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Physiognomy and structure of a seasonal deciduous forest on the Ibiapaba plateau, Ceará, Brazil[1]

Fisionomia e estrutura de uma floresta estacional decídua no planalto da Ibiapaba, Ceará, Brasil

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Abstract

The Brazilian semiarid region is dominated by caatinga. However, other vegetation formations occur, including deciduous and semi-deciduous forests. This study describes physiognomy and structure of a forest on the sedimentary Ibiapaba plateau. All plants within one hectare were separated into three components: woody plants with perimeter at soil level (PSL) ≥ 9 cm (WCLP), woody plants with PSL ≥ 3 and ≤ 8.9 cm (WCSP), and herb/subwoody plants (HSwC). WCLP included 88 species (33 families), WCSP 50 species (23 families) and HSwC only 7 species (5 families). Total density, basal area, and maximum and average height of WCLP were 5683 plants/ha, 47 m^2/ha, 18 and 5 m respectively. Total density and basal area of WCSP were 17500 plants/ha and 2.8 m^2/ha, respectively. Density of HSwC was 9 plants/m^2 and only 31% of the sampled area was occupied by this component.

Key words: basal area; dry tropical forest; phytosociology; plant height.

Resumo

O semi-árido brasileiro é dominado pela caatinga. Entretanto, outras formações vegetacionais são encontradas, por exemplo, as florestas decíduas e semidecíduas. Este estudo descreve a fisionomia e a estrutura de uma floresta estacional no planalto sedimentar da Ibiapaba, Ceará. Foi selecionada uma parcela de um hectare e as plantas separadas em três componentes: plantas lenhosas com perímetro ao nível do solo ≥ 9 cm (CLS), plantas lenhosas com perímetro ≥ 3 e ≤ 8.9 cm (CLI), e herbáceas/sublenhosas com perímetro < 3 cm (HSL). No CLS foram encontradas 88 espécies (33 famílias), no CLI 50 espécies (23 famílias) e no HSL sete espécies (cinco famílias). No CLS, densidade total, área basal e altura máxima e média foram 5683 plantas/ha, 47 m^2/ha, 18 e 5 m, respectivamente. No CLI, densidade e área basal foram 17500 plantas/ha e 2,8 m^2/ha. Em HSL, a densidade foi 9 plantas/m^2 e apenas 31% da área amostrada foi coberta por esse componente.

Palavras-chave: área basal; floresta tropical seca; fitossociologia; altura de planta.

Introduction

The heterogeneity of the flora and physiognomies of the different vegetations types in the Brazilian semiarid region is caused by two rainfall gradients, one in the South-North and the other in the East-West direction, and by marked geologic differences (Rodal *et al.* 2008). At higher altitudes, where aridity is less accentuated, the seasonal non-thorny formations occur (Araújo *et al.* 1998; Araújo *et al.* 1999; Rodal & Nascimento 2002; Ferraz *et al.* 2003; Araújo *et al.* 2005b). They belong to two physiognomic types: 1) non-forest formations, mainly savanna (*cerrado*) and closed shrubland (*carrasco*), on the sedimentary plateaus; and 2) perennial, seasonal forest formations, both on sedimentary and crystalline substrates (Rodal & Nascimento 2002; Araújo *et al.* 2005b).

Flora, physiognomy, and structure of these forests are scarcely known (Andrade & Rodal 2004; Rodal & Nascimento 2006), especially those occurring on sedimentary plateaus (Andrade & Rodal 2004). Moreover, there is no published detailed

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description of the vertical organization in these forests which help design projects to manage these forests in order to maintain biological diversity.

The description and classification of plant communities generally focuses on features such as floristic composition, structure and relative species abundances (Box & Fujiwara 2005). The species have different positions along a vertical gradient of light intensity, occurring one higher than the other to form the community's vertical structure (Whittaker 1975). The vertical differentiation is most pronounced in woody vegetation that has various synusia which may have floristic compositions independent of one another (Maarel 2005). Based on the vertical stratification of the vegetation, it is possible to infer the potential composition of functional groups of different strata. The vegetation can then be managed in order to maintain maximum local biological diversity.

Thus, this work aims to describe physiognomy and structure of three different strata of the seasonal deciduous forest of the Ibiapaba sedimentary plateau, Ceará. We aim to answer the following questions: 1) What are the physiognomy and the structure of this forest? 2) Is this forest structurally similar to other forest formations of the Brazilian semiarid domain or to non-forest formations of other sedimentary areas?

Material and Methods

Study area

The study area is located within the 2794 ha of seasonal forest inside the Reserva Natural Serra das Almas, Ceará state, Brazil. The seasonal forest occupies a narrow strip in the upper part of the steep eastern slope on the south-central Ibiapaba plateau, which forms the oriental border of the Middle Northern Sedimentary Basin (Lins 1978). The forest is limited to the west by *carrasco* vegetation, on top of the plateau, and by *caatinga* vegetation to the east, on the lower parts of the slope, extending to cover most of the lowlands in Ceará. In the forest area, a one-hectare plot was installed, at an altitude of about 650 m, within the following coordinates 40°54'5"W and 5°8'29"S; 40°54'45"W and 5°8'30"S; 40°54'46"W and 5°8'36"S and 40°54'50"W and 5°8'35"S.

Mean annual rainfall in the study area from 2000 to 2004 was 1044 mm, January to April being the rainiest period, corresponding to more than 80% of annual precipitation. In general, rainfall was concentrated in a single month and did not occur from July to December. The mean annual temperature during the study year (2004) was 24.8 °C.

The soil was characterized by digging a 1 × 1 m trench and collecting samples from the top 10-cm layer and from the layer below down to the parent material (75 cm depth). Physical (Tab. 1) and chemical (Tab. 2) analyses were performed in the Departamento de Ciências do Solo, Universidade Federal do Ceará. The soil was classified as a dystrophic Latosol, poorly developed, with low pH and low cation exchange capacity (T). In general, Ca, Mg, K, P, organic matter and nitrogen content were low and decreased from the superficial to the subsuperficial layer, while the opposite occurred with Al content. Texture varied from sandy to sandy loam. Coarse sand, silt and clay content increased with depth, while that of fine sand decreased.

Phytosociological survey

The plants were divided into three components: a) woody component with large perimeter (WCLP), which comprised all plants with stem perimeter at soil level (PSL) equal to or greater than 9 cm; b) woody component with small perimeter (WCSP), comprising plants with PSL ≥ 3 and ≤ 8.9 cm; and c) herb/subwoody component (HSwC), comprising plants with green stems, without or with slight lignification in the aerial part and that were up to 1 m tall and 2.9 cm perimeter, excluding the young plants of woody species.

The study hectare was divided into plots of different sizes, depending on the component analyzed. WCLP was analyzed in 100 contiguous 10 × 10 m plots and WCSP in 50 plots, 2 × 2 m each, placed in the right proximal corner of each alternate larger plot. In these two components, the height and PSL of all live plants (except lianas) were measured, following the criteria previously described. HSwC was analyzed in 100 plots 1 × 1 m each, at the left proximal corner of each of the larger plots, during the rainy season. In HSwC, all plants were identified and the plot area proportion covered by each species was estimated, with the help of a 1 × 1 m grid, divided into 100 squares of 0.1 × 0.1 m. Presence in one of the squares was counted as 1% coverage. The botanical material was incorporated into the EAC (Prisco Bezerra) herbarium, of the Universidade Federal do Ceará. APG III (2009) classification system was adopted.

The following phytosociological parameters were calculated for WCLP and WCSP: relative density (ReD, %), relative frequency (ReF, %), relative basal area (ReBa, %) and importance

Table 1 – Particle size analysis of soil samples from the forest seasonal deciduous montane forest of Reserva Natural Serra das Almas, Crateús, Ceará state.

Depth(cm)	Coarse sand (g/kg)	Fine sand (g/kg)	Silt (g/kg)	Clay (g/kg)	Texture class
0 to 10	130	710	80	80	Sand
11 to 75	240	510	140	110	Loamy sand

Table 2 – Chemical analysis of soil samples from the seasonal deciduous montane forest of Reserva Natural Serra das Almas, Crateús, Ceará state.

Depth (cm)	Sorptive Complex (cmolc.kg^{-1})					P (mg/kg)	V (%)	M (%)	C (g/kg)	N (g/kg)	pH	T (cmolc.kg^{-1})
	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Al^{3+}							
0 to 10	0.9	0.9	0.1	0.09	0.85	3	32	30	10.6	1.1	4	6.3
11 to 75	0.7	0.9	0.1	0.05	1.45	1	27	46	6.48	0.7	4.2	6.4

Ca^{2+} = calcium; Mg^{2+} = magnesium; Na^{+} = sodium; K^{+} = potassium; Al^{3+} = aluminum; P = phosphorus; V = base saturation; M = aluminum saturation; C = carbon; N = nitrogen; pH = soil pH; T = cation exchange capacity.

value (IV, %), using the formulas described by Rodal *et al.* (1992), and Shannon diversity index, according to Magurran (1988). The calculations were done using FITOPAC (Shepherd 2006).

Aiming to compare WCLP physiognomy and structure of the study area with that of other seasonal forests and non-forest formations within the Brazilian semiarid region (only surveys with inclusion criterion of PSL ≥ 3 cm) a table was organized containing information on total plant density, community basal area, maximum plant height, proportion of plants over 8 m tall, and mean and maximum stem diameters. For each compared site, information on altitude, mean annual rainfall and sample area were also included. Ten areas were included in the comparison, five classified as seasonal forests and five as non-forest formations.

Results

In the woody component with large perimeter (WCLP), 88 species were found, belonging to 31 families (Tab. 3). The families richest in species were: Fabaceae (19 species), Euphorbiaceae (10), Erythroxylaceae and Myrtaceae (six each). The Shannon diversity index (H') was 3.20 nats/plant. Total density and basal area were 5683 plant/ha and 47 m^2/ha, respectively. Species with the highest IV and relative basal areas were *Gymnanthes* sp.1, *Bauhinia pulchella* and *Piptadenia moniliformis*, which accounted for 28% of the total IV (Tab. 3). *Gymnanthes* sp.1, *Bauhinia pulchella* and *Croton argyrophylloides* were the species with the highest absolute frequencies (99%; 97% and 84%, respectively).

Maximum and average height were 18 and 5 m (± 2), respectively, and only 11% of the plants attained heights over 8 m. Maximum and average diameters were 65.2 and 8.4 cm (6), with 33% of all plants belonging to the 3 to 6 cm diameter class and 47% to the 6 to 9 and 9 to 12 cm classes. In the same WCLP component, two strata were identified. The lowest stratum was dominated by plants at most 8 m in height, with a continuous canopy distribution. The most abundant species in this stratum were *Gymnanthes* sp.1, *Bauhinia pulchella*, *Croton argyrophyloides* and *Maytenus* sp. The upper stratum was dominated by plants up to 12 m tall but some plants of *Brosimum gaudichaudii*, *Piptadenia moniliformis* and *Swartzia flaemingii* were taller, without forming a continuous canopy. *Aspidosperma subincanum*, *Piptadenia moniliformis*, *Swartzia flaemingii* and *Thiloa glaucocarpa* were the most frequent species in this upper stratum.

The woody component with small perimeter (WCSP) included 50 species, belonging to 22 families. The families richest in species were: Fabaceae and Euphorbiaceae (eight species each), Erythroxylaceae (four) and Bignoniaceae (three).

Table 3 – Phytosociological parameters of plants with stem diameters ≥ 9 cm in the forest of Reserva Natural Serra das Almas, Crateús, Ceará state, in decreasing order of their importance value (IV). N – number of individuals per hectare; NP – number of plots where the species was found; ReD – relative density of the species (%); ReBa – relative basal area of the species (%); and ReF – relative frequency of the species (%). Collectors: FSA – Francisca Soares Araújo; JRL – Jacira Rabelo Lima; LWLV – Luis Wilson Lima-Verde; MSS – Melissa S. Sobrinho; and SFV – Sandra Freitas Vasconcelos.

N°	Species/ Family	Voucher	IV	N	NP	ReD	ReBa	ReF
1	*Gymnanthes* sp.1 (Euphorbiaceae)	JRL 29	50	1507	99	26.52	18.2	4.88
2	*Bauhinia pulchella* Benth. (Fabaceae)	JRL 45	19	537	97	9.45	4.45	4.78
3	*Piptadenia moniliformis* Benth. (Fabaceae)	FSA 1298	17	122	70	2.15	11.1	3.45
4	*Croton argyrophylloides* Müll. Arg. (Euphorbiaceae)	FSA 1294	15	333	84	5.86	4.94	4.14
5	*Maytenus* sp. (Celastraceae)	JRL 100	12	279	76	4.91	3.31	3.75
6	*Thiloa glaucocarpa* (Mart.) Eichler (Combretaceae)	LWLV 1050	11	138	57	2.43	5.36	2.81
7	*Erythroxylum* cf. *vacciniifolium* Mart. (Erythroxylaceae)	JRL 69	9.9	167	73	2.94	3.37	3.6
8	*Arrabidaea dispar* Bureau ex K. Schum. (Bignoniceae)	JRL 20	9.6	203	80	3.57	2.1	3.94
9	*Aspidosperma discolor* A. DC. (Apocynaceae)	JRL 18	8.9	139	55	2.45	3.72	2.71
10	*Eugenia* cf. *piauhiensis* O. Berg (Myrtaceae)	JRL 62	8.1	158	72	2.78	1.79	3.55
11	*Swartzia flaemingii* Raddi (Fabaceae)	MSS 262	7.9	99	58	1.74	3.31	2.86
12	*Xylosma ciliatifolia* (Clos) Eichler (Salicaceae)	JRL 77	7.3	189	65	3.33	0.8	3.2
13	*Copaifera martii* Hayne (Fabaceae)	JRL 38	7.3	79	51	1.39	3.41	2.51
14	*Buchenavia capitata* (Vahl) Eichler (Combretaceae)	MSS 292	7	31	28	0.55	5.04	1.38
15	*Eugenia* aff. *uvalha* Cambess. (Myrtaceae)	JRL 73	6.7	133	60	2.34	1.36	2.96
16	*Alibertia myrciifolia* Spruce ex K Schum. (Rubiaceae)	JRL 102	6.5	115	63	2.02	1.36	3.1
17	*Eugenia* aff. *dysenterica* DC. (Myrtaceae)	FSA 1291	6.5	94	43	1.65	2.71	2.12
18	*Aspidosperma subincanum* Mart. (Apocynaceae)	JRL 17	6.1	74	44	1.3	2.62	2.17
19	*Combretum leprosum* Mart. (Combretaceae)	JRL 74	5.1	101	51	1.78	0.78	2.51
20	*Ephedranthus pisocarpus* R. E. Fr. (Annonaceae)	JRL 16	4.6	57	41	1	1.6	2.02
21	*Acacia langsdorfii* Benth. (Fabaceae)	JRL 40	4.6	74	26	1.3	2.01	1.28
22	*Brosimum gaudichaudii* Trécul. (Moraceae)	Probio 306	4.2	40	33	0.7	1.84	1.63
23	*Peixotoa jussieuana* Mart. ex A. Juss. (Malpighiaceae)	JRL 33	3.9	74	42	1.3	0.56	2.07
24	*Croton nepetifolius* Baill. (Euphorbiaceae)	JRL 28	3.8	75	39	1.32	0.57	1.92
25	*Dalbergia cearensis* Ducke (Fabaceae)	LWLV 1070	3.6	45	34	0.79	1.1	1.68
26	*Byrsonima gardneriana* A. Juss. (Malpighiaceae)	JRL 32	3.2	43	36	0.76	0.66	1.77
27	*Hymenaea eriogyne* Benth. (Fabaceae)	JRL 42	3.1	42	22	0.74	1.3	1.08
28	*Eugenia aurata* O. Berg (Myrtaceae)	JRL 60	3	46	34	0.81	0.48	1.68
29	*Agonandra brasiliensis* Miers (Opiliaceae)	JRL 56	2.8	31	21	0.55	1.23	1.03
30	*Vitex schaueriana* Moldenke (Lamiaceae)	JRL 64	2.7	32	22	0.56	1.08	1.08
31	*Aspidosperma multiflorum* A. DC. (Apocynaceae)	JRL 19	2.6	19	12	0.33	1.63	0.59
32	*Galipea* aff. *trifoliata* Auble. (Rutaceae)	JRL 36	2.3	30	21	0.53	0.72	1.03
33	*Guapira graciliflora* (Schmidt) Lundell (Nyctaginaceae)	JRL 34	2.3	31	25	0.55	0.5	1.23
34	*Erythroxylum stipulosum* Plowman (Erythroxylaceae)	JRL 86	2.3	45	26	0.79	0.2	1.28
35	*Manihot palmata* Mull. Arg. (Euphorbiaceae)	JRL 26	2.2	33	29	0.58	0.22	1.43
36	*Ipomoea brasiliana* (C. Martius) Meisner (Convolvulaceae)	JRL 25	2	37	24	0.65	0.18	1.18
37	*Secondontia* cf. *foliosa* A. DC. (Apocynaceae)	JRL 89	1.8	36	21	0.63	0.17	1.03
38	*Dalbergia* sp. (Fabaceae)	JRL 41	1.6	23	16	0.4	0.45	0.79
39	*Bauhinia* sp. (Fabaceae)	JRL 44	1.5	46	10	0.81	0.23	0.49
40	*Arrabidaea chica* (Humb. & Bonpl.) B. Verl. (Bignoniceae)	JRL 21	1.5	25	19	0.44	0.11	0.94
41	*Machaerium acutifolium* Vogel. (Fabaceae)	JRL 80	1.5	20	16	0.35	0.33	0.79
42	*Tocoyena formosa* (Cham. & Schltdl.) K. Schum. (Rubiaceae)	JRL 59	1.3	17	14	0.3	0.32	0.69

Nº	Species/ Family	Voucher	IV	N	NP	ReD	ReBa	ReF
43	*Paullinia cearensis* Somner & Ferrucci (Sapindaceae)	JRL 34	1.2	20	14	0.35	0.19	0.69
44	*Eugenia punicifolia* (Kunth) DC. (Myrtaceae)	JRL 63	1	16	13	0.28	0.12	0.64
45	*Gymnanthes* sp.2 (Euphorbiaceae)	JRL 27	0.9	16	11	0.28	0.1	0.54
46	*Trigonia nivea* Cambess. (Trigoniaceae)	MSS 248	0.8	13	11	0.23	0.07	0.54
47	*Croton grewioides* Baill. (Euphorbiaceae)	JRL 79	0.8	13	10	0.23	0.11	0.49
48	*Tassadia burchelii* E. Fourn. (Apocynaceae)	JRL 13	0.8	9	8	0.16	0.26	0.39
49	*Turnera blanchetiana* Urb. (Turneraceae)	JRL 65	0.7	12	10	0.21	0.03	0.49
50	*Erythroxylum* sp. (Erythroxylaceae)	JRL 87	0.7	11	9	0.19	0.07	0.44
51	*Cnidoscolus vitifolius* (Mill.) Pohl (Euphorbiaceae)	FSA 1309	0.7	10	10	0.18	0.04	0.49
52	*Ouratea* sp. (Nyctaginaceae)	JRL 54	0.7	7	7	0.12	0.23	0.34
53	*Helicteres heptandra* L.B. Sm. (Malvaceae)	JRL 51	0.7	12	8	0.21	0.05	0.39
54	*Ximenia americana* L. (Olacaceae)	JRL 55	0.6	12	6	0.21	0.11	0.3
55	*Dioclea megacarpa* Rolfe (Fabaceae)	JRL 37	0.6	8	8	0.14	0.08	0.39
56	*Jacaranda jasminoides* (Thunb.) Sandwith (Bignoniceae)	JRL 22	0.6	8	8	0.14	0.03	0.39
57	*Justicia strobilacea* (Nees) Lindau (Acanthaceae)	JRL 15	0.5	7	7	0.12	0.02	0.34
58	*Ouratea* cf. *parvifolia* Engl. (Nyctaginaceae)	JRL 53	0.5	5	5	0.09	0.14	0.25
59	*Amburana cearensis* (Allemão) A. C. Sm. (Fabaceae)	JRL 72	0.5	5	5	0.09	0.14	0.25
60	*Campomanesia* sp. (Myrtaceae)	JRL 61	0.5	6	6	0.11	0.07	0.3
61	*Paullinia* cf. *elegans* Cambess. (Sapindaceae)	JRL 35	0.5	6	6	0.11	0.05	0.3
62	*Hymenaea velutina* Ducke (Fabaceae)	JRL 43	0.4	6	5	0.11	0.06	0.25
63	*Gouania* sp. (Rhamnaceae)	JRL 58	0.4	5	5	0.09	0.02	0.25
64	*Rollinia leptopetala* R. E. Fr. (Annonaceae)	JRL 78	0.4	4	4	0.07	0.09	0.2
65	*Erythroxylum bezerrae* Plowman (Erythroxylaceae)	JRL 68	0.3	3	3	0.05	0.09	0.15
66	*Stachyarrhena* cf. *spicata* Hook. F. (Rubiaceae)	JRL 104	0.3	5	3	0.09	0.05	0.15
67	*Helicteres muscosa* Mart. (Malvaceae)	JRL 52	0.3	4	4	0.07	0.02	0.2
68	*Erythroxylum laetevirens* O.E. Schulz (Erythroxylaceae)	JRL 66	0.3	4	4	0.07	0.01	0.2
69	*Arrabidaea* sp. (Bignoniceae)	JRL 107	0.3	4	3	0.07	0.05	0.15
70	*Lonchocarpus araripensis* Benth. (Fabaceae)	JRL 49	0.2	2	2	0.04	0.11	0.1
71	*Senna cearensis* Afran. Fern. (Fabaceae)	JRL 46	0.2	3	3	0.05	0.01	0.15
72	*Trichilia elegans* A. Juss. (Meliaceae)	JRL 31	0.2	3	3	0.05	0.01	0.15
73	Rubiaceae	JRL 103	0.2	4	2	0.07	0.04	0.1
74	*Cochlospermum vitifolium* (Willd.) Spreng. (Bixaceae)	SFV 4	0.2	2	1	0.04	0.1	0.05
75	*Commiphora leptophloeos* (Mart.) J.B. Gillett (Burseraceae)	JRL 48	0.2	2	2	0.04	0.03	0.1
76	*Sapium* aff. *argutum* (Müll. Arg.) Huber (Euphorbiaceae)	JRL 75	0.2	2	2	0.04	0.02	0.1
77	*Croton blanchetianus* Müll. Arg. (Euphorbiaceae)	JRL 82	0.1	4	1	0.07	0.02	0.05
78	*Tabebuia* cf. *ochracea* (Cham.) Standl. (Bignoniceae)	JRL 23	0.1	1	1	0.02	0.07	0.05
79	*Luetzelburgia auriculata* (Allemão) Ducke (Fabaceae)	JRL 71	0.1	1	1	0.02	0.05	0.05
80	*Lindackeria ovata* (Benth.) Gilg (Achariaceae)	JRL 76	0.1	1	1	0.02	0.03	0.05
81	*Mimosa* sp. (Fabaceae)	JRL 39	0.1	1	1	0.02	0.02	0.05
82	*Colubrina cordifolia* Reissek (Rhamnaceae)	MSS 248	0.1	1	1	0.02	0.01	0.05
83	*Cordia rufescens* A. DC. (Boraginaceae)	JRL 24	0.1	1	1	0.02	0.01	0.05
84	*Peltogyne confertiflora* (Mart. ex Hayne) Benth. (Fabaceae)	JRL 50	0.1	1	1	0.02	0	0.05
85	*Erythroxylum barbatum* O. E. Schulz (Erythroxylaceae)	JRL 67	0.1	1	1	0.02	0	0.05
86	*Senna trachypus* (Mart. ex Benth.) H.S. Irwin & Barneby (Fabaceae)	JRL 47	0.1	1	1	0.02	0	0.05
87	*Bredemeyera floribunda* Willd. (Polygalaceae)	JRL 57	0.1	1	1	0.02	0	0.05
88	*Croton betaceus* Baill. (Euphorbiaceae)	JRL 81	0.1	1	1	0.02	0	0.05

The Shannon diversity index (H') was 3.26 nats/plant. Total density and basal area were 17500 plant/ha and 2.8 m^2/ha, respectively. Maximum and average heights were 5 m and 1.4 m (± 0.7), respectively, most of the plants being under than 2 m tall (83%) and less than 1.6 cm diameter (70%). Species with the highest IV were *Lantana* sp., *Xylosma ciliatifolium* and *Croton argyrophylloides*, which accounted for 32% of the total IV (Tab. 4). *Cranocarpus gracilis*, *Lantana* cf. *brasiliensis*, *Lantana* sp., *Justicia fragilis* and *Wedelia villosa* were exclusive to this component.

The herb/subwoody component (HSwC) had only seven species, belonging to 5 families (Tab. 5), excluding saplings and seedlings of species that reach larger sizes. The families Poaceae and Bromeliaceae had higher species richness for this component (two species each). The Shannon diversity index (H') was 1.16 nats/plant. Density was 9 plants/m^2 and only 33% of the sample area was occupied by this component. Most of the plants (63%) belonged to three species (*Streptostachys asperifolia*, *Pavonia* sp. and *Scaphispatha hastifolia*), which, together with *Bromelia auriculata*, accounted for most of the plant coverage of this component.

Discussion

Serra das Almas forest is physiognomically distinct from other seasonal montane forests and also from all non-forest formations already described in Northeast Brazil. In general, seasonal montane forests are physiognomically more variable than rain forests, varying from tall forests to low scrub (Pennington *et al.* 2009). Density of the most conspicuous component, trees and shrubs with large perimeters (WCLP), was higher than those of the other forests (Tab. 6), except one located at 1100 m in a crystalline mountain in Serra Talhada, Pernambuco (Ferraz *et al.* 2003), but lower than those of non-forest formations, especially *carrasco* (Araújo *et al.* 1998; Araújo & Martins 1999).

Basal area, on the contrary, was lower than that of other forests, except for basal area at 900 m in Serra Talhada, but higher than that of non-forest formations. Considering that basal area is a product of density and stem diameter, the average stem diameter in Serra das Almas is smaller than that of the other forests but greater than that of the non-forest formations. The tallest registered tree, in all compared areas, was found in Serra das Almas but the proportion of trees over 8 m tall was lower than that of the other forests, except Serra Talhada, but higher than that of the non-forest formations.

In Serra das Almas two distinct strata are distinguished, as has been registered for Neotropical deciduous forests elsewhere (*e.g.*, Murphy & Lugo 1986), that are essentially tree-dominated with a more-or-less continuous canopy and in which grasses are a minor element (Mooney *et al.* 1995). In non-forest formations in Northeast Brazil, especially closed shrubland (*carrasco*), only one stratum is recognized. The presence of scattered very tall trees emerging above the upper stratum distinguishes Serra das Almas from other deciduous forests in the region.

The woody vines formed a considerable proportion of the WCLP species, with 13 species (16%), distributed in nine families, corroborating Gentry's statement (1982, 1995) that vines are an important component in Neotropical seasonal forests, where they represent about 20% of the species.

Some of the highest IV species, in the WCLP, in Serra das Almas (*Arrabidaea dispar*, *Croton argyrophylloides*, *Piptadenia moniliformis*, *Rollinia leptopetala* and *Thiloa glaucocarpa*) are also important species in Northeastern non-forest formations (Oliveira *et al.* 1997; Araújo *et al.* 1998; Araújo *et al.* 1999), mainly those on the Middle Northern Sedimentary Basin, which extends for a large area west of the Serra das Almas location. Other important species, like *Aspidosperma discolor*, *A. subincanum* and *Brosimum gaudichaudii*, although present in these non-forest formations, occur with much lower densities.

On the other hand, many of the important species present in these formations were not found in the Serra das Almas forest. In spite of these differences, the flora of the Serra das Almas forest is relatively similar to that of the non-forest formations while it is very different from that of all other deciduous montane forests studied, with which it shares only a few species, none of them with high IV either in Serra das Almas or in those forests (Lima *et al.* 2009).

Comparisons of the other two plant components, the woody component with small perimeter (WCSP) and the herb/subwoody component (HSwC), with those of other Northeastern formations are difficult to make because of the scarcity of these measurements.

Table 4 – Phytosociological parameters of plants with stem diameters > 3 cm and < 9 cm in the forest of Reserva Natural Serra das Almas, Crateús, Ceará state, in decreasing order of their importance value (IV). N - number of individuals per hectare; NP - number of plots where the species was found; ReD - relative density of the species (%); ReBa - relative basal area of the species (%); and ReF - relative frequency of the species (%). Collectors: FSA - Francisca Soares Araújo; JRL - Jacira Rabelo Lima; LWLV - Luis Wilson Lima-Verde; MSS - Melissa S. Sobrinho; and SFV - Sandra Freitas Vasconcelos.

No	Species/ Family	Voucher	IV	N	NP	ReD	ReBa	ReF
1	*Lantana* sp. (Verbenaceae)	JRL 109	46.45	52	29	14.86	19.09	12.5
2	*Xylosma ciliatifolia* (Clos) Eichler (Salicaceae)	JRL 77	24.86	30	15	8.57	9.82	6.47
3	*Croton argyrophylloides* Müll Arg. (Euphorbiaceae)	FSA 1294	23.87	31	13	8.86	9.41	5.6
4	*Cranocarpus gracilis* A. Fernandes & P. Bezerra (Fabaceae)	JRL 84	21.02	28	16	8	6.12	6.9
5	*Gymnanthes* sp.1 (Euphorbiaceae)	JRL 29	19.13	28	13	8	5.53	5.6
6	*Justicia strobilacea* (Nees) Lindau (Acanthaceae)	JRL 22	13.53	15	9	4.29	5.37	3.88
7	*Croton betaceus* Baill. (Euphorbiaceae)	JRL 81	11.64	12	11	3.43	3.47	4.74
8	*Wedelia villosa* Gardner. (Asteraceae)	JRL 85	8.23	12	7	3.43	1.79	3.02
9	*Alibertia myrciifolia* Spruce ex K Schum. (Rubiaceae)	JRL 102	7.75	8	8	2.29	2.01	3.45
10	*Croton nepetifolius* Baill. (Euphorbiaceae)	JRL 28	7.65	8	8	2.29	1.92	3.45
11	*Evolvulus macroblepharis* Meisn. (Convolvulaceae)	JRL 83	7.54	9	8	2.57	1.52	3.45
12	*Bauhinia pulchella* Benth. (Fabaceae)	JRL 45	7.24	8	8	2.29	1.51	3.45
13	*Arrabidaea dispar* Bureau ex K. Schum. (Bignoniaceae)	JRL 20	6.32	7	6	2	1.73	2.59
14	*Helicteres heptandra* L.B. Sm. (Malvaceae)	JRL 51	5.85	6	6	1.71	1.55	2.59
15	*Justicia fragilis* Wall. ex Clarke (Acanthaceae)	JRL 25	5.42	8	1	2.29	2.7	0.43
16	*Vitex schaueriana* Moldenke (Lamiaceae)	JRL 64	5.05	5	4	1.43	1.9	1.72
17	*Banisteriopsis* cf. *stellaris* (Griseb.) B. Gattes (Malpighiaceae)	JRL 101	4.93	5	4	1.43	1.78	1.72
18	*Eugenia* aff. *uvalha* Cambess. (Myrtaceae)	JRL 73	4.83	4	4	1.14	1.97	1.72
19	*Lantana* aff. *brasiliensis* Link (Verbenaceae)	JRL 108	4.61	5	4	1.43	1.46	1.72
20	*Turnera blanchetiana* Urban. (Turneraceae)	FSA 65	4.61	5	5	1.43	1.03	2.16
21	*Bauhinia* sp. (Fabaceae)	JRL 44	4.47	7	2	2	1.61	0.86
22	*Maytenus* sp. (Celastraceae)	JRL 100	4.36	4	3	1.14	1.92	1.29
23	*Dalbergia* sp. (Fabaceae)	JRL 41	4	4	3	1.14	1.57	1.29
24	*Guapira graciliflora* (Schmidt) Lundell (Nyctaginaceae)	JRL 34	3.88	3	3	0.86	1.72	1.29
25	*Ipomoea brasiliana* (C. Martius) Meisner (Convolvulaceae)	JRL 42	3.63	4	4	1.14	0.76	1.72
26	*Helicteres muscosa* Mart. (Malvaceae)	JRL 52	3.38	4	3	1.14	0.95	1.29
27	*Peixotoa jussieuana* Juss. (Malpighiaceae)	JRL 33	3.11	3	3	0.86	0.96	1.29
28	*Machaerium acutifolium* Vogel. (Fabaceae)	JRL 80	2.93	3	3	0.86	0.78	1.29
29	*Manihot palmata* Mull. Arg. (Euphorbiaceae)	JRL 26	2.25	2	2	0.57	0.82	0.86
30	*Erythroxylum laetevirens* O.E. Schulz (Erythroxylaceae)	JRL 66	2.24	3	2	0.86	0.52	0.86
31	*Dalbergia cearensis* Ducke (Fabaceae)	LWLV 1070	1.94	2	2	0.57	0.51	0.86
32	*Jacaranda jasminoides* (Thunb.) Sandwith (Bignoniaceae)	JRL 43	1.94	2	2	0.57	0.51	0.86
33	*Croton grewioides* Baill. (Euphorbiaceae)	JRL 79	1.91	2	2	0.57	0.48	0.86
34	*Erythroxylum stipulosum* Plowman (Erythroxylaceae)	JRL 86	1.78	2	2	0.57	0.35	0.86
35	*Erythroxylum* cf. *vacciniifolium* Mart. (Erythroxylaceae)	JRL 69	1.78	2	2	0.57	0.34	0.86
36	*Aspidosperma subicanum* Mart. (Apocynaceae)	JRL 17	1.62	1	1	0.29	0.9	0.43
37	*Gymnanthes* sp2 (Euphorbiaceae)	JRL 27	1.3	2	1	0.57	0.3	0.43
38	*Arrabidaea* sp. (Bignoniaceae)	JRL 107	1.25	2	1	0.57	0.25	0.43

No	Species/ Family	Voucher	IV	N	NP	ReD	ReBa	ReF
39	*Agonandra brasiliensis* Miers (Opiliaceae)	JRL 56	1.22	1	1	0.29	0.51	0.43
40	*Eugenia* cf. *piauhiensis* O. Berg (Myrtaceae)	JRL 62	1.22	1	1	0.29	0.51	0.43
41	*Secondontia* cf. *foliosa* A. DC. (Apocynaceae)	JRL 89	1.22	1	1	0.29	0.51	0.43
42	*Erythroxylum* sp. (Erythroxylaceae)	JRL 87	1.07	1	1	0.29	0.35	0.43
43	*Senna cearensis* Afran. Fern. (Fabaceae)	JRL 46	1	1	1	0.29	0.28	0.43
44	*Piptadenia moniliformis* Benth. (Fabaceae)	FSA 1298	0.89	1	1	0.29	0.17	0.43
45	*Lindackeria ovata* (Benth) Gilg (Achariaceae)	JRL 76	0.84	1	1	0.29	0.13	0.43
46	*Sapium* aff. *argutum* (Müll. Arg.) Huber (Euphorbiaceae)	JRL 75	0.84	1	1	0.29	0.13	0.43
47	*Tocoyena formosa* (Cham. & Schltdl.) K. Schum. (Rubiaceae)	JRL 59	0.84	1	1	0.29	0.13	0.43
48	*Thiloa glaucocarpa* (Mart.) Eichler (Combretaceae)	LWLV 1050	0.84	1	1	0.29	0.13	0.43
49	*Ouratea* sp. (Nyctaginaceae)	JRL 54	0.84	1	1	0.29	0.13	0.43
50	*Cordia rufescens* A. DC. (Boraginaceae)	JRL 24	0.84	1	1	0.29	0.13	0.43

Table 5 – Families and species of herb and subwoody plants in the forest of Reseva Natural Serra das Almas, Crateús, Ceará state, with their respective proportions of ground cover and densities. Collectors: FSA – Francisca Soares Araújo, JRL – Jacira Rabelo Lima, LWLV – Luis Wilson Lima-Verde.

Family / species	Cover %	Density plant in 100 m²	Voucher
Araceae			
Scaphispatha hastifolia Hook.	1	58	FSA 1379
Bromeliaceae			
Bromelia plumieri (E. Morren) L.B. Sm.	1	0	LWLV 982
Bromelia auriculata L.B. Sm.	8	79	LWLV 1222
Cyperaceae			
Cyperus agregatus (Willd.) Endl.	1	8	JRL 106
Malvaceae			
Pavonia sp.	3	168	JRL 90
Poaceae			
Lasiacis cf. *sorghoidea* (Desv. ex Ham.) Hitchc. & Chase	1	33	FSA 1378
Streptostachys asperifolia (Kuntw.) Desv.	18	580	FSA 1307

coupled with differences in methodology. One of these studies, including WCSP, was conducted in the same place as our study and also in Curimataú (PB), and Betânia (PE) (Araújo *et al.* 2005a). However, the sampling method was the point quarter method, contrary to the plot method in our study, making it difficult to compare results. Differences shown by the two methods for Serra da Almas (Tab. 7) illustrate this dificulty.

The openness of the canopy in seasonal montane forests allows not only the establishment but also the maintenance of the WCSP (Quigley & Platt 2003), even outside gaps (Whittaker 1975; Gentry & Dodson 1987). The WCSP component has usually been ignored in vegetation studies in the region. In fact, its contribution to the basal area is small and it has little value in surveys directed to estimate fuel wood or timber availability. Floristic surveys usually consider that the plants in this component are merely young individuals of species which are also present in the larger component (WCLP). This occurs in forests elsewhere (Whittaker 1975; Quigley & Platt 2003). However, one family (Asteraceae) was exclusive and another one (Verbenaceae) had most of its representatives in this component, including some exclusive species (*Lantana* cf. *brasiliensis* and *Lantana* sp.). Therefore, inclusion

Table 6 - Altitude (Alt), mean annual rainfall (MAR), sampled area; total plant density (TPD), community basal area (CBA), maximum plant height (MxH), proportion of plants above 8 m height (> 8), and mean (MD) and maximum stem diameters (MxD) of forest and non forest formations in semiarid Northeast Brazil (only surveys with inclusion criterion of PSL ≥ 3 cm).

Location	Alt. (m)	MAR (mm)	Area (ha)	TPD (pl/ha)	CBA (m^2/ha)	MxH (m)	H > 8 (%)	MD (cm)	MxD (cm)	References
Forest formations										
Serra das Almas, CE	650	1044	1	5683	47.0	18	11	8.4	65	This study
Triunfo 1, PE	1100	1260	0.2	6515	56.7	14	8	8.1	102	Ferraz *et al.* 2003
Triunfo 2, PE	900	1066	0.1	3060	46.7	15	12	10.5	60	Ferraz *et al.* 2003
Pesqueira, PE	1082	681	0.3	4910	67.2	16	21	9.8	72	Correia 1996
Jataúba, PE	1020-1120	764	0.3	4406	49.6	15	12	8.7	80	Moura 1997
Serra de Bodopitá, PB	-	500	0.2	3165	31.28	-	-	-	-	Oliveira *et al.* 2009
Serra de Bodocongó, PB	-	500	0.2	3010	33.19	-	-	-	-	Oliveira *et al.* 2009
Serra do Monte, PB	-	500	0.2	4530	33.19	-	-	-	-	Oliveira *et al.* 2009
Serra do Canoió, PB	-	500	0.2	4145	23.25	-	-	-	-	Oliveira *et al.* 2009
Non forest formations										
Padre Marcos, PI	420	637	0.45	4618	24.2	9	<1	8.1	48	Oliveira *et al.* 1997
Baixa Fria, CE	750-760	838	0.25	5952	14.2	8	10	5.0	29	Araújo *et al.* 1998
Carrasco, CE	750-760	838	0.25	5722	26.8	13	9	6.5	40	Araújo *et al.* 1998
Estrondo, CE	750-760	838	0.25	6596	19.5	11	<1	5.4	27	Araújo *et al.* 1998
Capivara, PI	600	680	1	5827	31.9	-	-	-	-	Lemos & Rodal 2002

Table 7 – Results obtained with the plot and the quarter point methods for the wood component of small perimeters (≥ 3 cm and ≤ 8.9 cm) in the same area of the seasonal deciduous forest of Serra das Almas, Ceará.

	Plot	Quarter point
Number of families	22	6
Number of species	50	8
Shannon Index (nats/plant)	3.26	1.403
Absolute density (plant/ha)	17500	3423
Basal area (m^2/ha)	2.8	0.002
Mean stem diameter (cm)	1.4	0.53

of this component is recommended in future studies in the region.

Density in this component of the forest was quite high, three times higher than that of the larger trees and shrubs (WCLP), but its contribution to basal area was rather small, slightly above 5% of the basal area of the larger tree and shrub component. The high density of the WCSP component entangled the vegetation, rendering it difficult to penetrate. Together with the influence of the WCLP component, it probably contributed to the suppression of the herb/subwoody component, through light, water and nutrient competition. Density (9 plants/m^2) and soil coverage (30%) in this herb/subwoody component were low, as usually reported for other forests (Richard 1996). Within the Brazilian Northeast region, many recent measurements of this component in *caatinga* areas found much higher densities, from 16 to 1587 plants/m^2 (Barbosa *et al.* 2005; Reis *et al.* 2006).

The larger size (height and diameter) of plants in Serra das Almas than in the non forest formations may result from greater water availability. Non-forest sites tend to have less annual rainfall than Serra das Almas and the topographic position favors the forest in Serra das Almas. Most of the carrasco sites are on top of the flat plateau and their deep, very sandy soil retains little moisture after rain events. Some of the infiltrated water seeps to the slope position where the forest is located. In fact, there is a natural fountain in the forest area but far from the study site, which was chosen to avoid its influence. Many other fountains punctuate the hundreds-of-kilometers long eastern slope of the Ibiapaba plateau and a few of them are still surrounded by forests, but unfortunately most of these forests have small and decreasing areas and only two are in protected reserves.

Mean annual rainfall is not a differentiating factor among the compared montane forests. Rainfall ranges from lower to higher than that at Serra das Almas and the structure of these forests follows no systematic trend in relation to rainfall. Rainfall distribution over the year may be as important or even more important than total annual rainfall (Murphy & Lugo 1986). Rainfall tends to be more evenly distributed closer to the coast (Pesqueira and Jataúba) than further away (Serra Talhada and Serra das Almas). This may explain the higher similarity in structure of Serra Talhada and Serra das Almas forests which are close but still hundreds of kilometers away, although other factors may be involved. Both Serra Talhada forests are small remnants of only a few hectares and have been disturbed to a higher degree than the remaining forests. The absence of taller trees in both Serra Talhada forests may result from selective cutting. Local information refers to the previous presence of much larger trees in the region. The high density of small plants at the 1100 m site may reflect regrowth in the openings left after cutting of larger trees.

Thus, it is possible to conclude that Serra das Almas forest is physiognomically distinct form the other seasonal montane forests and also from all non-forest formations analyzed in Northeast Brazil. The vegetation structure at Serra das Almas is in an intermediate position between the forests and the non-forest formations. It has a great abundance of tall, thin trees and shrubs, compared to the relative openness of the also tall but larger stemmed trees in the forests and the higher abundance of smaller trees and shrubs in the non forest formations.

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References

Andrade, K.V.S.A & Rodal, M.J.N. 2004. Fisionomia e estrutura de um remanescente de floresta estacional semidecídua de terras baixas no Nordeste do Brasil. Revista Brasileira de Botânica 27: 463-474.

APG – Angiosperm Phylogeny Group. 2009. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. Botanical Journal of the Linnean Society 161: 105-121.

Araújo, F.S.; Sampaio, E.V.S.B. & Rodal, M.J.N. 1998. Organização comunitária do componente lenhoso de três áreas de carrasco em Novo Oriente/CE. Revista Brasileira de Biologia 58: 85-95.

Araújo, F.S.; Martins, F.R. & Shepherd, G.J. 1999. Variações estruturais e florísticas do carrasco no planalto da Ibiapaba, estado do Ceará. Revista Brasileira de Biologia 59: 663-678.

Araújo, F.S.; Rodal, M.J.N.; Barbosa, M.R.V. & Martins, F.R. 2005b. Repartição da flora lenhosa no domínio da Caatinga. *In*: Araújo, F.S.; Rodal, M.J.N. & Barbosa, M.R.V. (orgs.). Análise das variações da biodiversidade do bioma caatinga: suporte a estratégias regionais de conservação. Ministério do Meio Ambiente, Brasília. Pp. 17-35.

Araújo, F.S.; Rodal, M.J.N. & Barbosa, M.R.V. 2005a. Análise das variações da biodiversidade do bioma caatinga: suporte a estratégias regionais de conservação. Ministério do Meio Ambiente, Brasília. 445p.

Barbosa, M.R.V.; Lima, R.B.; Agra, M.F.; Cunha, J.P. & Pessoa, M.C.R. 2005. Vegetação e flora fanerogâmica do Curimataú, Paraíba. *In*: Araújo, F.S.; Rodal, M.J.N. & Barbosa, M.R.V. (orgs.). Análise das variações da biodiversidade do bioma caatinga: suporte a estratégias regionais de conservação. Ministério do Meio Ambiente, Brasília. Pp. 121-138.

Box, E.O. & Fujiwara, K. 2005. Vegetation types and their broad-scale distribution. *In*: van der Maarel, E. (ed.). Vegetation ecology. Blackwell Publishing, Oxford. Pp. 106-128.

Correia, M.S. 1996. Estrutura da vegetação da mata serrana de um brejo de altitude em Pesqueira – PE. Dissertação de Mestrado. Universidade Federal de Pernambuco, Recife. 89p.

Ferraz, E.M.N.; Rodal, M.J.N. & Sampaio, E.V.S.B. 2003. Physiognomy and structure of vegetation along an altitudinal gradient in the semi-arid region of Northeastern Brazil. Phytocoenologia 33: 71-92.

Gentry, A.H. 1982. Patterns of neotropical plant species diversity. Evolution Biological 15: 1-84.

Gentry, A.H. 1995. Diversity and floristic composition of neotropical forest. *In*: Bullock, S.H.; Mooney, H.A. & Medina, E. (eds.). Seasonally dry tropical forest. Cambridge University Press. Cambridge. Pp. 146-194.

Gentry, A.H. & Dodson, C.H. 1987. Diversity and biogeography of neotropical vascular epiphytes. Annals of the Missouri Botanical Garden 74: 205-233.

Lemos, J.R. & Rodal, M.J.N. 2002. Fitossociologia do componente lenhoso de um trecho da vegetação de caatinga no Parque Nacional da Serra da Capivara, Piauí, Brasil. Acta Botanica Brasilica 16: 23-42.

Lima, J.R.; Sampaio, E.V.S.B. Rodal, M.J.N. & Araújo, F.S. 2009. Composição florística da floresta estacional decídua montana da Serra das Almas, Ceará, Brasil. Acta Botanica Brasilica 23: 756-763.

Lins, R.C. 1978. A bacia do Parnaíba: aspectos fisiográficos. Instituto Joaquim Nabuco de Pesquisas Sociais, Recife. 65p.

Maarel, E.V.D. 2005. Vegetation ecology- an overview. *In*: Vegetation ecology. Blackwell Publishing, Malden. Pp. 1-51.

Magurran, A.E. 1988. Ecological diversity and its measurement. Cambridge University Press, Cambridge. 177p.

Mooney, H.A.; Bullock, S.H. & Medina, E. 1995. *In:* Bullock, S.H.; Mooney, H.A. & Medina, E. (eds.). Seasonally dry tropical forest. Cambridge University Press Cambridge. Pp. 1-9.

Moura, F.B.P. 1997. Fitossociologia de uma mata serrana semidecídua no brejo de Jataúba, Pernambuco, Brasil. Dissertação de Mestrado. Universidade Federal de Pernambuco, Recife. 260p.

Murphy, P.G. & Lugo, A.E. 1986. Ecology of tropical dry forest. Annual Review of Ecology and Systematics 17: 67-88.

Oliveira, M.E.A.; Sampaio, E.V.S.B.; Castro, A.A.J.F. & Rodal, M.J.N. 1997. Flora e fitossociologia de uma área de transição carrasco-caatinga de areia em Padre Marcos, Piauí. Naturalia 22: 131-150.

Oliveira, P.T.B.; Trovão, D.M.B.M.; Carvalho, E.C.D.C.; Souza, B.C. & Ferreira, L.M.R. 2009. Florística e fitossociologia de quatro remanescentes vegetacionais em áreas de serra no Cariri paraibano. Revista Caatinga 22: 169-178.

Pennington, R.T.; Lavin, M. & Oliveira-Filho, A.T. 2009. Woody plant diversity, evolution and ecology in the tropics: perspectives from seasonally dry tropical forests. Annual Review of Ecology, Evolution, and Systematics 40: 437-57.

Quigley, M.F. & Platt, W.J. 2003. Composition and structure of seasonally deciduos forests in the Americas. Ecological Monographs 73: 87-106.

Reis, A.M.S.; Araújo, E.L.; Ferraz, E.M.N. & Moura, A.N. 2006. Inter-annual variations in the population structure of an herbaceous of caatinga vegetation in Pernambuco, Brazil. Revista Brasileira de Botânica 29: 497-508.

Richards, P.W. 1996. The tropical rain forest: an ecological study. Cambridge University Press, Cambridge. 575p.

Rodal, M. J.N.; Barbosa, M.R.V. & Thomas, W.W. 2008. Do the seasonal forests in Northeastern Brazil represent a single floristic unit? Brazilian Journal of Biology 68: 631-637.

Rodal, M.J.N. & Nascimento, L.M. 2006. The arboreal component of a dry forest in Northeastern Brazil. Brazilian Journal of Biology 66: 479-491.

Rodal, M.J.N. & Nascimento, L.M. 2002. Levantamento florístico da floresta serrana da Reserva Biológica de Serra Negra, microrregião de Itaparica, Pernambuco. Brasil. Acta Botanica Brasilica 16: 481-500.

Rodal, M.J.N.; Sampaio, E.V.S. & Figueiredo, M.A. 1992. Manual sobre métodos de estudos florísticos e fitossociológico – ecossistema caatinga. Sociedade Botânica do Brasil, Brasília. 24p.

Shepherd, G.J. 2006. Fitopac V. Universidade Estadual de Campinas, Campinas. 78p.

Whittaker, R.H. 1975. Communities and ecosystems. Macmillan, New York. 162p.

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