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Floristic composition, diversity and structure of the "cerrado" *sensu stricto* on rocky soils in northern Goiás and southern Tocantins, Brazil

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ABSTRACT – (Floristic composition, diversity and structure of the "cerrado" *sensu stricto* on rocky soils in northern Goiás and southern Tocantins, Brazil). The "cerrado" *sensu stricto* is a savanna woodland physiognomy which occupies most of central Brazil, with the degree of canopy cover varying from 10% to 60% at a site with trees reaching up to seven meters high. It occurs mostly on deep and well-drained soils but can also be found on shallower ones. The diversity and structure of the "cerrado" *sensu stricto* on shallow and rocky Cambisols and Litosols were studied here. Sixteen 20 x 50 m^2 plots were sampled in a random design over patches of this vegetation in northern Goiás State and southern Tocantins. All stems from 5 cm diameter at 30 cm from the ground level were measured. Vouchers were collected and deposited at the IBGE herbarium. A total of 87 species in 65 genera and 33 families were found. Diversity index was 2.87 nats ind^{-1}, density was 836 stems ha^{-1} with a basal area of 8.4374 m^2 ha^{-1}. Sørensen's index indicated higher similarities between plots at the same site indicating a geographical gradient influencing the floristic composition of the "cerrado" *sensu stricto* on rocky soils. Czekanowski's index confirmed this trend. TWINSPAN classification final groups were defined by preferential species of more fertile soils, in opposition to those typical of dystrophic soils and to common species to gallery forests occurring on sloping terrains with gullies.

Key words - cerrado, diversity, rock outcrops, savanna, woody vegetation

RESUMO – (Composição florística, diversidade e estrutura do cerrado *sensu stricto* sobre solos rochosos no Norte de Goiás e Sul de Tocantins). O cerrado *sensu stricto* é uma savana que ocupa grande parte do Brasil Central, apresentando cobertura lenhosa de 10% a 60% onde árvores alcançam até sete metros de altura. Ocorre principalmente em solos bem drenados e profundos mas é também encontrado em solos mais rasos. A diversidade e a fitossociologia do cerrado *sensu stricto* em Cambissolos e Litossolos rochosos foram aqui estudadas. Dezesseis parcelas de 20 x 50 m^2 foram amostradas aleatoriamente sobre manchas dessa vegetação no Norte de Goiás e Sul de Tocantins. Os troncos com diâmetros a partir de 5 cm a 30 cm do nível do solo foram medidos. As coletas foram depositadas no herbário do IBGE. Um total de 87 espécies em 65 gêneros e 33 famílias foram encontrados. O índice de diversidade de Shannon foi de 2,87 nats ind^{-1}, a densidade foi de 836 troncos ha^{-1} e a área basal foi de 8,4374 m^2 ha^{-1}. O índice de Sørensen indicou similaridades mais elevadas entre parcelas no mesmo local, sugerindo a existência de um gradiente geográfico influenciando a composição florística do cerrado *sensu stricto* sobre solos rochosos. O índice de Czekanowski confirmou esta tendência. Os agrupamentos finais da classificação por TWINSPAN foram definidos por espécies preferenciais de solos mais férteis, em oposição à espécies típicas de solos distróficos e à espécies comuns com matas de galeria, que ocorreram nas grotas.

Palavras-chave - afloramento de rochas, cerrado, diversidade, savana, vegetação lenhosa

Introduction

The "cerrado" *sensu stricto* is a savanna woodland physiognomy, with the degree of canopy cover varying from 10% to 60% at a site with trees reaching up to seven meters high (Eiten 1972, 1983), which occupies most of central Brazil (Ribeiro & Walter 1998). It occurs on the uplands mostly on deep and well drained soils presenting an herbaceous layer dominated by grasses and a woody layer with varying heights mostly from three to five meters. The two layers are rich in species but present few epiphytes (Felfili *et al*. 2001).

Several authors found changes in the floristic composition and physiognomy of "cerrado" formations related to environmental traits especially soil and water (Waibel 1948, Alvin & Araújo 1952, Goodland 1971, Eiten 1978, Goodland & Ferri 1979, AB'Saber 1983, Cole 1986, Silva Júnior *et al*. 1987, Araújo & Haridasan 1989, Eiten 1991, Ratter & Dargie 1992, Felfili & Silva Júnior 1993, Felfili *et al*. 1994, Haridasan *et al*. 1997, Felfili *et al*. 1998, Rossi *et al*. 1998, Ratter *et al*. 2000). Felfili *et al*. (2000), analyzing changes in the floristic composition in permanent plots of "cerrado" *sensu stricto* over nine years verified that this vegetation is resilient to disturbances by fire and tend to persist as a physiognomy showing changes in dominant species over time. These show that there are spatial and temporal gradients influencing the patterns of diversity and structure in the "cerrado" *sensu stricto*.

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Although occurring mostly in Latosols on the uplands, the “cerrado” *sensu stricto* occurs in lesser proportions in Neosols, Cambisols and Litosols, especially in the latter two that according to Reatto *et al*. (1998) represent about 3.1% and 7.3% respectively of the “cerrado” biome area. “Cerrado” vegetation occurs as mosaics in central Brazil with similar patches occurring in disjunct sites of the biome. The physical conditions that determine the occurrence of the mosaics were analyzed by Cochrane *et al*. (1985) that proposed a land system zoning for central Brazil, adopted as a basis for the project Biogeography of the “cerrado” biome (Felfili *et al*. 1994, 1997, Haridasan *et al*. 1997, Filgueiras *et al*. 1998, Felfili & Silva Júnior 2001, Felfili *et al*. 2004), where the authors have showed that there is an agreement in floristic and structural patterns of the vegetation and the proposed zoning. Environmental characteristics have a greater influence on floristic and structure of the vegetation than the geographic proximity (Felfili *et al*. 1994, Felfili & Felfili 2001).

Most studies are focused on “cerrado” *sensu stricto* on Latosols and Neosols while little is known on this vegetation on Cambisols and Litosols, especially those on rocky and concretionary soils. Floristic differentiations are expected for the “cerrado” *sensu stricto* on rocky soils due to the shallowness of the soils and the rock coverage that probably exert a selective pressure on the species establishment and development.

The objective of this study was to analyse the floristic composition, alpha and beta diversity and the phytosociological structure of the “cerrado” *sensu stricto* on rocky soils over a geographic gradient in northern Goiás and southern Tocantins.

Material and methods

Study-sites – The sampling was conducted at the north and northeastern Goiás State and southern Tocantins State on rocky soils (table 1) including several patches of “cerrado” *sensu stricto* on rocky and concretionary soils on sloping terrain. IBGE 1:100.000 charts (IBGE 1988) were used to guide the field regional survey in search of patches of the “cerrado” *sensu stricto*.

The climate of the region is Aw by Köppen classification, the vegetation is a mosaic of “cerrado” *sensu stricto* on Latosols, on Neosols, on Cambisols, and on Litosols, gallery forests and semideciduous forests. Seasonally deciduous forests also occurs in southern Tocantins (Brasil 1981, 1982, Cochrane *et al*. 1985, IBGE 2006).

Table 1. Latitude, longitude, altitude, soil types of the study sites in Goiás and Tocantins States in central Brazil. Source: BRASIL (1981, 1982), Cochrane *et al*. (1985) and IBGE (2006) soils maps.

Study site	Plot no. (1,000 m^2)	Latitude (S) and Longitude (W)	Altitude (m)	Soil type
Colinas, GO	1	13°49’58” and 47°27’11”	808	Cambisol with rocky concretions
Colinas, GO	2	14°11’42” and 47°03’34”	540	Cambisol with rocky concretions, sloping terrain
Colinas, GO	3	14°11’45” and 47°03’33”	540	Cambisol with rocky concretions, sloping terrain, gulleys and rocky outcrops
Colinas, GO	4	14°11’04” and 47°03’15”	540	Cambisol with rocky concretions, sloping terrain
Cavalcante, GO	5	13°49’14” and 47°10’45”	740	Litholic neosol with rocky outcrops
Cavalcante, GO	6	13°49’38” and 47°27’03”	730	Litholic neosol with rocky outcrops
Cavalcante, GO	7	13°49’44” and 47°26’56”	730	Cambisol with rocky concretions, gulleys and rocky outcrops
Cavalcante, GO	15	13°48’58” and 47°48’18”	800	Litolic neosol with rocky outcrops and lateritic concretions
Cavalcante, GO	16	13°49’00” and 47°48’07”	800	Litolic neosol with rocky outcrops and lateritic concretions
Almas, TO	8	11°10’44”and 47°08’27”	455	Plintosol with lateritic outcrops and concretions
Almas, TO	9	11°12’14” and 47°10’49”	450	Plintosol with lateritic outcrops and concretions
Almas, TO	10	11°15’42” and 47°09’35”	525	Plintosol with lateritic outcrops and concretions
Mararosa, GO	11	13°55’09” and 49°14’45”	500	Plintosol with lateritic outcrops
Mararosa, GO	12	13°55’22” and 49°14’23”	434	Plintosol with rocky outcrops
Mararosa, GO	13	13°55’02” and 49°22’31”	750	Plintosol with rocky outcrops at the top of a hill
Mararosa, GO *	14	14°05’25” and 49°16’50”	850	Plintosol with rocky outcrops, lateritic concretions, near to a gulley.

* An archaeological site with pre-historic engraved petroglyphs

Vegetation sampling – The sampling of the woody vegetation comprised 16 plots of 20 x 50 m (1,000 m²) randomly distributed over the patches of rocky soils covered by "cerrado" *sensu stricto*. All standing stems, alive or dead, with diameter from 5 cm at 30 cm from the ground level (db) were identified and measured. The db was measured with a 50 cm caliper graduated in cm, if the stem had an irregular shape, two measures, at right angles to each other, were taken and an average was used. Each stem from bifurcated trees below 30 cm from the ground level was measured and had their basal area calculated. The height, as a vertical projection of the top of the crown to the ground level, was measured with a telescopic rod graduated in centimeters. Geographic coordinates were taken with a GPS (Global Positioning System) and altitude was taken with an altimeter. All the measures were taken following the methodology of the project 'Biogeography of the "cerrado" biome' (Felfili *et al*. 2004).

Vouchers were collected during the survey and in other excursions conducted during the dry and the wet seasons. They were deposited in the IBGE herbarium.

Floristic diversity – Shannon's diversity index and Pielou's evenness index were used to evaluate alpha diversity, which is related to the number of species and the distribution of individuals per species in a community. Species were listed according to the system of Cronquist (1988). The beta diversity, related to the differences in species composition and abundance between sites (Kent & Coker 1992), was evaluated by similarity indices and also by multivariate analyses. Shannon's diversity index (nats individual^{-1}) varies from zero to positive values depending on the chosen logarithmic scale but rarely surpasses five. The less even the distribution of the number of individuals per species the closer to zero becomes the Pielou's evenness index (Margurran 1988).

Beta diversity – Beta diversity or habitat diversity refers to the differences in species composition between different areas or environments (Margurran 1988). It can be either the differences between different vegetation types in a site or between the same physiognomy along a gradient (Felfili & Rezende 2003). Beta diversity is the opposite of similarity, if the similarity between the plots is high the beta diversity is low and vice-versa (Felfili *et al*. 2004). The same occurs in the interpretation of multivariate analyses, if the grouping is strong the beta diversity is low and vice-versa. Both approaches were used in this study to analyse beta diversity.

The presence-absence based similarity index of Sørensen and the Czekanowsky (Percent Similarity) index, that considers species abundance too (Kent & Coker 1992), were used to evaluate Beta diversity to check the patterns regarding the floristics as well as the community structure (Felfili *et al*. 2004).

The complete data set, a matrix of 87 species per 16 plots was classified by TWINSPAN and ordinated by Detrended Correspondence Analysis (DCA) (Kent & Coker 1992). The variable density (number of trees) of species per hectare for each site was used for the construction of the matrix for the multivariate analyses with cut levels of one, two, five and 10 for TWINSPAN classification. The groups derived from the classification were considered strong if the eigen-values were equal or higher than 0.3 (Hill 1979).

Structure – The phytosociological parameters density, dominance (basal area), frequency and IVI (Kent & Coker 1992) were calculated. The distribution of the individuals per diameter classes as well as the distribution of species by diameter classes were analysed, the division in classes followed Spiegel's formulae quoted by Felfili & Rezende (2003).

Results

Alpha diversity, floristic composition and structure – A total of 87 species in 65 genera and 33 families were found in the "cerrado" *sensu stricto* on rocky soils (table 2). Shannon's diversity index was 2.87 nats ind^{-1}, Pielou's evenness index was of 0.78.

Table 2. Floristic composition of the " cerrado" *sensu stricto* on rocky soils in Northern Goiásand Southern Tocantins State, Brazil.

Family/Species
ANACARDIACEAE
Anacardium occidentale L.
Astronium fraxinifolium Schott*
Myracrodruon urundeuva Allemão
ANNONACEAE
Annona coriacea Mart.
Xylopia aromatica (Lam.) Mart.
APOCYNACEAE
Aspidosperma subincanum Mart. ex DC.**
Aspidosperma tomentosum Mart.
Hancornia speciosa Gomez var. *speciosa*
Hancornia pubescens Nees & Mart.
Himatanthus obovatus (Müll. Arg.) Woodson
BIGNONIACEAE
Jacaranda brasiliana (Lam.) Pers.*
Tabebuia aurea (Silva Manso) Benth. & Hook. f. ex S. Moore
BOMBACACEAE
Pseudobombax longiflorum (Mart. & Zucc.) A. Robyns
Eriotheca gracilipes (K. Schum.) A. Robyns
Eriotheca pubescens (Mart. & Zucc.) Schott & Endl.
BURSERACEAE
Protium heptaphyllum (Aubl.) March.**
CARYOCARACEAE
Caryocar brasiliense Cambess.
Caryocar cuneatum Wittm.
CHRYSOBALANACEAE
Couepia grandiflora (Mart. & Zucc.) Benth. ex Hook. f.
Hirtella gracilipes (Hook. f.) Prance**
COMBRETACEAE
Terminalia argentea Mart.

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Family/Species
COMPOSITAE (ASTERACEAE)
Piptocarpha rotundifolia (Less.) Baker
CONNARACEAE
Connarus suberosus Planch.
Rourea induta Planch.
DILLENIACEAE
Curatella americana L.
Davilla elliptica A. St.-Hil.
EBENACEAE
Diospyros burchellii DC.
ERYTHROXYLACEAE
Erythroxylum campestre A. St.-Hil.
Erythroxylum deciduum A. St.-Hil.
Erythroxylum suberosum A. St.-Hil.
Erythroxylum tortuosum Mart.
FLACOURTIACEAE
Casearia sylvestris Sw.
GUTTIFERAE (CLUSIACEAE)
Kielmeyera coriacea (Spreng.) Mart.
Kielmeyera rubriflora Cambess.
HIPPOCRATEACEAE
Salacia crassifolia (Mart.) G. Don.
Salacia elliptica (Mart. ex Schult.) G. Don.
ICACINACEAE
Emmotum nitens (Benth.) Miers
LEGUMINOSAE (FABACEAE) CAESALPINIOIDEAE
Dimorphandra mollis Benth
Copaifera langsdorffii Desf.**
Hymenaea stigonocarpa Mart. ex Hayne
Sclerolobium aureum (Tul.) Benth.
Sclerolobium paniculatum Vogel var. *paniculatum*
LEGUMINOSAE (FABACEAE) PAPILIONOIDEAE
Acosmium dasycarpum (Vogel) Yakovl.
Andira paniculata Benth.
Bowdichia virgiloides (Vog) Yakovl.
Machaerium acutifolium Vogel
Machaerium opacum Vogel
Pterodon pubescens (Benth.) Benth.
Vatairea macrocarpa (Benth.) Ducke
LYTHRACEAE
Lafoensia pacari A. St.-Hil.
Physocalymma scaberrimum Pohl
MALPIGHIACEAE
Byrsonima coccolobifolia H.B.K.
Byrsonima crassa Nied.
Byrsonima verbascifolia (L.) L. C. Rich. ex Juss.
Heteropterys byrsonimifolia A. Juss.
MORACEAE
Brosimum gaudichaudii Trécul
Ficus sp.

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Family/Species
MELASTOMATACEAE
Miconia burchellii Triana
Mouriri elliptica Mart.
MYRTACEAE
Eugenia dysenterica DC.
Myrcia multiflora (Lam.) DC.
Myrcia pubipetala Miq.
Myrcia rostrata DC.
Myrcia sellowiana O. Berg
Myrcia tomentosa (Aubl.) DC.
Psidium myrsinoides O. Berg
NYCTAGINACEAE
Guapira noxia (Netto) Lund
OCHNACEAE
Ouratea hexasperma (A. St.-Hil.) Baill.
Ouratea spectabilis (Mart.) Engl.
PROTEACEAE
Roupala montana Aubl.
RUBIACEAE
Ferdinandusa elliptica Pohl
Guettarda viburnoides Cham. & Schltdl.
Rudgea viburnoides (Cham.) Benth.
Tocoyena formosa (Cham. & Schltdl.) K. Schum.
SAPINDACEAE
Dilodendron bipinnatum Radlk.*
Magonia pubescens A.St.-Hil.
SAPOTACEAE
Pouteria ramiflora (Mart.) Radlk.
SIMAROUBACEAE
Simarouba versicolor A. St.-Hil.
TILIACEAE
Luehea divaricata Mart. & Zucc.*
VOCHYSIACEAE
Callisthene fasciculata Mart.*
Callisthene mollissima Warm.
Qualea dichotoma (Mart.) Warm.*
Qualea grandiflora Mart.
Qualea parviflora Mart.
Salvertia convallariodora A. St.-Hil.
Vochysia elliptica (Spreng.) Mart.
Vochysia rufa Mart.

* = typical species of mesotrophic soils
** = gallery forest species occurring in gulleys

The density was of 836 individuals ha^{-1} with a basal area of 8.4374 m^2 ha^{-1}. Confidence intervals showed variations in standard error below 20% of the plot average suggesting a structural homogeneity of this vegetation in spite of the large distances between some plots (table 3).

Table 3. Phytosociology of the cerrado *sensu stricto* on rocky soils in Northern Goiás and Southern Tocantins State, Brazil. (DA = Absolute density (n ha^{-1}), DR = Relative density (%), FA = Absolute frequency (%), FR = Relative frequency (%), DoA = Absolute dominance (m^2 ha^{-1}), DoR = Relative dominance (%); Confidence interval for Density: CI = P[836 ± 172] = 0.95, Confidence interval for Basal area: CI = P[8.4374 ± 1.34] = 0.95).

Species	DA	DR	FA	FR	DoA	DOR	IVI
Callisthene mollissima	116.25	13.91	43.8	2.01	1.0539	12.50	28.41
Qualea parviflora	76.88	9.20	100.0	4.58	1.1172	13.25	27.03
Davilla elliptica	110.00	13.16	81.3	3.72	0.7003	8.31	25.19
Curatella americana	69.38	8.30	68.8	3.15	0.8191	9.72	21.17
Qualea grandiflora	46.25	5.53	68.8	3.15	0.4637	5.50	14.18
Dead trees	39.38	4.71	93.8	4.30	0.3470	4.12	13.12
Byrsonima crassa	23.13	2.77	75.0	3.44	0.1492	1.77	7.97
Psidium myrsinoides	21.25	2.54	62.5	2.87	0.1615	1.92	7.32
Byrsonima coccolobifolia	12.50	1.50	56.3	2.58	0.1101	1.31	5.38
Salvertia convallariodora	13.13	1.57	37.5	1.72	0.1594	1.89	5.18
Terminalia argentea	15.63	1.87	25.0	1.15	0.1789	2.12	5.14
Bowdichia virgilioides	9.38	1.12	62.5	2.87	0.0891	1.06	5.04
Sclerolobium paniculatum	10.00	1.20	31.3	1.43	0.1589	1.88	4.51
Astronium fraxinifolium	11.88	1.42	43.8	2.01	0.0848	1.01	4.43
Erythroxylum suberosum	11.88	1.42	50.0	2.29	0.0454	0.54	4.25
Lafoensia pacari	9.38	1.12	50.0	2.29	0.0637	0.76	4.17
Kielmeyera coriacea	9.38	1.12	43.8	2.01	0.0764	0.91	4.03
Pseudobombax longiflorum	3.13	0.37	31.3	1.43	0.1763	2.09	3.90
Anacardium occidentale	7.50	0.90	37.5	1.72	0.0938	1.11	3.73
Aspidosperma tomentosum	11.25	1.35	25.0	1.15	0.0995	1.18	3.67
Connarus suberosus	8.13	0.97	43.8	2.01	0.0480	0.57	3.55
Byrsonima verbascifolia	11.88	1.42	25.0	1.15	0.0819	0.97	3.54
Myrcia multiflora	10.00	1.20	18.8	0.86	0.1082	1.28	3.34
Eriotheca gracilipes	6.88	0.82	31.3	1.43	0.0876	1.04	3.29
Ouratea hexasperma	7.50	0.90	31.3	1.43	0.0793	0.94	3.27
Mouriri elliptica	4.38	0.52	18.8	0.86	0.1586	1.88	3.26
Acosmium dasycarpum	8.13	0.97	31.3	1.43	0.0620	0.74	3.14
Erythroxylum deciduum	5.00	0.60	43.8	2.01	0.0297	0.35	2.96
Simarouba versicolor	4.38	0.52	31.3	1.43	0.0837	0.99	2.95
Magonia pubescens	5.63	0.67	31.3	1.43	0.0652	0.77	2.88
Erythroxylum campestre	7.50	0.90	25.0	1.15	0.0691	0.82	2.86
Andira paniculata	5.00	0.60	25.0	1.15	0.0849	1.01	2.75
Caryocar brasiliense	3.75	0.45	25.0	1.15	0.0878	1.04	2.64
Tabebuia aurea	7.51	0.90	18.8	0.86	0.1300	1.54	3.02
Dimorphandra mollis	5.63	0.67	25.0	1.15	0.0593	0.70	2.52
Couepia grandiflora	3.75	0.45	31.3	1.43	0.0495	0.59	2.47
Vatairea macrocarpa	4.38	0.52	25.0	1.15	0.0499	0.59	2.26
Caryocar cuneatum	3.75	0.45	12.5	0.57	0.0859	1.02	2.04
Heteropterys byrsonimifolia	5.00	0.60	18.8	0.86	0.0387	0.46	1.92
Hymenaea stigonocarpa	3.75	0.45	18.8	0.86	0.0473	0.56	1.87
Pterodon pubescens	3.13	0.37	25.0	1.15	0.0279	0.33	1.85
Sclerolobium aureum	3.75	0.45	18.8	0.86	0.0341	0.40	1.71
Protium heptaphyllum	3.75	0.45	12.5	0.57	0.0564	0.67	1.69
Xylopia aromomatica	3.13	0.37	18.8	0.86	0.0281	0.33	1.57
Miconia burchellii	3.75	0.45	18.8	0.86	0.0216	0.26	1.56
Casearia sylvestris	2.50	0.30	25.0	1.15	0.0087	0.10	1.55
Eugenia dysenterica	3.13	0.37	18.8	0.86	0.0254	0.30	1.53

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Species	DA	DR	FA	FR	DoA	DOR	IVI
Salacia crassiflora	1.88	0.22	18.8	0.86	0.0366	0.43	1.52
Diospyrus burchellii	3.75	0.45	18.8	0.86	0.0175	0.21	1.52
Tocoyena formosa	3.75	0.45	18.8	0.86	0.0154	0.18	1.49
Callisthene fasciculata	3.13	0.37	18.8	0.86	0.0199	0.24	1.47
Hancornia speciosa	3.13	0.37	12.5	0.57	0.0414	0.49	1.44
Myrcia rostrata	3.13	0.37	18.8	0.86	0.0170	0.20	1.43
Guettarda viburnoides	2.50	0.30	18.8	0.86	0.0230	0.27	1.43
Himatanthus obovatus	3.13	0.37	18.8	0.86	0.0156	0.18	1.42
Vochysia rufa	2.50	0.30	18.8	0.86	0.0122	0.14	1.30
Machaerium acutifolium	2.50	0.30	12.5	0.57	0.0187	0.22	1.09
Physocalima scaberrimum	1.88	0.22	12.5	0.57	0.0199	0.24	1.03
Pouteria ramiflora	1.88	0.22	12.5	0.57	0.0188	0.22	1.02
Qualea dichotoma	0.63	0.07	6.25	0.29	0.0546	0.65	1.01
Myrcia tomentosa	1.88	0.22	12.5	0.57	0.0174	0.21	1.00
Emmotum nitens	1.25	0.15	6.25	0.29	0.0465	0.55	0.99
Copaifera langsdorffii	1.25	0.15	12.5	0.57	0.0202	0.24	0.96
Hancornia pubescens	1.88	0.22	12.5	0.57	0.0119	0.14	0.94
Dilodendron bipinnatum	1.25	0.15	12.5	0.57	0.0156	0.19	0.91
Luehea divaricata	1.25	0.15	12.5	0.57	0.0044	0.05	0.77
Hirtella gracilipes	1.88	0.22	6.25	0.29	0.0169	0.20	0.71
Myracruodruon urundeuva	2.50	0.30	6.25	0.29	0.0075	0.09	0.67
Aspidosperma subincanum	1.25	0.15	6.25	0.29	0.0177	0.21	0.65
Machaerium opacum	1.25	0.15	6.25	0.29	0.0171	0.20	0.64
Guapira noxia	1.25	0.15	6.25	0.29	0.0167	0.20	0.63
Myrcia sellowiana	1.88	0.22	6.25	0.29	0.0098	0.12	0.63
Roupala montana	1.25	0.15	6.25	0.29	0.0065	0.08	0.51
Vochysia elliptica	0.63	0.07	6.25	0.29	0.0090	0.11	0.47
Salacia elliptica	0.63	0.07	6.25	0.29	0.0072	0.09	0.45
Brosimum gaudichaudii	0.63	0.07	6.25	0.29	0.0060	0.07	0.43
Erioteca pubescens	0.63	0.07	6.25	0.29	0.0058	0.07	0.43
Erythroxylum tortuosum	0.63	0.07	6.25	0.29	0.0043	0.05	0.41
Ouratea spectabilis	0.63	0.07	6.25	0.29	0.0043	0.05	0.41
Piptocarpha rotundifolia	0.63	0.07	6.25	0.29	0.0040	0.05	0.41
Annona coriacea	0.63	0.07	6.25	0.29	0.0033	0.04	0.40
Ficus sp.	0.63	0.07	6.25	0.29	0.0031	0.04	0.40
Kielmeyera rubriflora	0.63	0.07	6.25	0.29	0.0030	0.04	0.40
Ferdinandusa elliptica	0.63	0.07	6.25	0.29	0.0030	0.04	0.40
Rourea induta	0.63	0.07	6.25	0.29	0.0028	0.03	0.39
Rudgea viburnoides	0.63	0.07	6.25	0.29	0.0023	0.03	0.39
Myrcia pubipetala	0.63	0.07	6.25	0.29	0.0020	0.02	0.39
Jacaranda brasiliana	0.63	0.07	6.25	0.29	0.0016	0.02	0.38
Total	836.00	100.00	2.181.00	100.00	8.4374	100.00	300.00

Eleven species represented 50% of the total IVI: *Callisthene mollissima*, *Qualea parviflora*, *Davilla elliptica*, *Curatella americana*, *Qualea grandiflora*, *Byrsonima crassa*, *Psidium myrsinoides*, *Byrsonima coccolobifolia*, *Salvertia convallariodora*, *Terminalia argentea*, and *Bowdichia virgilioides*. In spite of the high density, *Callisthene mollissima* presented lower basal area than *Qualea parviflora* as well as *Davilla elliptica* presented lower basal area than *Curatella americana* as a reflection of the small size of their individuals. A third of the species contained only one individual per ha confirming the pattern found for "cerrado" physiognomies where few species contain most of the plant density (Felfili 2000).

Regarding the diameter distribution (figure 1) almost all species reach up to 23 cm with 75% of them between five and 11 cm. A total of 97% of the individuals are below 26 cm with around 80% of them under 11 cm. Therefore, the majority of species and individuals reach at the most 11 cm diameter. Only ten species presented individuals above 26 cm diameter, they were *Callisthene mollissima*, *Caryocar brasiliense*, *Curatella americana*, *Emmotum nitens*, *Erythroxylum campestre*, *Mouriri elliptica*, *Pseudobombax longiflorum*, *Qualea grandiflora*, *Qualea dichotoma*, *Simarouba versicolor*.

Beta diversity – Sørensen's index (figure 2) showed in general, higher similarities between plots at the same site or at least at the same Municipality indicating a geographical gradient influencing the floristic composition of the "cerrado" *sensu stricto* on rocky soils. Beta diversity was higher when comparing plots of Tocantins State in Almas with those in Goiás. Within Goiás, the plots of Mararosa differed the most from the others. Czekanowski's index (figure 3) confirmed this trend but the beta diversity was lower between the plots in Tocantins and those in Goiás. Mararosa in the North of Goiás showed a structure closer to the plots in Cavalcante and Colinas.

TWINSPAN classification (figure 4) showed strong divisions forming at the first level (eigen-values = 0.3854) a large group with *Curatella americana* as an indicator species containing plots characterized by species preferential to richer soils such as *Astronium fraxinifolium*, *Callisthene fasciculata*, *Dilodendron bipinnatum* and another smaller group characterized by *Myrcia multiflora* and *Mouriri elliptica* plus the gallery forest species *Protium heptaphyllum* and *Copaifera langsdorffii*, common between gallery forest and "cerrado" (Felfili & Silva Júnior 1992). At a second level of division the plots from Almas (P9 and P10) were separated from the others in the first group and the plot containing gallery forest species was separated from the others in the second group at this level. In this latter plot, occurred a gulley where water rises at the rainy season giving support to the establishment of gallery forest species. At a third level of division the plots containing indicator species of fertile soils were separated from the others. The divisions were strong with eigen values above 0.3, suggesting a high beta diversity among plots.

TWINSPAN classification final groups were defined by preferential species of more fertile soils, in opposition to those typical of dystrophic soils and to common species to gallery forests occurring on sloping terrains with gullies.

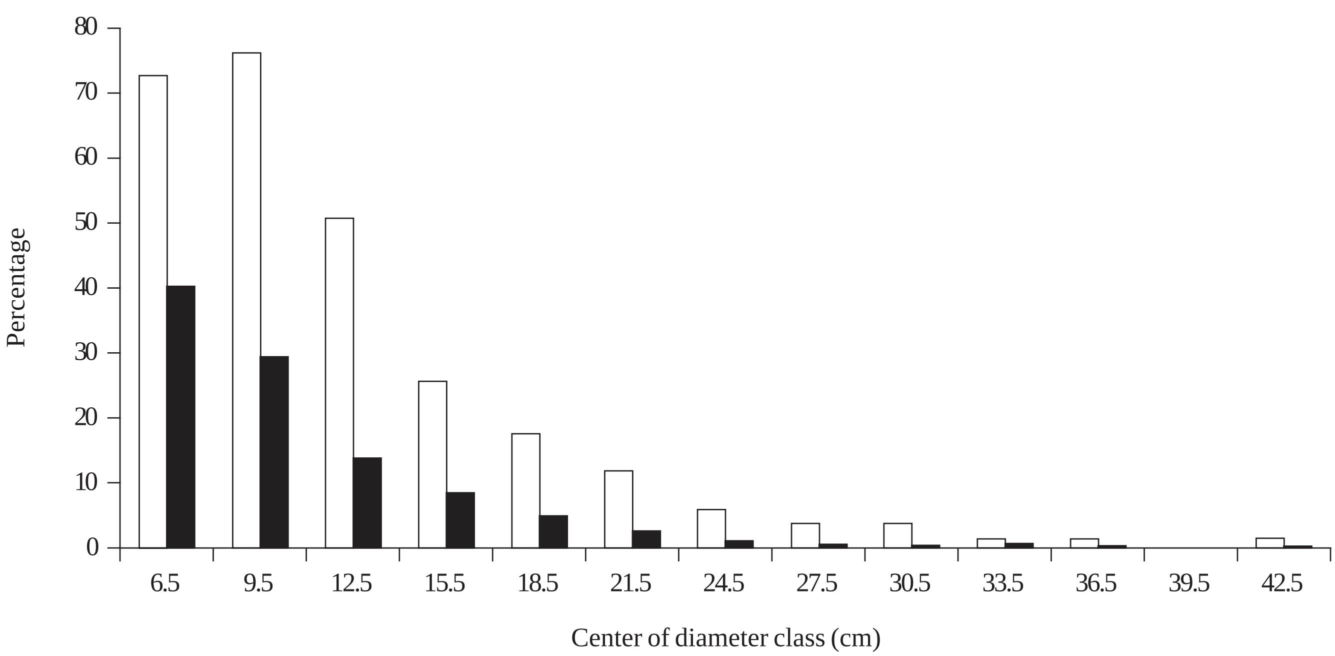

Figure 1. Distribution of the total number of species (%) and density (%) by diameter class in the "cerrado" *sensu stricto* on rocky and concretionary soils of northern Goiás and southern Tocantins State, Brazil (□ = Species (%), *n* = 85; ■ = Relative density, *n* = 836).

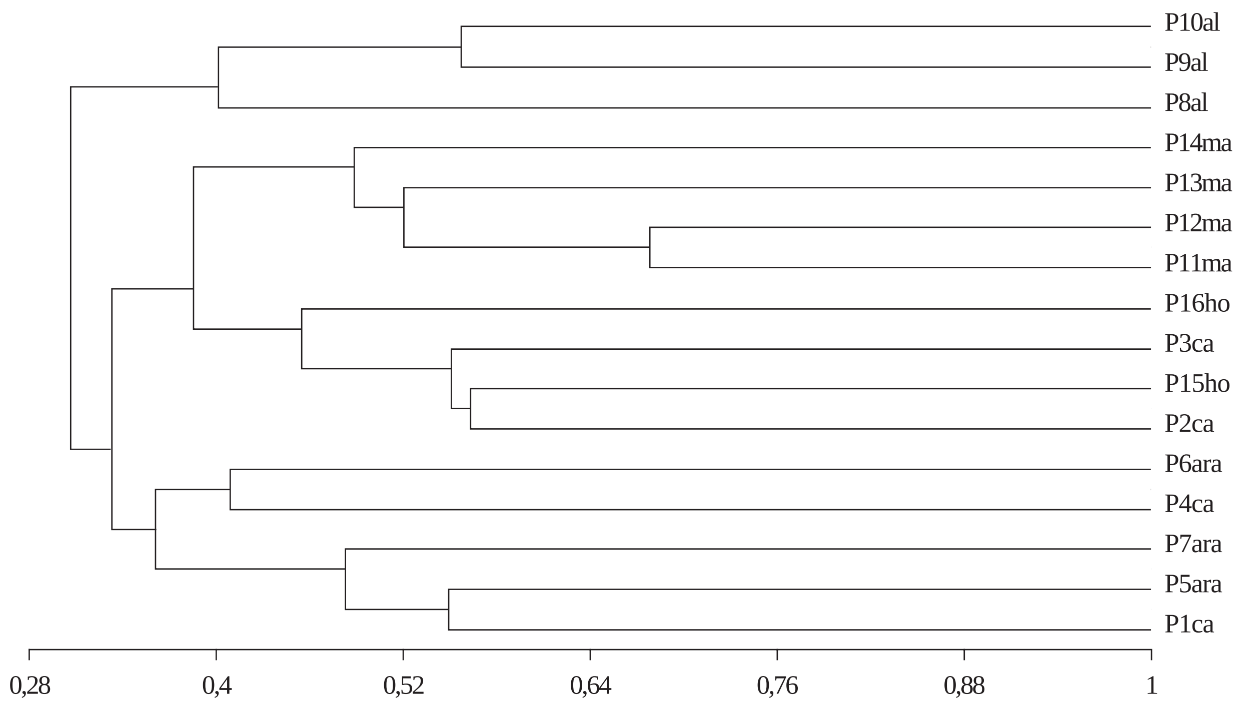

Figure. 2 Sørensen's similarity index for 16 (1,000 m²) plots of "cerrado" *sensu stricto* on rocky soils in Goiás and Tocantins State grouped by the method UPGMA. (al = Almas/TO; ma = Mararosa/GO; ho = Fazenda Horta, Cavalcante/GO; ara = Vale das Araras, Cavalcante/GO; ca = Cachoeira das Pedras Bonitas, Colinas/GO; P = plot).

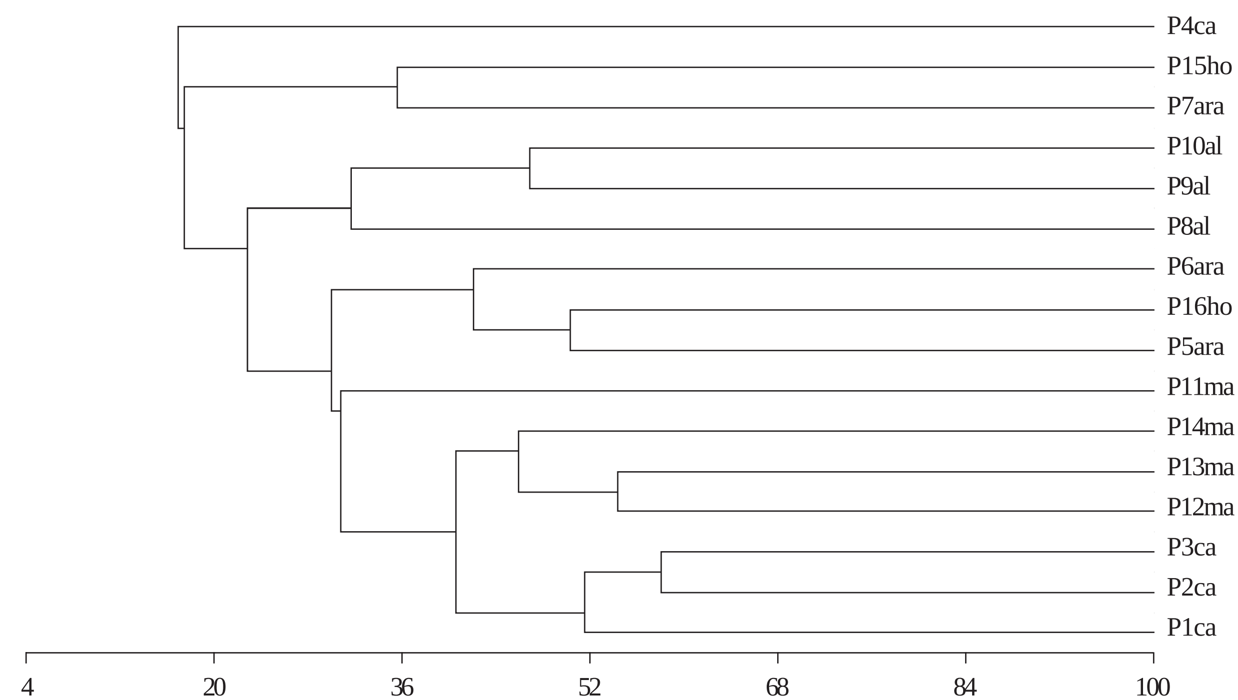

Figure 3. Czekanowski's (percent similarity) index for 16 (1,000 m²) plots of "cerrado" *sensu stricto* on rocky soils in Goiás and Tocantins State grouped by the method UPGMA. (al = Almas/TO; ma = Mararosa/GO; ho = Fazenda Horta, Cavalcante/GO; ara = Vale das Araras, Cavalcante/GO; ca = Cachoeira das Pedras Bonitas, Colinas/GO; P = plot).

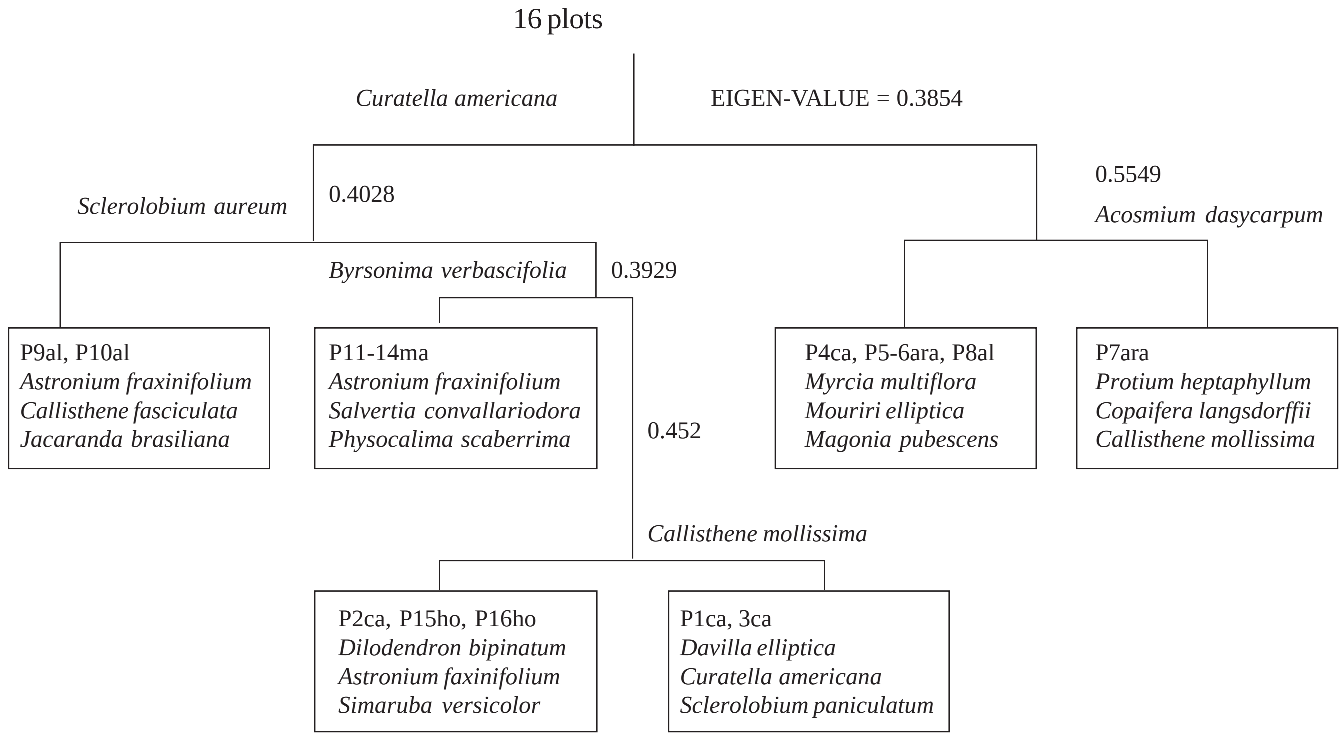

Figure 4. TWINSPAN classification for 16 (1,000 m^2) plots of "cerrado" *sensu stricto* on rocky soils in Goiás and Tocantins State. (al = Almas/TO; ma = Mararosa/GO; ho = Fazenda Horta, Cavalcante/GO; ara = Vale das Araras, Cavalcante/GO; ca = Cachoeira das Pedras Bonitas, Colinas/GO; P = plot).

Discussion

The ratio species x genera was nearly 1:1 suggesting a high genetic diversity within the woody component of the "cerrado", most species are not closely related to the others as also suggested by Felfili (1995) for gallery forest.

Shannon's diversity index was within the range found by Felfili *et al*. (1994, 1997, 2001) for "cerrado" *sensu stricto* in Latosols and in Neosols, following the same sampling methodology, suggesting that in this gradient of "cerrado" *sensu stricto* on rocky soils the diversity is high, reaching levels found for this physiognomy on the predominant soil types of the biome.

The values of density and basal area were also within the range found in several sites covered by the "cerrado" *sensu stricto* on Latosols or Neosols studied under similar methodology (Felfili & Silva Júnior 1992, 1993, Felfili *et al*. 1994, 1997, 1998, Rossi *et al*. 1998, Felfili *et al*. 2001). Five percent of dead standing trees is a value commonly found for the "cerrado" *sensu stricto* and indicates low disturbance in this vegetation (Felfili & Silva Júnior, 1992, 1993, Felfili *et al*. 1994, 1997, 1998, 2001).

Callisthene mollisima is a typical species in that region which is also favourable to the growth of *Davilla* and *Curatella*. This latter according to Felfili & Silva Júnior (1993) is typical of low altitude sites, those sites under 1,000 m high.

Qualea parviflora occurred in all sampled plots corroborating the widespread distribution of this species in central Brazil as found by Ratter & Dargie (1992), Felfili & Silva Júnior (1993), Ratter *et al*. (2000). Only nine of the 87 species occurred in more than 50% of the plots while 24 were found in only one plot. Few species are abundant and widespread in tropical formations as well as in the cerrado (Felfili 1995).

Preferential species of the first group by TWINSPAN were indicator species of fertile soils, some common to seasonal forests on limestone (table 2). The amount of litter accumulated in between rocks of these younger soils compared to the Latosols seems to be enough to support those species.

The floristic composition varies through the diameter classes since most species found in this study are small-sized and do not reach the larger classes. Therefore, richness decreases from the smaller to the higher diameter classes, a trait also common to gallery forests (Felfili 1995) and "cerrado" *sensu stricto* on Latosols (Felfili & Silva Júnior 1988) in central Brasil.

Preferential species by TWINSPAN classification, *Callisthene mollisima*, *Curatella americana*, *Davilla elliptica*, *Mouriri elliptica*, and *Myrcia multiflora* plus several indicator species of richer soils seem to be typical of "cerrado" *sensu stricto* on rocky soils in the region.

The "cerrado" *sensu stricto* on rocky and concretionary soils presented structural and diversity patterns in the same range to those found for this vegetation in other substrates over central Brazil. Generalist species such as *Qualea parviflora* were present in all plots but a geographical gradient could be detected. Preferential species to more fertile soils, to dystrophic soils and to humid soils in the gullies determined the species grouping.

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