What are the most important factors determining different vegetation types in the Chapada Diamantina, Brazil?

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Abstract

A transect was used to examine the environmental and biological descriptors of a compact vegetation mosaic in the Chapada Diamantina in northeastern Brazil, including the floristic composition, spectrum of plant life forms, rainfall, and soil properties that defined areas of cerrado (Brazilian savanna), caatinga (seasonally dry tropical forest thorny, deciduous shrub/arboreal vegetation) and cerrado-caatinga transition vegetation. The floristic survey was made monthly from April/2009 to March/2012. A dendrogram of similarity was generated using the Jaccard Index based on a matrix of the species that occurred in at least two of the vegetation types examined. The proportions of life forms in each vegetation type were compared using the chi-square test. Composite soil samples were analyzed by simple variance (ANOVA) to examine relationships between soil parameters of each vegetation type and the transition area. The monthly precipitation levels in each vegetation type were measured and compared using the chi-square test. A total of 323 species of angiosperms were collected distributed in 193 genera and 54 families. The dendrogram demonstrated strong difference between the floristic compositions of the cerrado and caatinga, sharing 2% similarity. The chi-square test did not demonstrate any significant statistical differences between the monthly values of recorded rainfall. The organic matter and clay contents of the soilsin the caatinga increased while sand decreased, and the proportions of therophyte, hemicryptophyte, and chamaephyte life forms decreased and phanerophytes increased. We can therefore conclude that the floristic composition and the spectrum of life forms combined to define the cerrado and caatinga vegetation along the transect examined, with soil being the principal conditioning factor determining the different vegetation types, independent of precipitation levels.

Keywords: Savanna, seasonally dry tropical forest, biological spectrum, soil, rainfall.

Quais são os fatores mais importantes na determinação de diferentes tipos de vegetação na Chapada Diamantina, Brasil?

Resumo

Foi estabelecida uma transecção para examinar descritores ambientais e biológicos em uma área compacta de vegetação em mosaico na Chapada Diamantina, Nordeste do Brasil. A composição florística, espectro de formas de vida, precipitação e propriedades do solo foram avaliadas na transecção entre cerrado (savana brasileira) e caatinga (floresta tropical sazonalmente seca espinhosa, vegetação arbustivo-arbórea decídua), separados por vegetação de transição cerrado-caatinga. O levantamento florístico foi realizado mensalmente de abril de 2009 a março de 2012. Foi feita análise de agrupamento a fim de determinar a similaridade entre as fisionomias de cerrado, a caatinga e a transição cerrado-caatinga. As proporções de formas de vida foram comparadas utilizando o teste qui-quadrado. Amostras compostas de solo foram analisadas por variância simples (ANOVA) testando a existência de diferenças entre os solos de cada tipo de vegetação. A precipitação mensal em cada tipo de vegetação foi mensurada e os resultados comparados com o teste qui-quadrado. Coletamos 323 espécies de angiospermas pertencentes a 193 gêneros e 54 famílias. A análise de agrupamento demostrou diferença entre a composição florística do cerrado e da caatinga, com apenas 2% de similaridade. O teste qui-quadrado não demonstrou diferença estatística entre os valores registrados para cada mês. À medida que os conteúdos de matéria orgânica e argila aumentaram e o de areia diminuiu na caatinga, a proporção das formas de vida terófito, hemicriptófito e caméfito diminuiu e a de fanerófitos aumentou. Podemos considerar que a composição florística e o espectro de formas de vida delimitaram o cerrado e a caatinga na transecção estudada e que o solo foi o principal fator condicionante para determinação dos diferentes tipos de vegetação, independentemente da precipitação.

Palavras-chave: Savana, floresta tropical sazonalmente seca, espectro biológico, solo, precipitação.

1. Introduction

The Chapada Diamantina, the northern extension of the Serra of the Espinhaço Range in Brazil, is included within the Caatinga biome of northeastern Brazil and hosts a large diversity of vegetation types associated with its physiographic spectrum, including cerrado (neotropical savanna), campo rupestre (open, rocky field grasslands), forest, and caatinga (seasonally dry tropical forest thorny, deciduous shrub/arboreal vegetation) (Harley, 1995; Juncá et al., 2005).

A number of floristic studies have already been undertaken in the Chapada Diamantina, including those considering: campo rupestre (Conceição et al., 2007; Neves and Conceição, 2010), cerrado (Costa et al., 2009), caatinga (Lima and Lima, 1998), submontane seasonal semi-deciduous forest, upper montane forest, and gallery forest (Funch et al., 2008; Nascimento et al., 2010; Couto et al., 2011). Rapid ecological surveys of diverse vegetation types have also been undertaken (Harley et al., 2005; Juncá et al., 2005; Funch et al., 2009), although most of the studies considered only be shrub-arboreal layer and/or made collections on irregular schedules.

Funch et al. (2009) published a vegetation map of the Chapada Diamantina National Park and the surrounding region describing vegetation types, based on Harley (1995), and associated with different soil types distributed contiguously within a relatively limited area. In light of the intriguingly close dispositions of different vegetation types under apparently identical macro-climatic conditions, we investigated cerrado and caatinga vegetation sites and their ecotone along an E-W transect just west of the National Park to contribute to our understanding of the phytogeography of Brazil.

Our study focused on the floristic compositions of the herbaceous-subshrub and shrub-arboreal layers, life forms, rainfall, and soil properties in addressing the question of which factors are most important in defining the cerrado and caatinga vegetation along this transect.

We hypothesized that variations in the physiognomy, floristic compositions, and structures of natural ecosystems could occur due to variations in the chemical and physical properties of their soils (Haridasan, 2000; Amorim and Batalha, 2006; Juhász et al., 2007; Silva et al., 2013), and that permeability and the proportions of fine particles would be the parameters most closely associated with species richness (Medinski et al., 2010). We also considered that: 1) climatic factors have a decisive role in determining species and plant community distributions (Terradas, 2001; Lavers and Field, 2006); 2) water availability is one of the principal determinants of vegetation cover (Silva and Batalha, 2008; Cianciaruso and Batalha, 2009), and; 3) life forms are important elements in vegetation descriptions (Raunkiaer, 1934).

2. Material and Methods

2.1. Study area

The Chapada Diamantina National Park has a much accentuated topography of low mountains with rocky peaks and steep slopes, narrow valleys with extensive plains to the west that are separated by long chains of hog-back mountains. Altitudes in the region vary from 400 to more than 2,000 m a.s.l. The isolated peaks and extended mountain chains have extensive rock outcrops and litholic neosols (thin, rocky soils of low fertility), while soils on the intermediary plains are predominantly latosols (deep, well-drained, acidic, with low fertility) (Juncá et al., 2005).

The regional climate is mesothermic (Cwb) (Köppen, 1948), with average monthly temperatures varying between 18 and 25 °C, with the lowest temperatures occurring during driest months. The average annual precipitation is 1,218 mm (for the period between 1951-2011). The rainy season usually begins in November and extends until March, while the dry season initiates in June and continues until October (Juncá et al., 2005).

The present study was conducted in two vegetation types: cerrado, represented by three local physiognomies (two sites of open cerrado – OP, rocky outcrop cerrado – ROC, and typical cerrado – TC) and caatinga (CAA). The cerrado-caatinga transition (CCT) between of these both vegetation types also was sampled (Table 1). These vegetation are contiguously distributed along a 10 Km E-W transect sampled (12º 26’ 05” S to 12º 27’ 7” S to 41º 31’ 05” W to 41º 35’ 52” W) just west of the Chapada Diamantina National Park in the Chapada Diamantina, Bahia State, Brazil. The phytophysiognomies of cerrado are included in cerrado *stricto sensu* (Ribeiro and Walter, 2008). Caatinga is characterized by a predominance of low shrubs and trees that are highly branched, often spiny, and deciduous in the dry season (Pennington et al., 2009).

2.2. Floristic composition and life forms

The vegetation types were selected along a 10 Km east-west transect based on the vegetation map of Funch et al. (2009) and identified in the field as distinct areas of well-conserved cerrado and caatinga. We established ninety 100 m^2 plots (15in each of the four vegetation types examined: the two types of cerrado, the cerrado/caatinga transition, and caatinga) for a total of 0.9 ha. Plant collections were performed monthly in all sites from April/2009 to March/2012 of both fertile and sterile plant material of herbaceous-subshrub and shrub-arboreal species (this period included three rainy seasons and three dry seasons). The voucher specimens were deposited in the Herbarium of the State University at Feira of Santana (HUEFS) and identified with the aid of specialists and by comparison with previously identified material. The classifications of the plant families followed the proposal of the APG III (2009).

The life forms of the specimens were classified according to Raunkiaer (1934), excluding epiphytes and considering succulents separately from phanerophytes.

Table 1. Descriptions of vegetation types physiognomies and vegetation types in the mosaic parameters cerrado-caatinga, Chapada Diamantina, NE Brazil.

	Species more important												
	Families more rich in species												
	Total numbers of species	**Numbers of exclusive species**	**Numbers of families (Number of genera)**	**Herbaceous-subshrub /shrub-Arboreal**	**Monocotyledons Dicotyledons**		**Species Nº**	**Species %**	**Density (individuals tree-shrub/ha)**	**Herbaceous-subshrub**	**IV(%)**	**Shrub-arboreal**	**IVI(%)**
cerrado ralo (site I) 12º 26' 18" S 41º 30' 53" W Alt.: 857 m	101	13 (12.87%)	25 (75)	9.10	19 (19%) 82 (81%)	Poaceae Asteraceae Fabaceae Rubiaceae Euphorbicaeae	14 12 12 8 6	14 12 12 8 6	2.380	*Trachypogon spicatus* *Bulbostylis fasciculata* *Pavonia cancelata* *Calea harleyi* *Jacquemontia evolvuloides*	54	*Annona coriacea* *Eugenia punicifolia* *Duguetia furfuracea* *Lippia microphylla* *Stryphnodendron* sp.	98
open cerrado ralo (siteII) 12º 26' 05" S 41º 31' 05" W Alt.: 889 m	93	5 (5.37%)	31 (72)	3.20	22 (24%) 71 (76%)	Poaceae Fabaceae Rubiaceae Cyperaceae Lamiaceae	15 12 6 5 5	16 13 6,5 5,5 5,5	2.160	*Trachypogon spicatusStigmaphyllom paraliasAxonopus polydactylus* *Ruellia incompta* *Bulbostylis fasciculata*	43	*Croton velutinus* *Annona coriacea* *Agarista* cf. *chapadensis* *Hyptis macranta* *Eugenia punicifolia*	64
rocky outcrop cerrado 12º 26' 08" S 41º 31' 04" W Alt.: 884 m	105	17 (16.19%)	33 (84)	2.82	15 (14%) 90 (86%)	Fabaceae Asteraceae Poaceae Rubiaceae Cyperaceae	14 9 9 7 5	13,5 9 9 7 5	4.960	*Trachypogon spicatus* *Echinolaena inflexa* *Axonopus polydactilus* *Stigmaphyllom paraliasSebastiania corniculata*	31	*Croton velutinus* *Annona coriacea* *Lippia microphylla* *Vochysia thyrsoidea* *Marcetia taxifolia*	53
typicalcerrado 12º 26' 16" S e 41º 31' 11" W Alt.: 843 m	119	25 (20.66%)	32 (85)	3.95	25 (21%) 94 (79%)	Poaceae Fabaceae Asteraceae Malvaceae Euphorbiaceae	20 19 8 7 6	17 19 7 6 5	5.250	*Trachypogon spicatus* *Stylosanthes scabra* *Pavonia cancellataStigmaphyllom paralias* *Mimosa somnians*	46	*Annona coriacea* *Dalbergia miscolobium* *Cordia rufescens* *Solanum stipulaceum* *Croton heliotropiifolius*	84

Table 1. Continued...

	Species more important												
	Families more rich in species												
	Total numbers of species	Numbers of exclusive species	Numbers of families (Number of genera)	Herbaceous-subshrub /shrub-Arboreal	Monocotyledons Dicotyledons		Species Nº	Species %	Density (individuals tree-shrub/ha)	Herbaceous-subshrub	IV(%)	Shrub-arboreal	IVI(%)
cerrado-caatinga transition 12º 26' 34" S e 41º 32' 01" W Alt.: 736 m	94	23 (24.46)	30 (69)	2.44	25 (26%) 69 (74%)	Poaceae Fabaceae Malvaceae Myrtaceae Convolvulaceae Euphorbiaceae Rubiaceae	16 10 7 6 5 5 5	17 11 7,5 6,5 5,5 5,5 5,5	3.680	*Hohenbergia* cf. *caatingae* *Panicum* sp *Streptostachys robusta* *Aristida sp.* *Billbergia porteana*	29	*Senegalia riparia* *Croton adamantinus* Bignoniaceae *Croton heliotropiifoliusActinostemon concolor*	65
caatinga 12º 27' 07" S e 41º 35' 58" W Alt.: 697 m	117	102 (87.17%)	(31) 77	3.03	21 (18%) 96 (82%)	Fabaceae Bignoniaceae Euphorbiaceae Malpighiaceae Cactaceae	16 15 13 8 7	15 13 11 7 6	6.520	*Neoglaziovia variegata* Poaceae *Tacinga werneri* *Cryptanthus*sp. *Tacinga funalis*	52	*Senegalia tenuifolia* *Maprounea guianensis* *Actinostemon* sp. *Erythroxylum oxypetalum* *Dalbergia cearensis*	38

The proportions of herbaceous-subshrub/shrub-arboreal (epiphytes, succulents, chamaephytes, hemicryptophytes, and therophytes /phanerophytes) species were calculated for each of the vegetation types, for cerrado-caatinga transition, and for the different cerrado physiognomies. The importance values (IV) of the herbaceous-subshrub species (the sum of coverage and relative frequency) and shrub-arboreal layer (the sum of the density, dominance and relative frequency) were used to identify the five most important species of each layer in each vegetation type (Neves, 2013).

2.3. Rain fall and soils properties

Rainfall gauges were installed in each vegetation type and in the ecotone. Monthly precipitations levels were measured between January/2010 and March/2012 (Figure 1). Three composite soil samples (0-20 cm) were collected in each vegetation type and in the ecotone. Each composite sample was taken by mixing soils from three random points, totaling 18 composite samples (12 in the cerrado, three in the caatinga and three in the cerrado-caatinga transition). The physical and chemical properties of these samples were analyzed in an agricultural laboratory (Embrapa Semi-Árido - PE), according Donagema et al. (2011).

2.4. Statistical analyses

To determine the floristic similarities between the cerrado, caatinga and ecotone sites (considering the different cerrado physiognomies), clustering analysis was performed based on their Jaccard similarity (JS) as derived from a binary matrix, using the Unweighted Pair Group Method with Arithmetic Mean (UPGMA) run on Past software (Hammer et al., 2001). The cut-off used in this study was 25% following Mueller-Dombois and Ellenberg (1974). We compared the proportions of species in each life form class among the different vegetation types and the three cerrado physiognomies using the chi-square test (χ^2). The average values and standard errors of each physical and chemical component of the soils in the different vegetation types were calculated and simple analysis of variance (ANOVA) was performed to detect statistical differences between them, utilizing Sisvar software (Ferreira, 2000). The Tukey test ($P<0.05$) was used to compare the observed averages. The rainfall indices in the vegetation areas were compared using the chi-square test (χ^2).

3. Results

3.1. Floristic composition

The numbers of species, genera and families, as well as the proportions of monocotyledons and eudicotyledon species, and the ratio of herbaceous-subshrub/shrub-arboreal species of cerrado phytophysiognomies, caatinga vegetation and cerrado-caatinga transition are presented in Table 1. A total of 323 species of angiosperms belonging to 193 genera and 54 families were encountered (Appendix), with 253 species (78%) occurring in only one of the vegetation types, 68 species (21%) in two types, and only four species (1%; *Casearia sylvestris* [Salicaceae], *Croton heliotropiifolius* [Euphorbiaceae], *Panicum* sp. [Poaceae] and *Syagrus* sp. [Arecaceae]) occurring in all sampled vegetation. Of the 325 of species, 260 species (80%) were eudicotyledons and 65 (20%) monocotyledons. The cerrado vegetation type showed the greatest richness (190 spp.; 58%) (Appendix). The cerrado and cerrado-caatinga transition shared 57 (18%) species belonging to 20 families (37%) and 43 genera (22%). The cerrado-caatinga transition and the caatinga shared 15 (5%) species belonging to 10 (19%) families and 15 (8%) genera. The families more rich in species are in the Table 1.

3.2. Life forms

The floristic spectra of life forms in the sampled vegetation are presented in Figure 2. Chi-Square tests indicated significant differences in the percentages of chamaephytes, therophytes and phanerophytes species between the caatinga and the cerrado, and between the caatinga and the cerrado-caatinga transition areas. Significant statistical differences (using the same test) were also noted between the cerrado (except the rocky outcrop cerrado) and caatinga, and between the cerrado and the cerrado-caatinga transition for the hemicryptophyte.

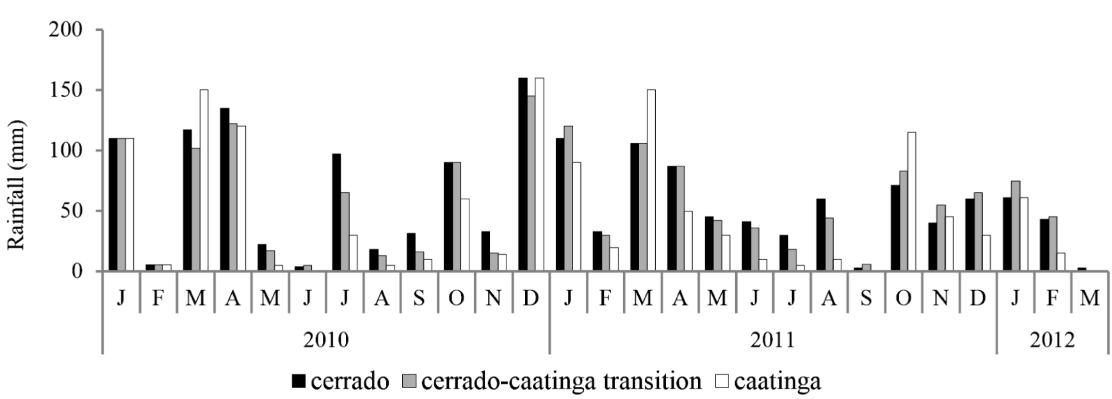

Figure 1. Rainfall (mm) in caatinga, cerrado, and their transition vegetation, Chapada Diamantina, NE Brazil.

3.3. Similarities

The dendrogram demonstrated strong difference between the floristic compositions of the cerrado and caatinga, sharing 2% of similarity (Figure 3). Caatinga is the most distinct physiognomy and the cerrado-caatinga transition area is more similar with cerrado (24%). The cerrado physiognomies form a coherent group with 39% similarity.

3.4. Rainfall and soil properties

The chi-square test did not demonstrate any significant statistical differences between the monthly values of recorded rainfall. The average values and standard errors of the physical-chemical parameters of the soils of each vegetation type and the different cerrado phytophysiognomies are presented in Table 2. The cerrado soil was predominately

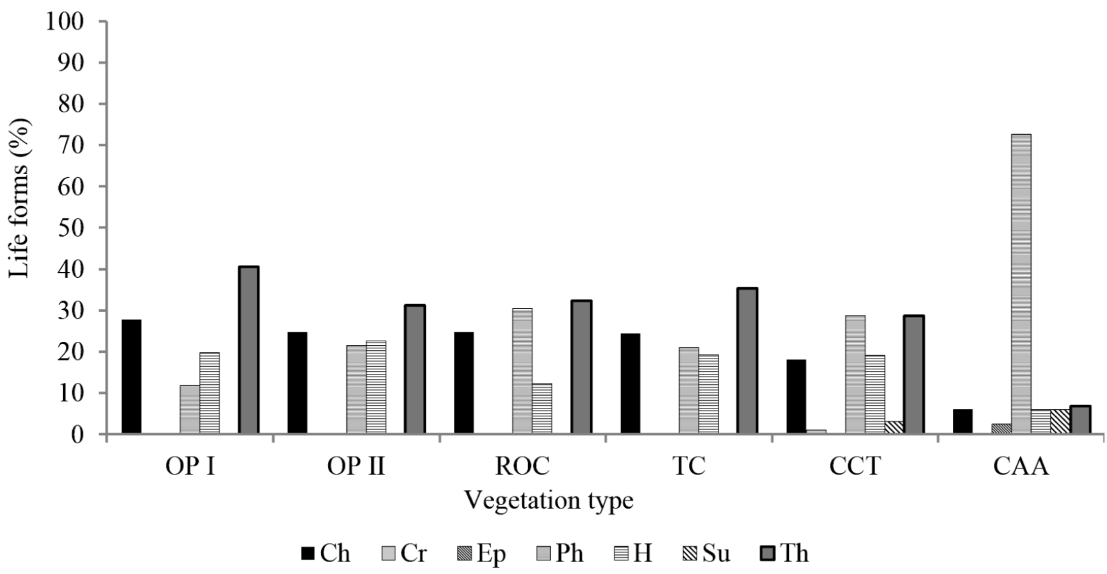

Figure 2. Floristic life form spectra in the different vegetation type, Chapada Diamantina, NE Brazil. Ch: chamaephyte; H: hemicryptophyte; Ph: phanerophyte; Th: therophyte; Cr: cryptophyte; Su: "succulent"; Ep: epiphyte; OPI = open cerrado, area I; OP II = open cerrado, area II; ROC = rocky outcrop cerrado; TC = typical cerrado; CCT = cerrado-caatinga transition; and CAA = caatinga.

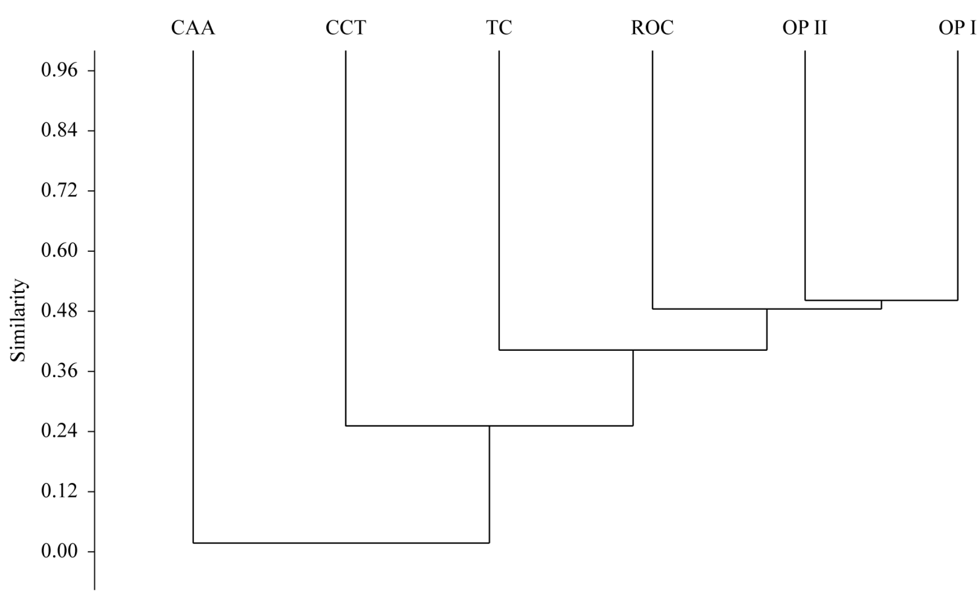

Figure 3. Cluster of floristic similarity (UPGMA) in the different vegetation type, Chapada Diamantina, NE Brazil. OPI = open cerrado, area I; OP II = open cerrado, area II; ROC = rocky outcrop cerrado; TC = typical cerrado; CCT = cerrado-caatinga transition; and CAA = caatinga.

Table 2. Averages and standard deviations of the physical and chemical characteristics of the soils in the different vegetation type areas, Chapada Diamantina, NE Brazil.

	OPI	OPII	ROC	TC	CCT	CAA	*F*
Physical characteristics							
DP (Kg/dm^{-3})	2.58±0.02a	2.59±0.02a	2.58±0.005a	2.55±0.02a	2.55±0.04a	2.58±0.05a	0.90
DS (Kg/dm^{-3})	1.34±0.02a	1.45±0.05ab	1.40±0.08ab	1.46±0.02b	1.39±0.02ab	1.45±0.017ab	3.43
Porosity (%)	47.99±0.44a	44.01±2.69 ab	44.48±2.22 ab	42.54±1.35b	45.44±0.44 ab	43.68±1.25 ab	3.97
Total sand (%)	88.66±1.14a	93.93±22.84a	91.73±3.21a	91.28±2.89a	71.87±4.07b	67.07±3.91b	42.81
Silt (%)	7.51±1.06a	3.33±1.61a	6.89±2.10a	4.58±2.99a	7.11±2.17a	12.51±7.69a	2.20
Clay (%)	3.82±9.51a	2.74±1.80a	1.37±1.12a	4.13±4.03a	21.01±2.1b	20.42±3.41b	37.20
Chemical characteristics							
MO (g/kg)	4.45±1.64a	3.51±2.31a	4.51±1.90a	7.08±1.36ab	15.59±8.34b	8.65±0.24ab	4.36
pH	5.2±0.10a	4.73±0.05bc	4.83±0.05b	4.36±0.11d	4.00±0.1e	4.56±0.05cd	70.29
P (mg/dm^3)	0.62±0.11ab	0.52±0.07a	0.87±0.11b	1.24±0.11c	0.77±0.11ab	0.70±0.19b	12.15
Al (cmol/dm^3)	0.43±0.07a	0.48±0.07a	0.4±0.08a	0.77±0.15b	1.32±0.07c	0.50±0.10ab	38.12
K (cmol/dm^3)	0.05±0.02a	0.05±0.002a	0.03±0.005a	0.04±0.005a	0.12±0.04b	0.12±0.004b	19.01
Ca (cmol/dm^3)	0.35±0.05a	0.51±0.13a	0.37±0.05a	0.47±0.15a	0.64±0.14ab	0.92±0.17b	7.96
Mg (cmol/dm^3)	0.78±0.02a	0.36±0.24a	0.80±0.68a	0.56±0.18a	0.80±0.10a	0.82±0.42a	2.18
Na (cmol/dm^3)	0.01±0.005ab	0.01±0a	0.01±0a	0.01±0.005ab	0.02±0.005b	0.01±0.00a	4.80
Potential acidity (cmolc/dm3)	11.6±1.19b	4.78±1.86a	9.29±1.99b	4.40±1.65a	5.17±0.34a	4.67±1.27a	12.44
Sum of bases (cmolc/dm3)	1.19±0.04ab	0.90±0.15a	0.87±0.12a	1.08±0.14a	1.58±0.07bc	1.87±0.26c	21.19
CEC (cmolc/dm3)	12.80±1.14c	6.01±1.55ab	10.16±2.03bc	5.48±1.75a	6.74±0.41ab	6.55±1.53ab	10.84
Base saturation (%)	9.66±1.15ab	16.67±5.03bc	9.00±1.73a	19.00±2.64c	23.67±0.57cd	29.00±2.64d	25.05

Different letters in the same lines indicate significant differences between the vegetation types (ANOVA, $P<0.05$). Densities of particles (DP), soil density (DS), porosity and proportions of total sand, silt, and clay and the chemical characteristics (organic matter (MO), phosphorus (P), aluminum (Al), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), Potential acidity, sum of bases (SB), cationic exchange capacity (CEC), and base saturation. Chapada Diamantina, NE Brazil. OPI = open cerrado I, OP II = open cerrado II, ROC = rocky outcroup cerrado, TC = typical cerrado, CCT = cerrado-caatinga transition, and CAA = caatinga. *F* values from ANOVA.

sandy, while cerrado-caatinga transition and caatinga areas were sandy clay loams. The soils in all of the vegetation types were dystrophic (base saturation < 50%), acidic (pH < 5, except in the open cerrado, site I) and had relatively low Al contents (Al < 1.3 cmol/dm^3, except in the cerrado-caatinga transition) and with exchangeable retention capacities less than 13, with high H^+ e Al^{+3} loads.

4. Discussion

The cerrado and caatinga vegetation sites as well as their transition, were well delimited in terms of their floristic compositions, life form spectra and soil properties. The cerrado vegetation demonstrated plant communities with ample varieties of three-dimensional structures and spatial heterogeneities, as reflected in the three different phytophysiognomies identified. Pennington et al. (2009) noted that cerrado vegetation physiognomies can be found under the same (or slightly more humid) climatic conditions as seasonal tropical dry forests, and that these vegetation types are often be found relatively close to one another.

Changes in the floristic compositions of the cerrado, cerrado-caatinga transition, and caatinga were accompanied by changes in the proportions of total sand, clay, and organic matter of their soils. Although high species-richness is often found in ecotone areas due to their greater environmental heterogeneity (Rodrigues and Nave, 2000), the transition zone studied here was less richness than the cerrado and caatinga surveyed. It is probable that the environmental conditions in that area are more rigorous and limit the occurrence of larger numbers of species (Mota et al., 2011).

The cerrado-caatinga transition area shared a greater percentage of species with the cerrado (approximately 70%) than with the caatinga (approximately 16%), indicating a high floristic similarity between them. More than 50% of the life forms shared between these two sites were therophytes –thus making essentially insignificant contributions to the overall differences in physiognomies between those vegetation types. Approximately 60% of the species shared by these two vegetation types were phanerophytes, which demonstrated deciduousness as a strategy to reduce water losses during the dry period (Neves, 2013).

The best represented life-form in the cerrado vegetation studied here was that of therophytes – a situation different from other cerrado *sensu stricto* areas that generally show high proportions of phanerophytes (Batalha and Martins, 2004; Costa et al., 2004). Phanerophytes were the most representative life forms in the caatinga vegetation studied – which was also different from the findings of Costa et al. (2007) in shrub caatinga communities growing in "warm and low latitude and altitude steppe climates (Bsh, according to the Köppen (1948) system)" that were well-represented by therophytes. While the principal strategy used in Caatinga phytoclimates to avoid water loss during the dry season is a predominance of therophytes, the caatinga studied here adapted a phanerophyte strategy of leaf-fall (Larcher, 2000).

The systematic collections undertaken in the present study, which covered three rainy seasons, three dry seasons, and three intermediate seasons, may have been responsible for the contrast between our life form data and those of studies by Batalha and Martins (2004) and Costa et al. (2004, 2009) who all made shorter and less frequent collections. Batalha and Martins (2004) noted that species whose buds are not exposed to the open air (i.e. hemicryptophytes, cryptophytes, and therophytes) tend to be under-represented among collections undertaken during just a single period. Consecutive collections during a 36 month period (in the present study) allowed for ample sampling of the floristic composition.

No significant differences were observed between the three different cerrado phytophysiognomies in terms of their soil properties (principally in relation to physical parameters) and their respective floristic spectrums of life forms. Dantas and Batalha (2011) encountered relationships between edaphic conditions and floristic composition and richness in a fine-scale study of a cerrado area. Marimon Junior and Haridasan (2005) noted that soil fertility did not support the hypothesis of the contiguous occurrence of cerradão vegetation and cerrado *sensu stricto* vegetation. The same authors reported that the greater percentage of clay in the cerradão site allowed the establishment of greater densities of trees due to greater soil-water availability. Ruggiero et al. (2002) reported that campo cerrado, cerrado *sensu stricto* and cerradão could not be distinguished based on soil chemical parameters. The greater species richness and densities of shrub-arboreal individuals in the typical cerrado site in the present study appeared to be associated with the greater proportions of clay and organic material there that would presumably increase water retention, aid the growth of soil microorganisms, and increase nutrient availability for plant growth (Motta et al., 2002). The presence of blocks of stone in the rocky outcrop cerrado, the occurrence of wild-fires in the typical cerrado, and the densities of arboreal individuals and the interactions between different species in each phytophysiognomy appear to be factors generating the distinct cerrado phytophysiognomies.

While low precipitation levels (less than 700 mm/year) concentrated into as few as three consecutive months during the summer in the southern hemisphere and associated with average temperatures of 26 °C (Nimer, 1989) are considered typical conditions for the establishment of caatinga vegetation (Andrade-Lima, 1981; Sampaio, 1995), rainfall was not a useful factor for delimiting cerrado and caatinga vegetation, such as their transition, in the present study. The soil-water relationships in these vegetation sampled may be influenced by their respective proportions of total sand and clay, because although the cerrado-caatinga transition and caatinga sites had rainfall levels slightly less than that of the cerrado, the water retentions of their soils would presumably be greater due to their larger proportions of clay and organic matter – thus favoring the establishment of greater plant abundances and species richnesses in the shrub-arboreal layer (Motta et al., 2002).

This study demonstrates that the floristic compositions, floristic life form spectra, and the heterogeneity of the soil were elements that delimited cerrado, cerrado-caatinga transition, and caatinga. The soil was the principal conditioning factor determining the different vegetation types, independent of precipitation levels. As the organic matter and clay contents of the soil increased and the percentages of sand decreased the proportions of therophytes, hemicryptophytes and chamaephytes diminished, while phanerophytes increased. The importance of edaphic conditions, and not just the scarcity and irregularity of rainfall, as is usually supposed, must be considered as a factor in establishing caatinga vegetation.

It must also be emphasized that no single variable determined the occurrence of each vegetation type, but rather the interactions between them. Species interactions themselves likewise influence the establishment of vegetation formations, as species richness depends on a mix of factors that can alter the effects of other variables.

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Appendix. Species list in the vegetation types and cerrado physiognomies, such as in the cerrado-caatinga transition, Chapada Diamantina, NE Brazil.

Species	Voucher	LF	OP I	OP II	ROC	TC	CCT	CAA
Acanthaceae								
Ruellia incomta Lindau	230	Ch	x	x	x	x		
Thyrsacanthusramosissimus (Moric.) V.M.Baum	229	H					x	x
Agavaceae								
Herreria sp.		Th						x
Amaranthaceae								
Alternanthera cf. *brasiliana* Kuntze	327	Th	x	x	x	x		
Gomphrena agrestis Mart.	214	Th	x	x	x	x	x	
Gomphrena mollis Mart.	202	Th			x			
Pfaffia acutifolia O. Stützer		Th				x		
Anacardiaceae								
Astronium sp.		Ph						x
Spondias sp.	439	Ph						x
Annonaceae								
Annona coriacea Mart.	199	Ph	x	x	x	x		
Duguetia furfuracea (A. St.-Hil.) Saff.	210	Ch	x	x	x	x		
Apocynaceae								
Blepharodon nitidum (Vell.) Macbr.	397	Th				x		
Ditassa retusa Mart.	231	Ph		x	x			
Hancornia speciosa Gomez	265	Ph	x	x	x			
Oxypetalum capitatum Mart.	433	Th	x					
cf. *Prestonia coalita* (Vell.) Woodson		Th						x
Secondatia floribunda A.DC.		Th				x		
Araceae								
Philodendron lundii Warm.		H						x
Arecaceae								
Syagrus sp.		Ph				x	x	x
Asteraceae								
Acanthospermum australe Kuntze		Ch	x		x	x		
Aspilia hispidantha H. Rob.	398	Th	x		x	x		
Calea harleyi H.Rob.	377	Ch	x	x	x	x		
Conocliniopsis prasiifolia (DC.) R.M. King & H. Rob.	381	Ch	x	x	x	x	x	
Chaptaliaintegerrima (Vell.) Burkart	302	Th	x					
Chaptalia sp. 2		Th	x					
Chromolaena sp.	301	Th	x					
Elephantopus hirtiflorus DC.	376	H	x	x		x		
Eremanthus capitatus (Spreng.) MacLeish	383	Ph			x			
Lasiolaena blanchetti (Baker) R.M.King & H.Rob.	379	Th			x			
Lepidaploa chalybaea (Mart. ex. DC.) H.Rob.	375	Ch	x		x	x	x	
Lepidaploa cotoneaster Willd ex. Spreng.	374	Ch	x		x		x	
Platypodanthera melissifolia (DC.) R.M.King & H.Rob.	473	Th				x		
Porophyllum ruderale (Jacq.) Cass.	384	Th				x		
Stilpnopappus tomentosus Gardner	380	Th	x	x	x			
Trichogonia salviifolia Gardner	473	Th				x		
Tridax procumbens L	474	Th	x					

LF = Life form; Ch: chamaephyte; H: hemicryptophyte; Ph: phanerophyte; Th: therophyte; Cr: cryptophyte; Su: "suculenta"; Ep: epiphyte; OPI: open cerrado (site I); OPII (site II): open cerrado II; ROC: rocky outcrop cerrado; TC: typical cerrado; CCT: cerrado-caatinga transition; CAA: caatinga.

Appendix. Continued...

Species	Voucher	LF	OP I	OP II	ROC	TC	CCT	CAA
Bignoniaceae								
Arrabidaea selloi (Spreng.)		Ph						x
Bignonia binata Thunb.	457	Ph						x
Bignonia convolvuloides (Bureau & K.Schum.) L.G.Lohmann	466	Ph						x
Bignonia erubescens S.Moore		Ph						x
Fridericia chica (Bonpl.) L.G.Lohmann	465	Ph						x
Fridericia cinerea (Bureau ex K.Schum.) L.G.Lohmann	308	Ph					x	
Fridericia platyphylla (Cham.) L.G.Lohmann	313	Ph						x
Mansoa hirsuta DC.		Ph						x
Neojobertia candolleana Bureau & K.Schum.		Ph					x	
Proterantha glandulosa A.H. Gentry	310	Ph						x
Tabebuia spongiosa Rizzini	463	Ph						x
Bignoniaceae 1		Ph						x
Bignoniaceae 2		Ph						x
Bignoniaceae 3		Ph						x
Bignoniaceae 4		Ph						x
Bignoniaceae 5		Ph						x
Bignoniaceae 6		Ph						x
Boraginaceae								
Cordia cf. *rufescens* A.DC.	24	Ch				x	x	
Varronia leucomalloides (Taroda) J.S.Mill	410	Th					x	
*Heliotropiumscorpioides*Willd. ex Roem. & Schult.	246	Th	x					
Bromeliaceae								
Billbergia porteana Brongn. ex. Beer	469	H					x	
Cryptanthus sp.	343	H						x
Hohenbergia cf. caatingae var. *eximbricata* L.B. Smith & Read	470	Cr					x	
Neoglaziovia variegata Mez	342	H						x
Tillandsia loliacea Mart. Ex Schult.f.		Ep						x
Tillandsia streptocarpa Baker		Ep						x
Tillandsia cf. *tenuifolia* L.	309	Ep						x
Burseraceae								
Commiphora leptophloeos (Mart.) J.B. Gillett	462	Ph						x
Cactaceae								
Arrojadoa penicillata (Gürke) Britton & Rose	471	Su					x	x
Cereus albicaulis Luetzelb.		Su						x
Species	Voucher	LF	OP I	OP II	ROC	TC	CCT	CAA
Pilosocereus glaucochrous (Werderm.) Blyles & G.D.Rowley		Su					x	x
Stephanocereus leucostele A.Berger		Su						x
*Tacinga funalis*Britton & Rose		Su						x
Tacinga palmadora (Britton & Rose) N.P.Taylor & Stuppy		Su						x
Tacinga werneri (Eggli) N.P.Taylor & Stuppy		Su					x	x
Capparaceae								
Cynophalla flexuosa (L.) J.Pres		Ph						x
*Cynophalla jacobinae*Moric. ex Eichler		Ph						x

LF = Life form; Ch: chamaephyte; H: hemicryptophyte; Ph: phanerophyte; Th: therophyte; Cr: cryptophyte; Su: "suculenta"; Ep: epiphyte; OPI: open cerrado (site I); OPII (site II): open cerrado II; ROC: rocky outcrop cerrado; TC: typical cerrado; CCT: cerrado-caatinga transition; CAA: caatinga.

Appendix. Continued...

Species	Voucher	LF	OP I	OP II	ROC	TC	CCT	CAA
Neocalyptrocalyx longifolium (Mart.) X.Cornejo & H.H.Iltis		Ph						x
Caricaceae								
Jacaratia corumbensis Kuntze		Ph						x
Caricaceae 1		Ph						x
Combretaceae								
Terminalia sp.		Ph						x
Commelinaceae								
Commelina erecta L.	200	Th		x	x	x	x	
Convolvulaceae								
Bonamia burchellii Hallier f.	369	Ph					x	
Evolvulus elegans Moric.	314	Ch				x	x	
Evolvulus elaeagnifolius Dammer	311	Th						x
Evolvulus glomeratus Choisy	227	Ch	x	x	x	x	x	
Ipomoea subtomentosa (Chodat & Hassl.) O´Donell	221	Ph	x	x	x	x	x	
Jacquemontiaagrestis Meisn.	209	Ch	x	x	x	x		
Jacquemontia montana Meisn.	226	Ph	x	x	x	x		
Jacquemontia nodiflora G.Don	370	Ph					x	
Cyperaceae								
Bulbostylis capillaris Nees	442	H	x	x	x			
Bulbostylis fasciculata Cherm.	315	H	x	x	x	x		
Bulbostylis junciformis C.B.Clarke.	316	H	x	x	x			
Cyperus agregatus (Willd.) Endl.	317	Th	x	x	x	x	x	
Rhynchospora sp.	351	H	x	x	x			
Cyperaceae	444	Th				x		
Ericaceae								
Agarista cf. *chapadensis* (Kin.-Gouv.) Judd	332	Ph		x				
Gaylussacia brasiliensis Meisn.	232	Ch		x	x			
Erythroxylaceae								
Erythroxylum betulaceum Mart.	335	Ch					x	x
Erythroxylum oxypetalum O.E. Schulz	338	Ph						x
*Erythroxylumsuberosum*A.St.-Hill.	339	Ch	x	x		x		
Erythroxylum sp.		Ch						x
Euphorbiaceae								
Actinostemonconcolor Mül.Arg.	271	Ph					x	x
*Actinostemon*sp.		Ph						x
Croton adamantinus Mull. Arg.	236	Ch					x	
Croton argyrophyllus Kunth		Ch						x
Croton compressus Lam.		Ph						x
Croton echioideus Baill.	329	Ph						x
Croton glandulosus L.		Th						x
Croton heliotropiifolius Kunth.	234	Ph				x	x	x
Croton limae A.P. Gomes, M.F. Sales & P.E. Berry	331	Ph						x
Croton velutinus Baill.	233	Ch		x	x			
Euphorbia potentilloides Boiss.	208	Ch	x	x	x	x		
Jatropha sp.		Ph						x
Maprounea guianensis Aubl.	235	Ph					x	x

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Appendix. Continued...

Species	Voucher	LF	OP I	OP II	ROC	TC	CCT	CAA
Microstachys daphinoides Müll.Arg.	333	Ch		x		x		
Microstachys serrulata Müll.Arg.	401	Ph	x		x			
Sapium glandulosum Druce	394	Ph						x
Sebastiania corniculata Pax	401	Ch	x	x	x	x		
Sebastiania salicifolia Pax		Ch	x		x	x		
Stillingia saxatilis Müll.Arg	307	Ch	x					
Tragia friesii Pax & K.Hoffm.	303	Th	x			x	x	
Icacinaceae								
Emmotum nitens (Benth.) Miers	238	Ph			x			
Iridaceae								
Sisyrinchiumluzula Klotzsch ex Klatt	440	Th		x				
Lamiaceae								
Eriope hypenioides Mart. Ex Benth.	321	Ph		x	x			
Raphiodon echinus (Nees & Mart.) Schauer.	363	H	x	x		x		
Hyptis macrantha A.St.-Hil.	197	Ch		x				
Hyptisplatanifolia Mart.	320	Ch	x	x	x	x	x	
Hyptis rugosa Benth.	409	Ch	x					
Hypenia vitifolia Pohl.	322	Ch	x	x	x	x		
Fabaceae								
Aeschynomene brevipes Benth.	247	Ph	x	x	x	x		
Aeschynomene histrix Poir.	282	Ch	x	x	x	x	x	
Aeschynomene martii Benth.		Ph						x
Andira humilis Mart.	276	Th	x	x	x	x		
Bauhinia catingae Harms		Ph						x
Centrolobium tomentosum Guill. ex Benth.		Ph						x
Chamaecrista flexuosa Greene	248	Ch	x	x	x	x		
Chamaecrista repens var. multijuga (Benth.) H.S.Irwin & Barneby.	249	Ch	x	x	x	x	x	
Chamaecrista rotundifolia Greene	228	Ch				x	x	
Crotalaria holosericea Nees & Mart.	275	Ph				x		
Dalbergia cearensis Ducke		Ph						x
Species	Voucher	LF	OP I	OP II	ROC	TC	CCT	CAA
Dalbergia miscolobium Benth.	203	Ph		x	x	x	x	
Dimorphandra gardneriana Tul.	253	Ph			x			
Hymenaea stigonocarpa Mart. Ex Hayne	212	Ph			x	x	x	
Lonchocarpus obtusus Benth.		Ph						x
Machaerium acutifolium Vogel		Ph						x
Machaerium brasiliense Vogel		Ph						x
Machaerium nictitans Benth.	461	Ph						x
Mimosa hirsutissima Mart.	287	Th				x		
Mimosa paludosa Benth. (P1)	286	Th	x		x	x		
Mimosa quadrivalvis L.	274	Th				x		
Mimosa somnians Humb. & Bonpl. ex.Willd.	213	Ph	x					
Periandra mediterranea (Vell.) Taub.	349	Ph			x			
Phanera microstachya (Raddi) L.P.Queiroz		Ph						x
Piptadenia irwinii G.P.Lewis		Ph						x
Poeppigia procera C.Presl	281	Ph						x
Pseudopiptadeniabrenanii G.P.Lewis & M.P.Lima		Ph					x	x

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Appendix. Continued...

Species	Voucher	LF	OP I	OP II	ROC	TC	CCT	CAA
Senegalia langsdorffii (Benth.) Bocage & L.P.Queiroz	425	Ph						x
Senegalia piauhiensis (Benth.) Bocage & L.P.Queiroz	428	Ph						x
Senegalia riparia (Kunth)Britton & Rose in Britton & Killip	254	Ph					x	x
Senegalia tenuifolia Britton & Rose	426	Ph						x
Senna esplendida (Vogel) H.S.Irwin & Barneby		Ph						x
Senna macranthera (Coll) H.S.Irwin & Barneby	399	Ph				x		
Senna rugosa (G.Don) H.S.Irwin & Barneby	400	Ph				x		
Stryphnodendron rotundifolium Mart.		Ph	x	x				
Stylosanthes gracilis Kunth	262	Ch		x	x	x		
Stylosanthes macrocephala M.B.Ferreira & Sousa Costa	250	Ch	x		x	x	x	
Stylosanthes scabra Vogel.	251	Ch	x	x	x	x	x	
Stylosanthes seabrana B.L.Maass & ´t Mannetje	371	Ch					x	
Tachigali sp.		Ph		x	x			
Zornia gemella Vogel.	252	Th	x	x		x		
Zornia sericea Moric.	284	Th	x	x		x		
Lythraceae								
Cuphea sessilifolia Mart.	225	Ch	x	x	x	x		
Loganiaceae								
Antonia ovata Pohl	218	Ph			x			
Spigelia cf. *anthelmia* L.		Th			x	x		
Loranthaceae								
Struthathus cf. *flexicaulis* Mart.	319	Th		x	x	x	x	
Malpighiaceae								
Banisteriopsis stellaris (Griseb.) B.Gates	293	Th		x	x	x		
Byrsonima sericea DC.	292	Ph		x	x	x		
Byrsonima correifolia A.Juss.	337	Ph				x		
Byrsonima sp. (caatinga)		Ph						x
Heteropterys sp.		Ph						x
Mascagnia sp.		Ph						x
Stigmaphyllon auriculatum A.Juss.	456	Th						x
Stigmaphyllon paralias A.Juss.	211	Th	x	x	x	x	x	
Tetrapterys sp.	352	Ph			x			
Malpighiaceae 1	458	Ph						x
Malpighiaceae 2		Ph						x
Malpighiaceae 3		Ph						x
Malpighiaceae 4		Ph						x
Malvaceae								
Ceiba erianthos (Cav.) K.Schum.	344	Ph						x
Helicteres velutina K.Schulz.	435	Ph						x
Herissantia crispa (L.) Briz.	396	Th			x		x	
Luehea sp.		Ph						x
Gossypium sp.	475	Ph						x

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Appendix. Continued...

Species	Voucher	LF	OP I	OP II	ROC	TC	CCT	CAA
Pavonia cancellata Cav.	360	Th	x	x	x	x	x	
Pavonia glazioviana Gürke	387	Th						x
Pavonia martii Mart. ex Colla	391	Th					x	
Sida angustissima Miq.	390	Th	x	x		x	x	
Sida cordifolia L.	389	Th				x		
Sida galheirensis Ulbr.	395	Th		x			x	
Sida linifolia Cav.	392	Th	x		x		x	
Sida spinosa L.	387	Th				x		
Waltheria indica L.	362	Ch	x			x	x	
Waltheria macropoda Turcz.	361	Ch	x			x		
Wissadula hirsuta C. Presl	386	Ch	x		x	x		
Melastomataceae								
Marcetia macrophylla DC.	240	Ph			x			
Miconia cf. *albicans* Steud.	273	Ph			x			
Miconia alborufescens Naudin	241	Ph			x			
Tibouchina blanchetiana Cogn.	239	Ph		x	x			
Moluginaceae								
Mollugo verticillata L.	207	Th		x		x		
Myrtaceae								
Campomanesia guaviroba Benth. & Hook.f.		Ph						x
Campomanesia cf. *sessiliflora* var. *lanuginosa* (Chodat. & Hassl.) Landrum	345	Ph				x	x	
Eugenia cf. *cerasiflora* Miq.	406	Ph				x		
Eugenia cf. *punicifolia* DC.	204	Ph	x	x	x	x	x	
Eugenia sonderiana O.Berg	405	Ph		x		x		
Myrciablanchetiana (O.Berg) Mattos	404	Ph			x			
Myrcia cf. *rufipes* DC.	346	Ph				x	x	
Species	Voucher	LF	OP I	OP II	ROC	TC	CCT	CAA
Myrcia splendes O.Berg.	270	Ph		x	x		x	
Myrciaria floribunda O.Berg.		Ph					x	x
Psidium cf. *brownianun* Nied.	216	Ph					x	
Psidium grandifolium Mart.	359	Ph				x		
Psidiumschenckianum Kiaersk.	403	Ph					x	
Ochnaceae								
Ouratea cf. *floribunda* Engl.	245	Ph		x	x	x		
Orchidaceae								
Campylocentrum micranthum (Lindl.) Rolfe		Ch						x
Epidendrum sp.		Ch						x
Oncidium sp.		Ch						x
Trichocentrum cebolleta (Jacq.) M.W.Chase & N.H.Williams	328	Th					x	
Oxalidaceae								
Oxalis frutescens sub. *frutescens* Linnaeus	242	Th	x	x	x	x	x	
Arecaceae								
Syagrus sp.		Ph				x	x	x
Passifloraceae								
Passiflora cincinnata Mast.	295	Th				x	x	
Passiflora edmundoi Sacco	325	Th	x			x	x	

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Appendix. Continued...

Species	Voucher	LF	OP I	OP II	ROC	TC	CCT	CAA
Piriqueta duarteana (A. St.-Hil., A. Juss & Cambess) Urb.	452	Th	x		x			
*Piriqueta sidifolia*var.*multiflora* Urb.	289	Th	x		x			
Turnera blanchetiana Urb.	434	Ph						x
Turnera melochioides var.*latifolia* Urb.	288	Th	x		x	x	x	
Phyllanthaceae								
Astrocasia sp.		Ph						x
Phyllanthus orbiculatus Rich.	353	Ch						x
Phytolacaceae								
Microtea paniculata Moq.	201	Th	x	x		x	x	
Picramniaceae								
Picramnia sp.		Th						x
Poaceae								
Aristida sp. 1	421	H	x	x		x	x	
Axonopus barbigerus Hitchc.	260	H			x		x	
Axonopus polydactylus (Steud.) Dedecca	259	H	x	x	x	x		
Dichanthelium sciurotis Trin.		H	x		x	x		
Digitaria insularis (L.) Fedde	258	H				x		
Echinolaena inflexa Chase	415	H	x	x	x			
Eragrostis polytricha Nees	257	H	x	x			x	
Eragrostis solida Nees		H				x	x	
Eragrostis sp.	300	H		x		x		
Eragrostis sp.	418	H				x		
Gymnopon sp. 1		H	x					
Ichnanthus zehntneri Mez	298	H					x	
Melinis minutiflora P.Beauv.	414	H		x				
Melinis repens (Willd.) Zizka.	261	H		x		x	x	
Mesosetum loliiforme Chase	255	H	x	x	x	x		
Mesosetum sp. 1	297	H			x			
Mesosetum sp. 2	417	H			x			
Panicum sellowii Nees	256	H				x	x	
Panicum sp. 1	416	H						x
Panicum sp. 2	419	H	x			x	x	x
Paspalum arenarium Schrad.	423	H		x		x		
Raddia portoi Kuhlm.	413	H						x
Schysachirium sp. 1	422	H	x	x				
Setaria gracilis Kunth	412	H				x		
Setaria parviflora Poir. Kerguélen	424	H				x		
Setaria setosa P.Beauv.	411	H				x	x	
Setaria tenax Desv.		H				x	x	
Setaria sp. 1	296	H				x	x	
Setaria sp. 2	299	H					x	
Setaria sp. 3		H					x	
Streptostachys ramosa Zuloaga & Soderstr.	420	H	x	x				
Streptostachys robusta Renvoize	347	H	x		x	x	x	
Trachypogon spicatus Kuntze	156	H	x	x	x	x	x	
Poaceae sp. 1		H	x	x				
Poaceae sp. 2		H		x				
Poaceae sp. 3		H	x	x		x	x	

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Appendix. Continued...

Species	Voucher	LF	OP I	OP II	ROC	TC	CCT	CAA
Polygalaceae								
Polygala decumbens A.W.Benn.	205	Th	x	x	x	x	x	
Polygala obovata A.St.-Hil.	206	Th	x		x	x	x	
Polygala trichosperma Jacq.	326	Th	x	x	x	x		
Polygala sp. nova	220	Th	x					
Portulacaceae								
Portulaca hirsutissima Cambess.	215	Th	x	x	x	x	x	
Portulaca mucronata Link	318	Th		x	x	x		
Primulaceae								
Myrsine guianensis (Aubl.) Kuntze.	336	Ph		x	x			
Rubiaceae								
Alseis floribunda Schott	323	Ph						x
Borreria sp.	453	Th	x					
Chomelia sp. 1	455	Ph						x
Chomelia sp. 2	459	Ph					x	
Diodella apiculta (Willd. ex Roem. & Schult.) Delprete	454	Th			x			
Declieuxia fruticosa Kuntze	224	Th	x		x			
Mytracarpus salzmannianus DC.	223	Th	x	x	x	x	x	
Species	Voucher	LF	OP I	OP II	ROC	TC	CCT	CAA
Mytracarpus sp.	431	Th	x	x	x	x		
Palicourea marcgravii A.St.-Hil.	460	Ph				x		
Psyllocarpus asparagoides Mart.	222	Th	x	x	x	x	x	
Psyllocarpus sp.	334	Th	x	x	x			
Randia armata DC.		Ph					x	x
Richardia grandiflora Steud.	432	Ch	x	x	x	x	x	
Simira sp.		Ph						x
Rubiaceae 1	430	Th	x	x				
Rubiaceae 2		Ph						x
Rutaceae								
Zanthoxylum nannophyllum (Urb.) Alain		Ph						x
Zanthoxylum sp.2		Ph						x
Salicaceae								
Casearia cf. *sylvestris* Sw.	237	Ph				x	x	x
Sapindaceae								
*Cupania oblongifolia*Mart.		Ph				x		
Diatenopteryx grazielae Vaz & Andreata	368	Ph						x
Serjania lethalis A.St.-Hil.	268	Ph			x	x		
Serjania pinnatifolia Radlk.	269	Ph						x
Sapindaceae		Ph						x
Smilacaceae								
Smilax elastica Griseb.	324	Ph			x			
Solanaceae								
Schwenkia sp.	355	Th	x	x	x	x	x	
Solanum buddlejifolium Sendtn.	266	Ph	x	x		x	x	
Solanum stenandrum Sendtn	358	Th	x	x	x	x	x	
Solanum cf. *stipulaceum* Brouss. Roem. & Schult.	357	Ph				x		

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Appendix. Continued...

Species	Voucher	LF	OP I	OP II	ROC	TC	CCT	CAA
Verbenaceae								
Aegiphila verticillata Vell.	354	Ph	x		x			
Lippia microphylla Cham.	198	Ph	x	x	x			
Lippia sp.	467	Ph					x	
Stachytarpheta crassifolia Schrad	365	Ch	x	x	x			
Vitex sp.		Ph						x
Vitaceae								
Cissus bahiensis Lombardi	450	Th						x
Vochysiaceae								
Vochysia thyrsoidea Phol	290	Ph			x			
Undetermined								
Undetermined 1	437	Th	x					
Undetermined 2	438	Th					x	
Undetermined 3		Ph					x	
Undetermined 4		Ph					x	
Undetermined 5		Ph					x	
Undetermined 6		Ph						x
Undetermined 7		Ph						x
Undetermined 8		Ph						x
Undetermined 9		Ph						x
Undetermined 10		Ph						x
			100	93	105	121	94	117

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