 e o índice de Simpson (*C'*) foi 0,05. A diversidade beta entre o local estudado e outras áreas de Cerrado (central e disjuntos) foi considerada alta e a estatística apontou maior similaridade com Cerrado *sensu stricto* de tabuleiro litorâneo. Por fim, os resultados permitem caracterizar a área como relíquia vegetacional, que pela visível penetração da flora da Caatinga, aliada às modificações climáticas, ao desinteresse na preservação e aceleração do desmatamento pelo antropismo, tende a diminuir, restringindo-se à área bem menos ampla do que a que abrangeu a região no passado.

Palavras-chave: Manchas de Cerrado; Lavras da Mangabeira; Serra do Boqueirão.

INTRODUCTION

The Brazilian Cerrado is considered to host the highest biodiversity savanna environment of the world (Silveira, 2010), with more than 11,000 indigenous plant species cataloged (Klink & Machado, 2005), covering an estimated range of 2,036,448 Km^2 (ca. 22%) of the Brazilian territory (Instituto Brasileiro de Geografia e Estatistica, 2004).

The vegetation of the Cerrado biome comprises phyto-physiognomies including forest, savanna and grassland formations, "forest" being defined as an area with dominance of arboreal species (Ribeiro & Walter, 1998; Tavares, 2017).

The soil is mostly dystrophic, with a low pH and low concentration of available calcium and magnesium and a high concentration of interchangeable aluminum (Lopes & Cox, 1977; Neri et al., 2007). The soil characteristics, such as depth, fertility and draining capacity influence the phyto-physiognomies as much as the anthropic action does (Pivello & Coutinho, 1996; Neri et al., 2007).

Ceará state has 57% of its territory covered by forest-ranked formations (8,500,000 ha), the Caatinga being its main biome, comprising 88% of the plant cover. The Cerrado covers a much smaller area (0.4%) of the state (Brasil, 2016).

Freire (2007) conceptualizes enclaves as landscapes that differ in biotic configuration from the surrounding environment, as a result of the action of natural factors, mostly biogeographic, through geological time.

One of the many explanatory hypotheses for the presence of Cerrado enclaves in other biomes as the Amazonian and Atlantic rainforests, Caatinga (Brazilian semiarid) and coniferous forests in Southern Brazil is the Quaternary Refuge Hypothesis, which explains the expansion/retraction events of forests and arid environments through the rapid climatic variations of the Quaternary Period (Ab'Saber, 1963; Cole, 1986; Carneiro-Filho, 1993; Santos et al., 2015).

The Southern Ceará state enclaves were first identified by Figueiredo & Fernandes (1987) and are restricted to small sedimentary reliefs located in the municipalities of Lavras da Mangabeira, Aurora, Granjeiro, Várzea Alegre, Farias Brito, Cedro, Jucás and at the top of the Chapada do Araripe (Figueiredo, 1997; Moro et al., 2015; Nepomuceno, 2016).

According to Figueiredo & Fernandes (1987), the soil in those areas is deep (ca. 2 m), red with a well-defined tone in the subsurface horizons, well-drained, being classified as podzol, which is present in the region along with other types as the noncalcic Bruno.

The execution of conservation of the biodiversity projects and sustainable management plans is only possible when the vegetation, its limitations and resilience capacity of the area of interest are properly known (Ferraz et al., 2013). Xavier (2009) emphasizes that phytosociology and floristics studies are important contributions to the knowledge of forest formations, as they display a survey on the species richness and heterogeneity of the sampled areas. For Tavares (2017), the floristics and phytosociology knowledge of forests are essential for the conservation of those formations, especially for conservation efforts, a major concern in Brazil, due to the high level of anthropic perturbations and a progressive weakening of the environmental public policies.

In this sense, this study aims in an analysis of the aspects of floristic composition, diversity and phytosociology of a Cerrado fragment at the Serra do Boqueirão, Lavras da Mangabeira municipality, Ceará state, Brazil. This is the first effort in studying the descriptive, structural and similarity aspects on the regional flora. This contribution is also highly relevant because

of the invasion of the Cerrado fragments by the typical Brazilian semiarid vegetation, the Caatinga. As observed in this spot, this is mostly caused by topographic degradation, climate change and anthropic action due to agriculture, cattle ranching and construction industries, as well as lack of interest from the government in environment conservation and a weakening of environmental policy. As a result, the Cerrado fragments are being highly supressed and occupy an area that is much smaller than it was in the past.

MATERIAL AND METHODS

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 designated as the Lavras da Mangabeira microregion and Southern-Central Ceará mesoregion (Instituto Brasileiro de Geografia e Estatistica, 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 of a private property, surprisingly well-preserved, without any agricultural or ranching 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 (Fundação Cearense de Meteorologia e Recursos Hídricos, 2019), the rain season being from January to April. The average annual temperature is 26.8º C (Instituto Nacional de Pesquisas Espaciais, 2019).

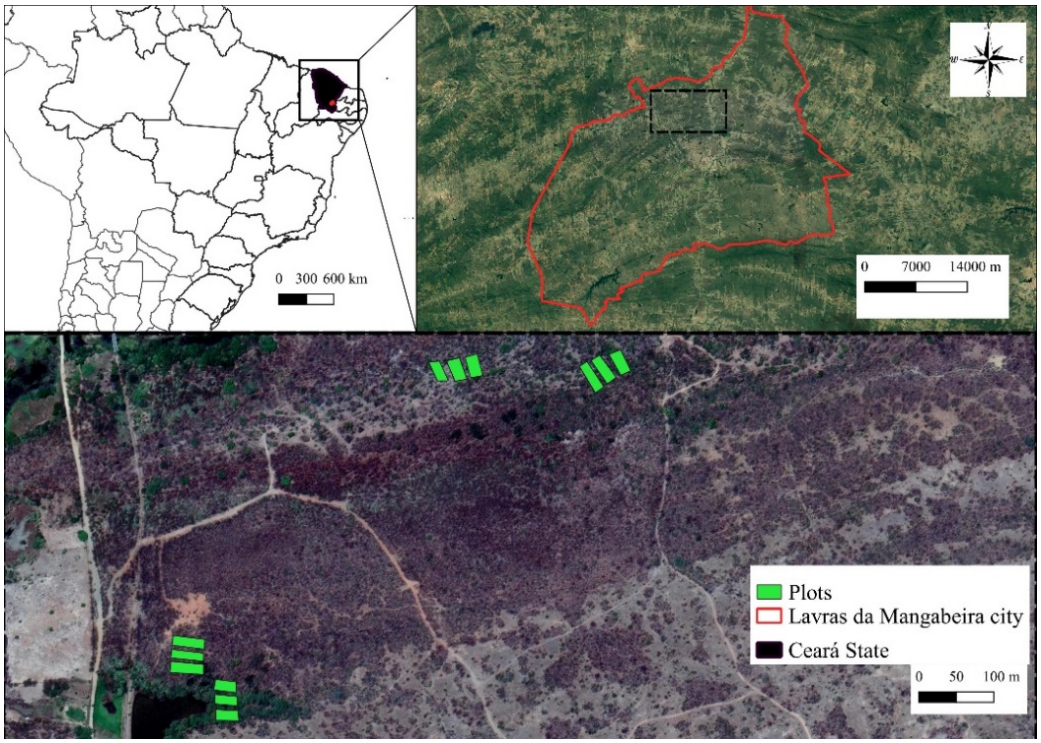

Figure 1: Geo**graphic loc**ation of Serra do Boqueirão, Lavras da Mangabeira, Southern Ceará.

The region is intensely faulted, with the fault lines converging in a West-East direction, joining the Patos fault lining in Paraíba State. The local site of study lies between the Várzea Alegre, Granjeiro and Cuncas faults. The relief consists mainly of desiccated structural crystalline surfaces, with elongated dales and interfluves. The highly desiccated interfluves bear narrow horizontal surfaces with parallel grooves generally running along the fractures of the slopes (Figueiredo & Fernandes, 1987).

Sample Sufficiency

To test the sufficiency of the samples, the REGRELRP procedure on the SAEG software version 9,1 (SAEG, 2007) was used, as in Calixto Júnior & Drumond (2011), following the sense of "species/area curve".

The sample precision was also tested by the standard error method. The coverage of this sample was observed by the calculation of the confidence interval for the density and dominance parameters, with an error limit from 10 to 95% of probability, according to Felfili & Rezende (2003).

Data collection and treatment

A forest inventory was made to characterize the Cerrado vegetation, using the parcel methodology as proposed by Mueller-Dumbois & Ellenberg (1974): twelve parcels with 360 m^2 (12m x 30m) of area were systematically established, totalizing 0.432 ha of area covered.

Every living individual with a DNS (30 cm-height from soil) ≥ 3 cm was measured, as well as the total height. The measure of DNS was made with a caliper and for the total height, a graduated telescopic rod, according to Ferraz et al. (2013). In case of secondary shoots, the one with the largest diameter was measured and if it conformed to the inclusion criterions; that one and the other shoots were included, as suggested by Rodal (1992).

The botanical determination of the material was made using floral and vegetative morphological characters and by comparison with catalogued preserved specimens housed at the following botanical collections: Herbário Caririense Dárdano de Andrade-Lima, Universidade Regional do Cariri (HCDAL-URCA) and Herbário Prisco Bezerra, Universidade Federal do Ceará (EAC-UFC). Specialists and literature were also consulted for determination. The classification was based on APG IV (Angiosperm Phylogeny Group, 2016) and the taxon orthography was based on the databanks of the Missouri Botanical Garden (2019) and Flora do Brasil 2020 (2019).

Phytosociological Analysis

The phytosociological parameters were calculated with the Fitopac version 2.1.2 (Sheperd, 2010) software. The general parameters of the plant community, such as: total density, basal area, heights and diameters; and species-related parameters: absolute density (AD), relative density (RD), absolute frequency (AF), relative frequency (RF), absolute dominance (ADo), relative dominance (RDo), cover value index (CVI) and importance value index (IVI) were analyzed.

For the analysis of the alpha-diversity, related to the abundance and number of the species of the community, the following indexes were used: diversity of Shannon-Weaver (*H'*) (on Neperian base), concentration of Simpson (*C'*) and equitability of Pielou (*J'*), allowing the representation of the uniformity of the distribution of the individuals among every species (Magurran, 1988).

Similarity analysis

To identify the floristic similarity between the studied area and other surveys in different Cerrado areas (either disjunct or Central Cerrado) an absence/presence matrix of the species cited in ten other surveys made in eight Brazilian states was compared: Saporetti-Junior et al. (2003), Abaeté-MG; Silva-Neto et al. (2016), Dueré-TO; Assunção & Felfili (2004), APA do Paranoá-DF; Finger & Finger (2015), Chapada dos Guimarães and Baixada Cuiabana-MT; Moro et al. (2011), Fortaleza-CE; Medeiros et al. (2008), Carolina-MA; Oliveira et al. (2015), Jaborandi-BA; Imaña-Encinas et al. (2007), EcoMuseu do Cerrado, Pirinópolis-GO; Costa & Araújo (2007), Chapada do Araripe, Barbalha-CE and Neri et al. (2007), Rio Jequitinhonha basin-MG.

All synonymy was eliminated using the software of the Royal Botanical Garden Species Index. The comparison between areas was conducted using the Jaccard similarity index (*J'*),

which expresses the similarity between areas based on the number of shared species. The resulting floristic similarity matrix was used for a cluster analysis by the UPGMA method, generating a dendrogram (Sneath & Sokal, 1973), using Euclidian distance as dissimilarity measure, with the PAST version 3.23 (Hammer et al., 2011) software.

RESULTS AND DISCUSSION

Sample Sufficiency

In the determination of sample sufficiency by linear regression with plateau response (Figure 2), the minimum number sampling points and the intersection points between the crescent slope and the plateau were considered. The intersection was obtained from the ninth parcel (3,240 m^2 of sampled area), with 78% of the species sampled, and no new registers of species were obtained in the latest three parcels, thus considering the sampling effort sufficient for the area.

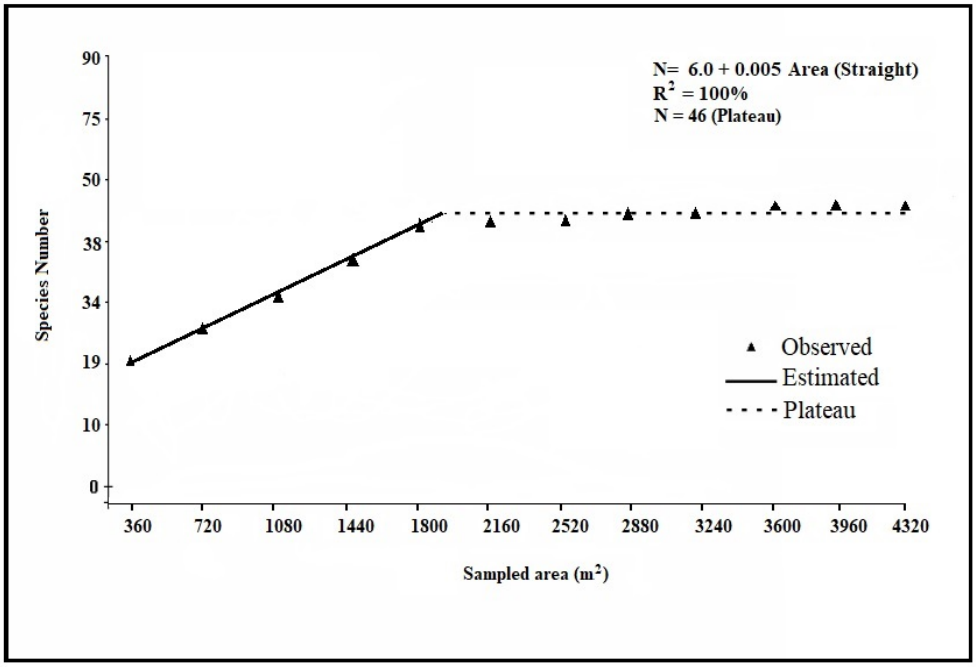

Figure 2. Graphic representation of sample sufficiency of the Cerrado fragment, Serra do Boqueirão, Lavras da Mangabeira, Ceará.

The inventory, with a total of 906 arboreal individuals, generated an estimative of absolute density of 2,097.22 ind.ha^{-1} (IC = ± 202.67 ind.ha^{-1}) at 95% probability and 6.16% standard error; a basal area (dominance) estimate of 5.17 m^2 ha^{-1} (IC = ± 6.93 m^2 ha^{-1}) at 95% of probability and 8.09% standard error. These values agree with an adequate and comprehensive sampling precision for the estimation of quantitative variables (Felfili & Rezende, 2003).

Floristic composition and diversity

The sampled individuals belong to 46 species distributed among 43 genera and 22 botanical families (Table 1). The species-richest families were: Fabaceae (11), Bignoniaceae (4), Malvaceae (4), Rubiaceae (3) and Salicaceae (3), which corresponds to 54.3% of the total of species sampled. Four other families had two species and thirteen families had individuals from only one species. Fabaceae included 23.9% of the species found.

Table 1: Floristic composition of a Cerrado fragment, Serra do Boqueirão, Lavras da Mangabeira, Northeast of Brazil.

Family	Species	Common Name	Dominion	Voucher
Anacardiaceae	*Anacardium occidentale* var. microcarpum	Cajuí	Cer	13690
	Astronium fraxinifolium Schott	Gonçalo-Alves	Cer	13691
Annonaceae	*Annona leptopetala* (R.E.Fr.) H.Rainer	Bananinha	Cer	13492
Apocynaceae	*Aspidosperma cuspa* (Kunth) S.F. Blake	Pereiro-branco	Cer	13822
	Aspidosperma pyrifolium var. molle (Mart.) Müll.Arg.	Pereiro-preto	Caa	13531
Bignoniaceae	*Cuspidaria argentea* (Wawra) Sandwith	Cipó-rosa	Cer	13466
	Handroanthus impetiginosus (Mart. ex DC.) Mattos	Ipê-roxo	Cer	13541
	Tabebuia aurea (Silva Manso) Benth & Hook.f. ex S. Moore	Craibeira	Cer	13612
	Jacaranda caroba (Vell.) DC.	Caroba-boca-de-sapo	Cer	13464
Bixaceae	*Cochlospermum vitifolium* (Willd.) Spreng.	Pacoté	Caa	13652
Burseraceae	*Commiphora leptophloeos* (Mart.) J.B.Gillett	Umburana-de-cambão	Caa	13495
Cactaceae	*Cereus jamacaru* DC.	Mandacaru	Caa	-
Combretaceae	*Combretum glaucocarpum* Mart.	Sipaúba	Caa	13535
	Combretum leprosum Mart.	Mofumbo	Caa	14048
Dilleniaceae	*Curatella americana* L.	Lixeira	Cer	13688
Euphorbiaceae	*Croton jacobinensis* Baill.	Marmeleiro	Caa	13497
Fabaceae	*Dahlstedria araripensis* (Benth.)	Angelim	Cer	13693
	Amburana cearensis (Allemão) A.C.Sm.	Umburana-de-cheiro	Caa	-
	Dalbergia cearenses Ducke	Violete	Caa	-
	Plathymenia reticulata Benth.	Pau-amarelo	Cer	13692
	Luetzelburgia auriculata (Allemão) Ducke	Pau-mocó	Caa	13651
	Hymenaea stigonocarpa Mart. ex Hayne	Jatobá-de-veado	Cer	13647
	Bauhinia sp.	Pata-de-vaca	Caa	-
	Libidibia ferrea (Mart. ex Tul.) L.P.Queiroz	Pau-ferro	Caa	13611
	Machaerium acutifolium Vogel	Coração-de-negro	Cer	-
	Mimosa tenuiflora (Willd.) Poir.	Jurema-preta	Caa	-
	Vatairea macrocarpa (Benth.) Ducke	Amargoso	Cer	-
Lythraceae	*Lafoensia vandelliana* Cham. & Schldt. Subsp. vandelliana	Romã-brava	Cer	13584
Malpighiaceae	*Byrsonima gardneriana* A. Juss.	Murici	Cer	13493
Malvaceae	*Helicteres macropetala* A. St.-Hil.	Saca-rolha	Cer	13557
	Luehea candicans Mart. & Zucc.	Açoita-cavalo1	Cer	13556
	Luehea paniculata Mart. & Zucc.	Açoita-cavalo2	Cer	54641*
	Pseudobombax marginatum (A.St.-Hil., Juss. & Cambess.) A.Robyns	Embiratanha	Caa	-
Moraceae	*Brosimun gaudichaudii* Trécul	Inharé	Cer	13689
Myrtaceae	*Psidium myrsinites* DC.	Araçá-bravo	Cer	13537
Olacaceae	*Ximenia americana* L.	Ameixa	Caa	-
Rubiaceae	*Coutarea hexandra* (Jacq.) K.Schum.	Quína-Quina	Cer	54746*
	Guettarda viburnoides Cham. & Schltdl.	Veludo-branco	Cer	13491
	Tocoyena formosa (Cham. & Schltdl.) K.Schum.	Jenipapo	Cer	13483
Rutaceae	*Zanthoxylum sp.*	Laranjinha	Cer	-
	Laetia sp.	Pau-piranha	Caa	13467
Salicaceae	*Prockia crucis* P. Browne ex L.	Farinha-seca	Cer	54741*
	Xylosma ciliatifolia (Clos) Eichler	Espinho-de-judeu	Cer	-
Simaroubaceae	*Simarouba amara* Aubl.	Pau-Paraíba	Cer	13648
Vochysiaceae	*Qualea parviflora* Mart.	Pau-terra	Cer	13463
	Callisthene fasciculata Mart.	Carvoeiro	Cer	13462

*Identified species at Herbário Prisco Bezerra (EAC), Universidade Federal do Ceará – UFC. Cer = Cerrado; Caa = Caatinga.

Like many other tropical forests, a richness of the family Fabaceae was observed (Matos; Felfili, 2010). According to Cordeiro (2002) in the Cerrado this family is associated to the capacity of symbiotic nitrogen fixation, which represents an adaptive advantage under unbalanced environmental conditions.

According to Pereira et al. (2011), the richest families in Cerrado *stricto sensu* are: Fabaceae, Malvaceae, Anacardiaceae, Apocynaceae and Bignoniaceae, and the richness of each family varies between localities and usually the sum of species numbers is above 50% of the total per hectare, which corroborates with the results of this study. Mendonça et al. (2008) state that the presence of the families Vochysiaceae, Fabaceae and Myrtaceae is frequent in Central Brazilian Cerrado.

Studies made at Chapada do Araripe, Ceará (ca. 50 Km in a straight line from the sampling site) in an area of Cerrado *s.s.* (Barbalha municipality) by Costa & Araújo (2007) and Bezerra (2018) in a "cerradão" area at Crato municipality had shown similar results about family representativity and taxon numbers. Other studies made in Cerrado areas in different regions of Brazil corroborate these studies: Medeiros et al. (2008), Lemos et al. (2013) and Oliveira et al., (2015) in the Northeastern Cerrado; Saporetti-Junior et al. (2003); Assunção & Felfili (2004), Matos & Felfili (2010) and Oestreich-Filho (2014) in the central region Cerrado.

As for the number of individuals, the seven best represented families corresponded to 80.3% of the total of individuals sampled, which are distributed as follows: Fabaceae (20.3%), Vochysiaceae (19.9%) Anacardiaceae (11.1%), Annonaceae (9.6%), Bignoniaceae (6.7%), Rubiaceae (6.6%) and Myrtaceae (6.1%). The remaining families had values below 5% individuals. Similar results were obtained by Gentry et al. (1997) and Mendonça et al. (1998), who have shown Fabaceae and Vochysiaceae as the best represented families of the Central Brazilian Cerrado, in terms of number of individuals. These results agree with the tendency of a few families dominating others in the phyto-physiognomies of Cerrado *s.s.* in Brazil (Sampaio et al., 2018).

The success of the family Vochysiaceae is probably associated to the capacity of aluminum accumulation by some of its species (Haridasan, 2000; Mews et al., 2011), which represents a competitive advantage in dystrophic soils with low saturation of interchangeable bases, low cationic exchange capacity, high acidity and high aluminum concentration, as is the case of most soils of the Cerrado biome. Furthermore, many species of those families have reproductive strategies well-adapted to the climatic conditions of the Cerrado, with seed dispersal in the beginning of the wet season, good germination ratio and absence of seed dormancy (Oliveira, 2008).

The alpha diversity index of Shannon-Weaver (*H'*) was 3.18; the equitability of Pielou (*J'*) was 0.83 and the concentration index of Simpson (*C'*) was 0.05. These values suggest a high species richness (and thus an elevated alpha diversity), a high uniformity of the size of the populations and a low concentration of species. According to Saporetti Junior et al. (2003), *H'* values beyond 3.11 indicate well-preserved plant formations. Hypothetically, the value of *J'* obtained suggests that a total of only 17% of species reaches the maximum diversity in the community, according to Brower et al. (1998).

Results agreeing with this study were appointed by Silva-Neto et al. (2016), in which values of *H'* e *J'* were respectively 3.21 and 0.86 in a Cerrado *s.s.* area in Tocantins state, Central Brazil. In this case, it was possible to observe a tentatively high floristic heterogeneity of the arboreal component, along with a low ecological dominance.

The alpha diversity in the Cerrado spot at the Serra do Boqueirão is considered high in comparison with the typical semiarid Caatinga areas, in which the Shannon-Weaver indexes vary from 1.10 to 3.09 (Calixto Júnior & Drumond, 2014). Medeiros et al. (2008) point to Shannon-Weaver values between 3.11 and 3.62 as representative for many areas of the central Cerrado in Mato Grosso, Minas Gerais and Goiás states and Distrito Federal.

The presence of rare species is not usual, having only two (*Prockia crucis* e *Luetzelbugia auriculata*) occurring isolated (only one individual registered) and four others (*Coutarea hexandra*, *Pseudobombax marginatum*, *Helicteres macropetala* e *Mimosa tenuiflora*) registered only two individuals. Thirteen species (28,2%) are represented by five or less individuals.

P. crucis and *H. macropetala* are cited in phytosociological surveys in Southern Ceará for the first time in this study.

Thirty species in the sample (65.5%) are typical of Cerrado environments. The remainder of species (34.8%) are characteristic of the Caatinga that penetrate the enclave and with this intromission, compete with the Cerrado species, without, however, shading the physiognomy, as observed by Figueiredo & Fernandes (1987). *Pseudobombax marginatum* and *Mimosa tenuiflora*, correspond to 8.6% of the sampled individuals, along with 14 other typical Caatinga species.

Aspidosperma pyrifolium (12 espécimes), *Ximenia americana* (8) and *Amburana cearensis* (6) are typical examples.

Also important to note is the presence of eleven individuals of *Curatella americana* ("lixeira" or "simbaíba") an abundant species of the Central Cerrado, but absent in surveys at the *s.s.* Cerrado of Chapada do Araripe (Costa & Araújo, 2007) or occurring in low frequencies in savanna vegetation on pre-coastal "tabuleiros" in Fortaleza, Ceará (Moro et al., 2011).

Curatella americana is considered a colonizer and even a pioneer in savanna areas, given its performance and adaptive potential (Winterhalder, 1996; Calgaro et al., 2015) and due to its adaptations to fire resistance, like cracked stem and wide leaves. It is a typical example of a larger physiognomy that covered that area in the past, today represented only as a vegetation relict. According to Figueiredo & Fernandes (1987), this fact is evidenced by the global evolution of the landscape, especially the surface and soil structure. The deep weathering occurring in the semiarid confirms the occurrence of climatic conditions that were different from those occurring today, which allowed the development of the phytogeographic profile of Serra do Boqueirão and other Cerrado spot areas.

The occurrence of *C. hexandra* ("quina-quina"), a rare species of high therapeutic value, creates a demand for studies like this one, since species with similar characteristics have been decimated through human history, as well as the fragment in study, which has been suffering severe damage for either climate change and anthropic actions like the development industry and the weakening of environment conservation actions through public policies, both observed at sites in Serra do Boqueirão, what affects the resistance and resilience of this relict plant community.

Castro et al. (1998) warn about the risks of the lack of knowledge of the floristic patrimony of the Cerrado, considering it as a problem that could negatively affect the supply of genetic variability for future generations, and in addition points out that the phyto-diversity and the compartmentalized architecture of the Cerrado biome hinders the extrapolation of results achieved by quantitative floristic surveys.

Analysis of phytosociological parameters

The values of total basal area and total absolute density were respectively 5.17 m^2/ha^{-1} and 2,097.22 $ind./ha^{-1}$. Similar values were found by Felfili et al. (1997), who compared eleven areas on the Chapada of Pratinha and Chapada dos Veadeiros (Central Brazilian Cerrado) and calculated basal area values from 5.8 to 11.3 m^2/ha^{-1}. Incidentally, the basal area value found in this study differs from the one of Costa & Araujo (2007) at the Chapada do Araripe (Barbalha, Ceará), which was of 19.2 m^2/ha^{-1}, despite the convergence in the absolute density value (2.224 m^2/ha^{-1}). This is explained by the pedological and altitudinal differences between the two sites, since the Chapada shows an arboreal community that configures a "Cerradão" physiognomy, characteristic of more elevated areas (ca. 950 m) and deep and sandy soils. Species like the "Pequi" (*Caryocar coriaceum* Wittm.) and the "Visgueiro" (*Parkia platycephala* Benth), for example, have high values of basal area when adult, dominating the environments where they concentrate, being present in high numbers in the "Cerradão" of the Chapada do Araripe, but do not survive the different conditions of the tabletops of lesser elevation of Serra do Boqueirão, with a higher average temperature and a smaller precipitation regime.

Medeiros et al. (2008) presented a total basal area value of 6.8 m^2/ha^{-1} in a study made in a "thin Cerrado" in Maranhão state, Northeastern Brazil, with a remarkable similarity with Serra do Boqueirão at Lavras da Mangabeira.

The density and basal area in different Cerrado communities is highly variable, densities from 664 through 8.135 individuals per hectare and basal areas from 4.73 m^2/ha to 42.19 m^2/ha (Costa & Araújo, 2007; Moro et al., 2011). This is due to the large physiognomic variation of the Cerrado *sensu lato*, covering from forest ("Cerradão") to grassland ("campo limpo") landscapes (Gottsberger & Silberbauer-Gottsberger, 2006; Ribeiro & Walter, 2008). Intermediate (savanna) physiognomies are those classified as Cerrado *sensu stricto* (Ribeiro & Walter, 2008), and the density and basal area of the studied fall within those registered for other Cerrado *sensu stricto* areas (Felfili et al., 2002; Fidelis & Godoy, 2003; Moro et al., 2011).

The species with highest importance value (IVI) were: *A. occidentale*, *Q. parviflora*, *H. stignocarpa, C. fasciculata* and *A. leptopetala* (Table 2). Sampaio et al. (2018) obtained similar results in a Cerrado *sensu stricto* area at the Rio Parnaíba basin, Northeastern Brazil, in which *Q. parviflora* was the highest IVI species.

Table 2: Phytosociological parameters of the Cerrado fragment on Serra do Boqueirão, Lavras da Mangabeira, Northeastern Brazil. Decreasing values by Importance Value Index (IVI), where: N = Number of Individuals; AD = Absolute Density; AF = Absolute Frequency; ADo = Absolute Dominance; RD = Relative Density (%); RF = Relative Frequency (%); RDo = Relative Dominance (%); CVI = Cover Value Index and IVI = Importance Value Index.

Species	N	AD	RD	AF	RF	ADo	RDo	CVI	IVI
A. occidentale	71	164.4	7.84	91.67	5.31	3.01	25.14	32.98	38.29
Q. parviflora	103	238.4	11.7	66.67	3.86	1.04	8.66	20.02	23.89
H. stignocarpa	85	196.8	9.38	33.33	1.93	1.29	10.75	20.13	22.07
C. fasciculata	78	180.6	8.61	91.67	5.31	0.66	5.5	14.1	19.42
A. leptopetala	87	201.4	9.6	83.33	4.83	0.42	3.48	13.08	17.91
G. virbunoides	54	125	5.96	58.33	3.38	0.6	4.98	10.94	14.32
P. myrsinites	56	129.6	6.18	75.00	4.35	0.24	2.04	8.22	12.57
A. fraxinifolium	30	69.4	3.31	91.67	5.31	0.42	3.5	6.81	12.13
D. cearensis	19	44	2.1	91.67	5.31	0.45	3.73	5.83	11.15
D. araripensis	15	34.7	1.66	58.33	3.38	0.66	5.51	7.17	10.55
H. impetiginosus	27	62.5	2.98	83.33	4.83	0.28	2.35	5.33	10.16
P. reticulata	26	60.2	2.87	50.00	2.9	0.39	3.29	6.16	9.06
A. cuspa	29	67.1	3.2	66.67	3.86	0.1	0.8	4	7.86
C. argentea	19	44	2.1	83.33	4.83	0.08	0.7	2.79	7.63
B. gaudichaudii	20	46.3	2.21	33.33	1.93	0.39	3.29	5.49	7.43
C. americana	11	25.5	1.21	25.00	1.45	0.38	3.13	4.34	5.79
T. aurea	15	34.7	1.66	25.00	1.45	0.21	1.77	3.42	4.87
A. pyrifolium	12	27.8	1.32	50.00	2.9	0.06	0.53	1.86	4.76
B. crassifolia	12	27.8	1.32	41.67	2.42	0.06	0.53	1.86	4.27
L. replicata	20	46.3	2.21	16.67	0.97	0.08	0.65	2.86	3.82
X. americana	7	16.2	0.77	41.67	2.42	0.02	0.17	0.94	3.36
C. vitifolium	5	11.6	0.55	33.33	1.93	0.09	0.76	1.31	3.24
M. acutifolium	7	16.2	0.77	16.67	0.97	0.17	1.45	2.22	3.19
Zanthoxylum sp.	6	13.9	0.66	33.33	1.93	0.07	0.59	1.25	3.18
C. glaucocarpum	5	11.6	0.55	25.00	1.45	0.12	1.04	1.59	3.04
A. cearensis	6	13.9	0.66	33.33	1.93	0.05	0.4	1.06	2.99
C. jamacaru	5	11.6	0.55	25.00	1.45	0.1	0.84	1.39	2.84
J. caroba	6	13.9	0.66	25.00	1.45	0.06	0.5	1.16	2.61
V. macrocarpa	8	18.5	0.88	16.67	0.97	0.07	0.6	1.48	2.45
L. paniculata	4	9.3	0.44	25.00	1.45	0.06	0.51	0.95	2.4
Laetia sp.	4	9.3	0.44	25.00	1.45	0.06	0.46	0.9	2.35
L. candicans	8	18.5	0.88	16.67	0.97	0.04	0.35	1.23	2.2
C. leptopholeos	3	6.9	0.33	25.00	1.45	0.04	0.29	0.63	2.08
Xylosma sp.	5	11.6	0.55	16.67	0.97	0.04	0.32	0.87	1.84
C. jacobinensis	5	11.6	0.55	16.67	0.97	0.02	0.18	0.73	1.7
L. ferrea	4	9.3	0.44	16.67	0.97	0.03	0.28	0.72	1.68
Bauhinia sp.	5	11.6	0.55	16.67	0.97	0.02	0.15	0.7	1.66
C. leprosum	4	9.3	0.44	16.67	0.97	0.02	0.16	0.6	1.57
T. formosa	4	9.3	0.44	16.67	0.97	0.01	0.11	0.55	1.52
S. amara	6	13.9	0.66	8.33	0.48	0.02	0.19	0.85	1.33
C. hexandra	2	4.6	0.22	16.67	0.97	0	0.04	0.26	1.22
P. marginatum	2	4.6	0.22	8.33	0.48	0.01	0.1	0.32	0.8
H. macropetala	2	4.6	0.22	8.33	0.48	0.01	0.06	0.28	0.77
M. tenuiflora	2	4.6	0.22	8.33	0.48	0	0.04	0.26	0.75
L. auriculata	1	2.3	0.11	8.33	0.48	0.01	0.05	0.16	0.65
P. crucis	1	2.3	0.11	8.33	0.48	0	0.04	0.15	0.63

Twenty-two species presented IVI values below 3.8%, what represents less than 10% of the maximum observed value (38.29%), what indicates that these species are uncommon at the studied area, 50% of them being characteristic from the Caatinga, entering the fragment as competitors.

In this study, *Q. parviflora* was the most abundant species, followed by *A. leptopetala, H. stignocarpa* and *C. fasciculata*. Among those are two species of the family Vochysiaceae, a dominant family of Cerrado but unrecorded in the surveys made in the Caatinga, among the foremost representative (in number of individuals) of the sampled flora. The "Cajuí" (*Anacardium occidentale*) is another species that occurs in large numbers, being shown also as one of the greatest IVI index only by Moro et al. (2011) in other surveys at Northeastern Cerrado. This can be due to the scarcity of phytosociological descriptions in marginal areas of Cerrado in Ceará or to the mix of environmental factors such as soil composition, rainfall and elevation particular to the Serra do Boqueirão. On the other side, this species is considered as common in savanna formations (Ratter et al., 2003), especially at the North-Northeast part of the Cerrado biome, where it is widely abundant (Castro et al., 1998; Oliveira-Filho, 2006; Matos & Felfili, 2010).

Diametric and hypsometric distribution

The graph representing the studied community, by the distribution of individuals per diameter classes, is shaped as "reverse-J" (negative exponential), being composed mostly of young trees, with 68.1% of diameter equal or less than 8 cm (Figure 3). The average diameter value was of 7.26 cm. The maximum diameter encountered was of 36.3 cm in an individual of *A. occidentale* (the most abundant species of the area).

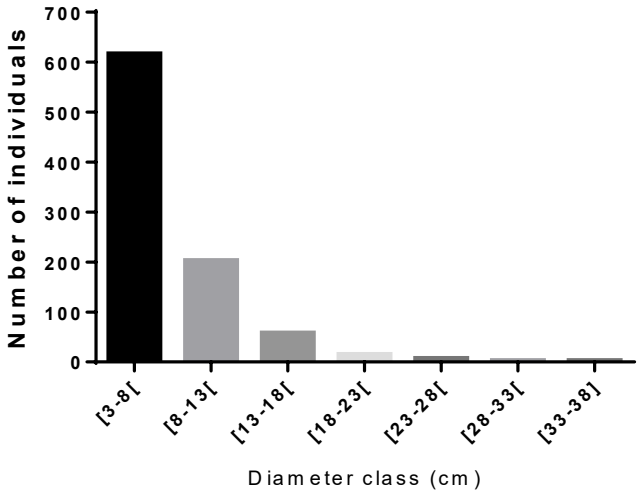

Figure 3: Distribution of individuals per diameter class in a Cerrado fragment at Lavras da Mangabeira, Northeastern Brazil.

These data corroborate the results obtained by Assunção & Felfili (2004) in a Cerrado *sensu stricto* area at Distrito Federal, in which a "reverse-J" diametric distribution was also found; the survey made by Ferreira et al. (2015) in a Cerrado *sensu stricto* area at Tocantins state showed similar results too, with 75% of the young individuals with diameters of less than 12 cm. The class distribution with a "reverse-J" pattern suggests that the area is self-regenerative (Assunção & Felfili, 2004; Ferreira et al., 2015; Cerqueira et al., 2017). The large amount of young individuals, with a diameter of less than 8 cm, points to an area in recovery after perturbations, which reinforces the need for preservation efforts. The possibility of self-regeneration contrasts with the increase of anthropic actions at the area, which along with climatic and edaphic factors hinders the development of that fragment.

According to Marangon et al. (2008), the observation of the development stage of forest formations is possible through analysis of the vertical structure, based on the distribution of individuals in the different levels of height classes, along with the data obtained in the diametric classes.

In the distribution of height classes (Figure 4), the highest concentration of individuals was at the intermediary classes, what corresponds to 68.3% of the total. Class 2 (5-7.9 cm height) by itself represents 45.3% of all individuals of the survey. However, 120 individuals (13%) have a height larger than 11 m, what is similar to the arboreal stratus of "Cerradão".

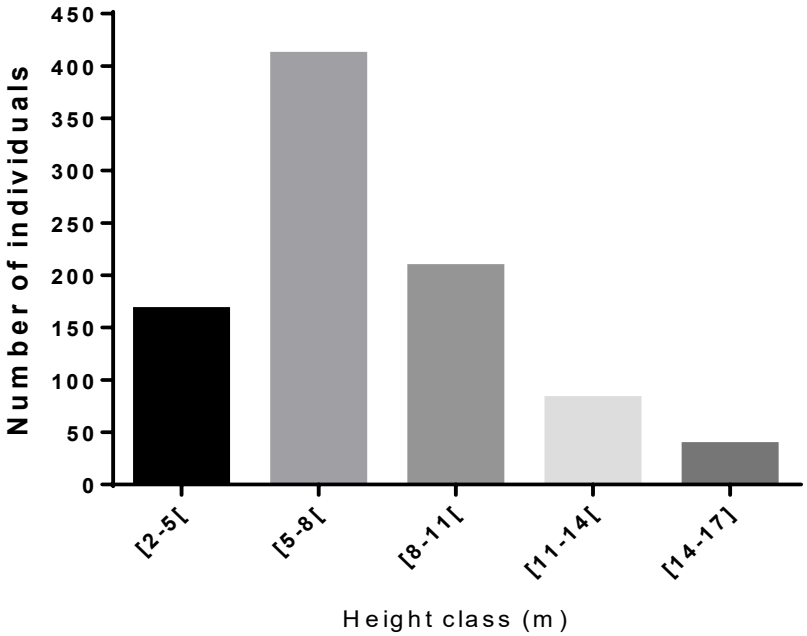

Figure 4: Distribution of individuals per height class in a Cerrado fragment at Lavras da Mangabeira, Northeastern Brazil.

The data from diameter and height classes were similar to the results obtained by Ferreira et al. (2015) in a survey made at a Cerrado *sensu stricto* in Gurupi, Tocantins, where the average height was of 7.31 m. This data corroborate those found by Assunção & Felfili (2004) in a study made at APA Lago Paranoá, Brasília and suggest that the Cerrado fragment of Serra do Boqueirão is in a phyto-physiognomic transition process.

The largest height registered was that of 17 m in some individuals of *D. araripensis* ("Angelim"). The total hypsometric average was of 7.15m; a value which approaches the inclusion criterion that classifies the forest formations of the Cerrado biome, which is of 8 m (Ferreira et al., 2015).

Similarity analysis

According to Magurran (1988), the beta diversity, or diversity among habitats is related with the differences between composition of species and their abundance between communities, which reflects floristic dissimilarity (Matos & Felfili, 2010).

The floristic similarity indexes (Jaccard matrix) calculated from the studied area and ten other Cerrado areas in different regions of Brazil are shown on Table 3 and point to the high heterogeneity between the areas, with low values of floristic similarity, which represents a high beta diversity among the studied area and the remaining ones.

Table 3. Similarity of Jaccard matrix for eleven Cerrado areas in different regions of Brazil.

	A	B	C	D	E	F	G	H	I	J	K
A	1										
B	0.0737	1									
C	0.08	0.1764	1								
D	0.0652	0.2752	0.2428	1							
E	0.1153	0.2517	0.2407	0.2177	1						
F	0.1525	0.1263	0.0961	0.0882	0.0901	1					
G	0.1408	0.1650	0.2280	0.1917	0.2407	0.1632	1				
H	0.0987	0.2549	0.3220	0.4179	0.2792	0.1206	0.2187	1			
I	0.0416	0.2127	0.2075	0.1095	0.1743	0.1333	0.1428	0.0909	1		
J	0.1296	0.0989	0.0869	0.1551	0.0961	0.0882	0.1363	0.1153	0.0101	1	
k	0.0816	0.4646	0.1728	0.3827	0.2230	0.0789	0.1728	0.3205	0.1558	0.1363	1

According to Kent & Coker (1992), values of comparison indexes equal or higher than 0.5 point to a high similarity. So, the similarity observed with the Jaccard index between the areas is considered low. The comparison indexes between the Serra do Boqueirão Cerrado and ten other areas varied from 0.0416 (Cerrado *s.s.* in Pirinópolis, Goiás state) to 0.1525 (urbanized area of Fortaleza, Ceará state), revealing a higher similarity with a savanna vegetation spot on a pre-coastal table in Ceará state, with an average annual rainfall of 1,338 mm (Table 4). In comparison with another area in Ceará state, Cerrado *s.s.* of Chapada do Araripe, Barbalha (ca. 50 Km in a straight line from the study site), the third largest similarity of the analysis observed (0.1296) had a lower value in comparison with the Cerrado *s.s.* in Carolina, southern Maranhão state.

The low floristic similarity evidenced in this study between areas geographically next to each other, as well as more distant areas, confirms the hypothesis of the existence of phyto-geographical patterns based on the distribution of the species. The differences observed suggest that the species of tropical forests are characterized by having a mosaic spatial distribution and even the communities located in nearby areas are floristic and structurally different, which agrees with study results that report a high diversity of the flora of tropical areas like the Brazilian Cerrado (Ferreira-Júnior et al., 2008).

Table 4: Floristic/environmental variables between 11 areas (A-K) of Cerrado located at Northeast, Central-west and Southeast Regions of Brazil.

Area	SN	FN	SA/ha	ARF/mm	Elv/m	IC/cm	AD m^2/ha^{-1}
A	46	22	0.43	904	289	DNS≥3	2097
B	85	44	0.30	1400	480	CAS≥10	4463
C	41	21	0.20	1500 a 1600	329	CAP≥15	--
D	54	30	1.00	1400 a 1450	1050	DNS≥5	882
E	114	36	3.28	--	500	DNS≥5	1740
F	37	24	1.00	1338	16	PNS≥9	1218
G	53	25	1.00	1718	150	DNS≥5	--
H	58	24	2.00	1059	918	DNS≥5	1027
I	83	38	0.40	1500	810	DAP≥5	1855
J	43	28	0.08	760	900	DNS≥3	2224
K	91	38	0.60	1059	918	CAS≥10	6476

Where: A = Serra do Boqueirão, Southern Ceará (this study); B = Saporetti-Junior et al. (2003), Abaeté, Minas Gerais; C = Silva-Neto et al. (2016), Dueré, Tocantins; D = Assunção & Felfili (2004), APA do Paranoá, Distrito Federal; E = Finger & Finger (2015), Chapada dos Guimarães and Baixada Cuiabana, Mato Grosso; F = Moro et al. (2011) urbanized zone of Fortaleza, Ceará; G = Medeiros et al. (2008), Carolina, Maranhão; H = Oliveira et al. (2015), Jaborandi, Western Bahia; I = Imaña-Encinas et al. (2007) EcoMuseu do Cerrado, Pirinópolis, Goiás; J = Costa & Araújo (2007), Chapada do Araripe, Barbalha, Ceará; K = Neri et al. (2007) Rio Jequitinhonha basin, Minas Gerais. Onde: SN = Species number; FN = Family number; SA = Sample area; ARF = Annual Rainfall; Elv. = Elevation; IC = Inclusion Criterion and DA = Total absolute density.

The analysis of the connection distance diagram shown in Figure 5 points to the formation of two groups, dependent on the location of the areas, stating that there is a link between geographical location and group formation. The first group was formed only in Ceará state areas (municipalities of Fortaleza - F, Barbalha - J and Lavras da Mangabeira - A). The second group had many subdivisions: the first in Minas Gerais state: areas B (Abaeté) and K (Vale do Jequitinhonha), which had the greatest floristic similarity among all analyzed areas (0.4646). The second subgroup (with the second largest similarity value) represents areas D and H (Distrito Federal and Western Bahia state), which are about 650 Km distant from each other.

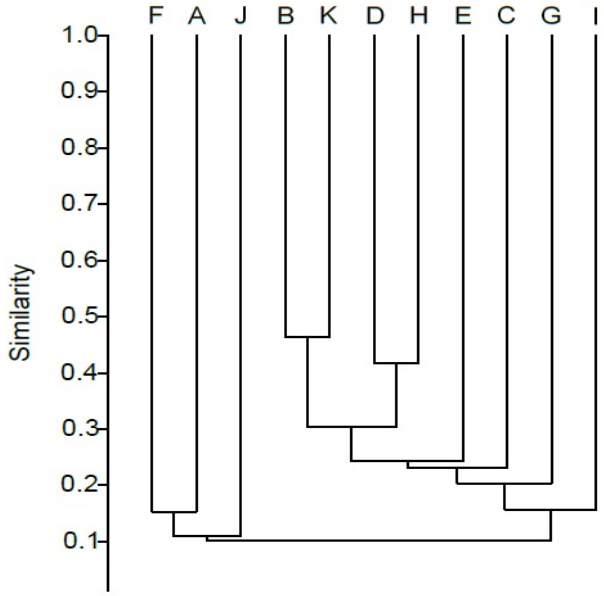

Figure 5. Dendrogram generated by the Jaccard similarity index between 11 areas of Cerrado in eight Brazilian states

The observed heterogeneity and low indexes in the floristic similarity comparison are important factors to be considered in the gathering for means of conservation of this relevant and threatened richness of biodiversity; in the present case expressed by a reminiscent of a larger Cerrado area that covered the region in the past. It still exists today within the Caatinga of the Brazilian Crystalline Shield, in the semiarid area, at mid-elevation hills like Serra do Boqueirão, but it is fading because conservation efforts are neglected, and because of the planetary climate change occurring since the last Ice Age.

CONCLUSIONS

The phytosociology and floristic diversity results point to the existence of a Cerrado *sensu stricto* located inside the Caatinga of the Brazilian Crystalline Shield, in the semi-arid region of Northeastern Brazil, Lavras da Mangabeira municipality. This study is the first to observe the vegetation structure of the area.

Typical Cerrado species like *Qualea parviflora* and *Callisthene fasciculata* (both Vochysiaceae) and *Anacardium occidentale* (Anacardiaceae) had the highest IVI values of the analyzed fragment, emphasizing structural and floristic bonds of the area, especially with the coastal savanna of Ceará state, as well as with other areas of marginal and central Cerrado areas.

The values of diversity, equability and concentration indexes suggest a high species richness (high alpha diversity), high uniformity of population size and low species concentration. The beta diversity is considered high by the heterogeneity in comparison with Cerrado areas in other regions of the country.

ACKNOWLEDGEMENTS

The authors thank Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES); Fundação Cearense de Apoio ao Desenvolvimento Científico e Tecnológico (FUNCAP); Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Embrapa Semiárido and Universidade Regional do Cariri (URCA).

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Authors' contributions: JTCJ: funding acquisition, metodology, investigation, project administration, supervision; JCM: conceptualization, data curation, formal analysis, methodology, writing – original draft; MANL: conceptualization, data curation, writing; GVC: conceptualization, software, investigation; BLMG: conceptualization, software, investigation; ESSTB: investigation, methodology; LMB: data curation, formal analysis, visualization; MAD: resources, methodology, writing – review and editing; ACAMM: validation, visualization; LSGR: formal analysis, software; MAPS: validation, visualization, resources; LSC: methodology, software.