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Flora and life-form spectrum in an area of deciduous thorn woodland (caatinga) in northeastern, Brazil

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Abstract

Caatinga, a deciduous thorny woodland vegetation, is encountered in the semi-arid region of northeastern Brazil. In view of the importance of the herbaceous component of caatinga plant communities, a characterization of the flora of the Não Me Deixes Reserve in Ceará State, Brazil (4°49′34″S, 38°59′09″W, at 210 m a.s.l.) was undertaken. The reserve has 300 ha of caatinga vegetation, including dense tree steppe and open tree steppe. The mean annual rainfall is 732.8 mm, concentrated between February and May (78%). The flora was surveyed at monthly intervals between February 2000 and June 2001. We encountered 133 species belonging to 47 families. The herbaceous/woody ratio was 1.4. Based on field observations, the life-form spectrum was characterized according Raunkiaer's system, and compared with his normal spectrum. The life-form spectrum observed was: therophytes (42.9%), phanerophytes (26.3%), camaephytes (15.8%), hemicryptophytes (12.8%), and cryptophytes (2.3%). Previous data on the caatinga herbaceous flora, as well as the present study, indicate that the floristic richness of this biome has been underestimated, and that the herbaceous/woody proportion varies according to its physiognomy and water status.

Keywords: Deciduous woodland; Caatinga; Semi-arid region; Life-form spectrum

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1. Introduction

The Brazilian northeastern region covers 1,542,246 km^2 (IBGE, 1998). Of this area, 750,000 km^2 has a semi-arid climate (Ab'Saber, 1977) corresponding to Koeppen's BSh climatic type (Andrade-Lima, 1981). This semi-arid region demonstrates varying degrees of edapho-climatic aridity, generally associated with its distance to the Atlantic coast, altitude, geomorphology, degree of dissection of the landscape, slope, wind exposure, as well as soil depth and its physical and chemical composition. Rainfall usually totals less than 750 mm/year in most of this domain, and it is concentrated in three consecutive months during the southern hemisphere summer or summer/autumn (November until June). Temperatures vary little, with an annual average of approximately 26 °C (Nimer, 1989). The seasonal xerophilous thorn woodland/shrubland, regionally denominated caatinga, prevails in the semi-arid lowlands on an extensive regional crystalline basement complex (Andrade-Lima, 1981; Sampaio, 1995). The term caatinga refers to xerophytic, woody, thorny, and deciduous physiognomies with a seasonal herbaceous layer (Veloso et al., 1991). It comprises a mosaic of vegetation types varying from dry thorn forest to open shrubby vegetation (Andrade-Lima, 1981). These variations have been attributed to large-scale variations in the climate, orographic patterns, and small-scale variations in topography and soils (Andrade-Lima, 1981; Sampaio, 1995). Although many authors have stressed the importance of herbaceous species within caatinga physiognomies (Veloso et al., 1991; Sampaio, 1995; Rizzini, 1997), most floristic and phytosociological studies have focused only the woody component (Tavares et al., 1969a, b, 1970, 1974; Gomes, 1980; Figueiredo, 1987; Fonseca, 1991; Rodal, 1992; Araújo et al., 1995; Lima and Lima, 1998; Camacho, 2001; Lemos and Rodal, 2002; Pereira et al., 2002; Alcoforado-Filho et al., 2003; Nascimento et al., 2003). Few studies have been devoted to the structure and flora of the herbaceous layer in plant communities of caatinga (Figueiredo, 1983; Santos, 1987; Oliveira et al., 1988; Oliveira, 1995; Ferraz et al., 1998).

Plant species and individuals can be grouped into different life-form classes based on structural and functional similarities (Mueller-Dombois and Ellenberg, 1974). Life-forms have close relationships with environmental factors (Mueller-Dombois and Ellenberg, 1974) and can be viewed as strategies for obtaining resources (Crosswhite and Crosswhite, 1984; Cody, 1986). Raunkiaer (1934) proposed a life-form classification system based on the manner in which plants protect their perennating buds during unfavourable seasons. According to this classification system, plant species can be grouped into five main classes: phanerophytes, camaephytes, hemicryptophytes, cryptophytes, and therophytes. This sequence corresponds to an increasing protection of the perennating buds.

Climatic types can be characterized by the prevailing life-forms in plant communities growing under a given climatic regime, using the proportions of species in each life-form class, or the biological spectrum (Raunkiaer, 1934; Cain, 1950; Mueller-Dombois and Ellenberg, 1974). Studies carried out in arid and semi-arid areas have shown that there is a high proportion of life-forms that lose their aerial shoots during the driest months (therophytes, hemicryptophytes, and cryptophytes) (van Rooyen et al., 1990). The importance of therophytes increases as rainfall decreases and becomes more irregular (Raunkiaer, 1934; Kovács-Lang et al., 2000).

Few studies have shown high herbaceous species richness in areas of caatinga (Silva, 1985; Santos, 1987). In these studies, species were classified subjectively according to their growth habit, without precisely stating their life-form. In the present study, we used

Raunkiaer's life-forms system to characterize the flora of the Não Me Deixes Reserve and to examine the importance of the richness of the herbaceous stratum in this vegetation type in an area of semi-arid *caatinga* vegetation in northeastern Brazil. According Raunkiaer's system, as well as data from literature, it would be expected that plant communities in areas with low annual rainfall levels, high mean temperatures, and severe periods of drought (such as the caatinga) would have high proportions of species in life-forms classes that afford high drought protection (mainly therophytes).

2. Materials and methods

The present study was carried out in the Não Me Deixes Reserve, in the state of Ceará, northeastern Brazil (4°49′34″S × 38°58′9″W, at 210 m a.s.l.). Climatic data (rainfall and temperature) were obtained from the Ceará Foundation of Meteorology and Water Resources (FUNCEME). The mean annual rainfall and temperature were 732.8 mm and 26.6 °C, respectively. Most rainfall (79.6%) was concentrated between February and May. Soils at the Não Me Deixes Reserve are a mixture of planosols, solonetz, and regosols (BRASIL, 1972). The reserve has 300 ha of caatinga vegetation, classified as dense tree-steppe/savanna and open tree-steppe/savanna according to the official Brazilian system (RADAMBRASIL, 1983). These are the more widespread types of caatinga vegetation in semi-arid northeastern Brazil.

From February 2000 to June 2001 the vascular flora of the Não Me Deixes Reserve was surveyed monthly. All specimens collected were identified and subsequently incorporated into the EAC Herbarium collection. Data was organized listing the species, their families, and their life-forms. Observations were made on aerial shoot reduction during unfavourably dry conditions, and presence of subterranean reserve organs. Species were classified as phanerophytes, camaephytes, hemicryptophytes, cryptophytes, or therophytes according to Raunkiaer (1934). As our aim was to compare the caatinga life-form spectrum with Raunkiaer's normal spectrum, Cactaceae species were considered phanerophytes (see Cain, 1950). As there is no specific life-form class in Raunkiaer's original system for non self-supporting plants, these were classified according to the reduction of their aerial parts (Cain, 1950). We computed the proportion of species in each life-form class and compared these numbers to Raunkiaer's normal spectrum using a χ^2 test (Mann, 1998). Finally, we compared the ratio of herb/woody species in the reserve with other caatinga study sites. For this comparison, therophytes, cryptophytes, and hemicryptophytes were considered herbs.

3. Results

We recorded 133 species distributed among 103 genera and 47 families (Table 1). The families with the greatest number of species were Euphorbiaceae (16), Fabaceae (11), Asteraceae (7), and Convolvulaceae (7). Twenty two families (47%) were represented by only a single species. The herbaceous flora (hemicryptophytes, cryptophytes, and therophytes) comprised 77 species (57.9%), whereas the woody flora was represented by 56 species (42.1%) (Table 2), yielding a ratio of 1.4 between them. The biological spectrum of the Não Me Deixes Reserve had a high proportion of therophytes (42.9%), followed by phanerophytes (26.3%), camaephytes (15.8%), hemicryptophytes (12.8%), and cryptophytes (2.3%). The χ^2 test demonstrated significant differences between the Não Me

Table 1
List of species, families, their life-forms, and collection numbers in the Não me Deixes Reserve, Ceará State, Brazil. Life forms: Ph – phanerophytes, Ch – camaephytes, H – hemicryptophytes, Cr – cryptophytes, Th – therophytes

Species	Life-form	Number
Acanthaceae		
Justicia strobilacea (Ness) Lindau	Ch	
Justicia schomburgkiana (Nees) V.A.W. Graham	Ph	259
Dicliptera ciliaris Juss.	Ch	
Alismataceae		
Echinodorus subulatus Griseb.	H	340
Amaranthaceae		
Alternanthera brasiliana (L.)Kuntze	Th	171
Alternanthera tenella Colla	Th	40
Anacardiaceae		
Myracrodruon urundeuva Allemão	Ph	341
Apocynaceae		
Aspidosperma pyrifolium Mart.	Ph	337
Allamanda blanchetii A.DC.	H	336
Araceae		
Taccarum peregrinum Schott	Cr	290
Asclepiadaceae		
Schubertia sp.	Ch	
Asteraceae		
Aspilia attenuata Baker	Th	247
Trichogonia sp.	Th	221
Melanthera latifolia (Gardner)Cabrera	Th	83
Porophillum ruderale Cass.	Th	185
Stilpnopappus sp.	Th	262
Aspilia sp.	Th	159
Blainvillea lanceolata Baker	Ch	
Bignoniaceae		
Arrabidaea subverticillata Bureau & K.Schum.	Ph	255
Boraginaceae		
Cordia cf. *globosa* Humb., Bonpl.. & Kunth	Ph	12
Cordia sp.	Ph	301
Auxemma oncocalyx (Allemão) Taub.	Ph	201
Auxemma glazioviana Taub.	Ph	204
Heliotropium sp.	Ch	
Brassicaceae		
Brassica sp.	H	22
Burseraceae		
Commiphora leptophloeos (Mart.) J.B. Gillett	Ph	17
Cactaceae		
Cereus jamacaru DC.	Ph	
Capparaceae		
Cleome spinosa Jacq.	Ch	

Table 1 (*continued*)

Species	Life-form	Number
Caesalpiniaceae		
Chamaecrista calycioides Greene	Ch	
Chamaecrista cf. *duckeana* (P. Bezerra & Afr. Fern.) H.S. Irwin Barneby	Ch	
Caesalpinia bracteosa Tul.	Ph	198
Caesalpinia ferrea var. *glabrescens* Benth.	Ph	327
Senna trachypus (Benth.) H.S. Irwin & Barneby	Ph	323
Bauhinia cheilantha (Bong.) D. Dietr.	Ph	343
Cochlospermaceae		
Cochlospermum vitilfolium (Willd.) Spreng.	Ph	344
Combretaceae		
Combretum leprosum Mart.	Ph	269
Comelinaceae		
Commelina cf. *virginica* L.	H	338
Aneilema brasiliense C.B. Clarke	Th	333
Callisia cf. *filiformis* (M. Martens & Galeotti) D.R. Hunt	Th	126
Convovulaceae		
Aniseia heterantha Choisy	Th	235
Evolvulus ovatus Fernald.	Th	117
Evolvulus sp.	Th	230
Ipomoea bahiensis Willd. ex Roem. & Schult.	Ch	
Ipomoea rosea Choisy	Ch	
Jacquemontia cf. *velutina* Choisy	H	312
Jacquemontia sp.	H	249
Cucurbitaceae		
Cayaponia cf. *racemosa* Cogn.	Th	335
Cyperaceae		
Cyperus uncinulatus Schrad. ex Nees	Th	141
Euphorbiaceae		
Caperonia palustris (L.) A.St.Hil.	Th	329
Croton adenocalx Baill.	Ph	307
Croton glandulosus L.	Th	143
Croton moritibensis Baill.	Ph	281
Croton blanchetianus Baill.	Ph	280
Croton sp.	Th	63
Euphorbia heterophylla L.	Th	41
Dalechampia pernambucensis Baill.	Th	304
Jatropha mollissima Baill.	Ph	316
Phyllanthus caroliniensis Walter	Th	95
Phyllanthus orbiculatus Rich.	Th	50
Phyllanthus sp.	Th	94
Sebastiania corniculata (Vahl.) Müll.Arg.	Th	111
Sebastiania macrocarpa Mull. Arg.	Ph	46
Sebastiania sp.	Ph	275
Tragia cf. *volubilis* L.	H	20
Fabaceae		
Arachis dardani Krapov. & W.C. Greg.	Th	1
Macroptilium martii (Benth.) Marechal & Baudet	Th	241

Table 1 (*continued*)

Species	Life-form	Number
Macroptilium sp.	Th	245
Chaetocalyx scandens (L.) Urb.	H	258
Crotalaria holosericea Nees & Mart.	Ph	244
Desmodium sp.	Th	26
Dioclea grandiflora Mart. ex Benth	Ph	318
Aeschynomene sp.	H	326
Canavalia brasiliensis Mart. ex Benth.	Ch	
Stylosanthes humilis Kunth	Th	147
Galactia striata Urb.	H	251
Iridaceae		
Ebertia sp.	Cr	103
Lamiaceae		
Hyptis suaveolens (L.) Poit.	Th	324
Marsypianthes chamaedrys (Vahl) Kuntze	Th	150
Liliaceae		
Hippeastrum sp.	Cr	284
Lythraceae		
Cuphea circaeoides Sm. ex Sims	Th	299
Cuphea sp.	H	178
Cuphea campestris Mart. ex Koehne	Th	248
Pleurophora anomala Koehne	Th	291
Loganiaceae		
Spigelia anthelmia L.	Th	131
Malpighiaceae		
Heteropterys trichanthera A. Juss.	Ph	306
Stigmaphyllon auriculatum A. Juss.	Ph	287
Malvaceae		
Sida ciliaris L.	Th	115
Herissantia crispa (L.) Briz.	Ch	
Herissantia tiubae (K.Schum.) Brizicky	Ch	
Pavonia cancellata (L.) Cav.	Ch	
Wissadula contracta (Link) R.E. Fr.	H	238
Wissadula amplissima (L.) R.E. Fr.	Th	184
Mimosaceae		
Mimosa tenuiflora (Willd.) Poir.	Ph	273
Anadenanthera colubrina var. *cebil* (Griseb.)Altschul	Ph	272
Mimosa caesalpiniifolia Benth.	Ph	330
Piptadenia stipulacea (Benth.) Ducke	Ph	345
Piptadenia viridiflora (Kunth) Benth.	Ph	271
Molluginaceae		
Mollugo verticillata L.	Th	298
Nyctaginaceae		
Boerhavia diffusa L.	Ch	
Guapira sp.	Ph	283
Oxalidaceae		
Oxalis sp.	Th	264

Table 1 (*continued*)

Species	Life-form	Number
Passifloraceae		
Passiflora foetida L.	Ch	
Poaceae		
Urochloa mollis (Sw) Morrone & Zuloaga	Th	149
Digitaria sp.	Th	153
Panicum trichoides Sw.	Th	174
Paspalum scutatum Nees ex. Trin	Th	151
Paspalum sp.	Th	56
Setaria sp.	Th	175
Polygalaceae		
Polygala aff. *lancifolia* A. St.-Hil.	Th	89
Portulacaceae		
Portulaca cf. *halimoides* L.	H	311
Portulaca sp.	H	310
Talinum sp.	H	319
Rhamnaceae		
Crumenaria decumbens Mart.	Th	163
Zizyphus joazeiro Mart.	Ph	15
Rubiaceae		
Diodia teres Walter	Th	176
Diodia rigida Cham. & Schltdl.	Th	232
Mitracarpus hirtus (Sw.) DC.	Th	139
Spermacoce vegeta (Standl. & Steyerm.) C.D. Adams	Th	152
Staelia virgata K. Schum.	Th	328
Sapindaceae		
Cardiospermum corindum L.	Ch	
Scrophulariaceae		
Angelonia biflora Benth.	H	292
Angelonia pubescens Benth.	Th	193
Scoparia dulcis L.	Ch	
Tetraulacium sp.	Th	191
Sterculiaceae		
Waltheria indica L.	Ch	
Waltheria macropoda Turcz.	Ch	
Tiliaceae		
Corchorus sp.	Th	160
Turneraceae		
Turnera pumilea L.	Ch	
Turnera sp.	Ph	274
Violaceae		
Hybanthus ipecacuanha Baill.	H	13
Verbenaceae		
Stachytarpheta coccinea Schau	Th	267
Stachytarpheta sessilis Moldenke	Th	309
Lantana camara L.	Ph	308

Table 2
Results of χ^2 tests of the Não me Deixes Reserve and Raunkiaer's normal spectra

	Ph	Ch	H	Cr	Th	Total
Não Me Deixes, Ceará, Brazil (No. of species)	35	21	17	3	57	133
Não Me Deixes, Ceará, Brazil (% of species)	26.3	15.8	12.8	2.3	42.9	100.0
Raunkiaer's normal spectrum (% of species)	46	9	26	6	13	100
χ^2	2.87	1.72	1.39	0.25	4.67	10.89

Ph = Phanerophytes, Ch = Camaephytes, H = Hemicryptophytes, Cr = Cryptophytes, Th = Therophytes.

Deixes flora and Raunkiaer's normal spectra ($N = 100$, $p < 0.05$, d.f. $= 4$) (Table 2). Therophytes had the highest individual value obtained from χ^2 test, followed by phanerophytes (Table 2).

4. Discussion

Studies of the herbaceous flora and the structure of caatinga areas are scarce, and this study demonstrates the importance of herbaceous plants in caatinga species richness and physiognomy. Most published studies indicate that Leguminosae (Caesalpinioidae, Mimosoidae, and Papilionoidae), Euphorbiaceae, and Cactaceae are among the most species rich families in the *caatinga*, when only woody species are considered (Sampaio, 1995). When herbaceous species are included, other families become floristically important. Asteraceae and Convolvulaceae were among the richest families in the present study, and were represented mainly by herbaceous species (hemicryptophytes, cryptophytes, and therophytes). If species richness is compared among different studies (Table 3), it can be seen that the ratios between herbaceous and woody species are quite variable. Woody species may either be the richest (Alcoforado-Filho, 1993) or the poorest (Santos, 1987) components in caatinga plant communities. In the Não Me Deixes Reserve herbaceous and woody plant species showed nearly the same proportion.

The relative importance of each component can vary as a result of large-scale variations in climate, orography, and soils, as pointed out by Andrade-Lima (1981) and Sampaio (1995). In fact, Table 3 demonstrates that the sites with the lowest mean annual rainfall (Santos, 1987) had the highest herb/woody species ratios (Alcoforado-Filho, 1993). The relationship between climate and physiognomy becomes very evident when using the life-form approach. Raunkiaer's system was useful in characterizing the flora of a caatinga site in the present study. The high proportion of therophytes at the Não Me Deixes reserve is in agreement with the predictions for areas with Köppen's BSh climate (Cain, 1950), which corresponds to a therophytic phytoclimate (Raunkiaer, 1934). The predominance of therophytes reflects an effective strategy for avoiding water losses due to humidity extremes and water deficiencies (Van Rooyen et al., 1990). A high proportion of therophytes is a common feature of the biological spectra on hot steppes with a BSh climate (Table 4), although differences in other life-forms are difficult to interpret in terms of large-scale climatic patterns.

The data presented here demonstrates the importance of the herbaceous component in *caatinga* plant communities. Herbaceous plants may represent up to 2/3 of the plant species richness at a given location. The predominance of the BSh climate results in high

Table 3
Total, woody and herbaceous species richness, herbaceous/woody species ratio, mean annual rainfall, and elevation among different studies undertaken in areas of caatinga vegetation

Reference	Location	Elevation (m)	Annual rainfall (mm)	No. of locations	Inclusion	Woody species	Herbaceous species	Ratio herb/woody	Total
Gomes (1980)	Cariris Velhos/PB	246–590	300–900	10	B	32	—	—	32
Figueiredo (1987)	Salineira/RN region	—	459.7–659.7	8	A	43	—	—	43
Santos (1987)	Parnamirim/PE	400	579.2–585.4	7	All	52	136	2.6	188
This study	Quixadá/CE	210	732.8	1	All	56	77	1.4	133
Lemos and Rodal (2002)	Serra da Capivara/PI	600	689	1	A	56	—	—	56
Rodal (1992)	Floresta & Custódia/PE	317-542	631.8–650.9	4	A	56	—	—	56
Araújo et al. (1995)	Floresta & Custódia/PE	—	585	3	A	58	—	—	58
Alcoforado-Filho (1993)	Caruarú/PE	530	694	1	All	88	16	0.2	114

Inclusion: A = plants with stem diameter at soil level $\geqslant 3$ cm; B = plants with stem diameter at soil level $\geqslant 5$ cm.

Table 4
Life-form spectra of sites with a BSh climate

Locality	Source	Ph	Ch	H	Cr	Th
Não Me Deixes, Ceará, Brazil	Present study	26.3	15.8	12.8	2.3	42.9
Whitehill, South Africa	Admson (1939) in Cain (1950)	10	42	2	18	23
Timbuctu, Africa	Hagerup (1930) in Cain (1950)	24	36	9	6	25
Tripoli, North Africa	Raunkiaer (1934)	9	13	19	11	51
Cyrenaica, North Africa	Raunkiaer (1934)	8	14	19	8	50
Madeira Islands, lowlands	Raunkiaer (1934)	15	7	24	3	51

proportions of herbaceous life-forms that avoid unfavourable conditions by losing their aerial portions (hemicryptophytes, cryptophytes, and therophytes). Although it is difficult to make generalizations from the limited data available in the literature, the variations in herb/woody species ratios seen among different studies seem to represent differences in small-scale factors such as the soil and micro-climate at each site. More comparative studies will lend new insights into physiognomic variations in the caatinga.

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References

Ab'Saber, A.N., 1977. Espaços ocupados pela expansão dos climas secos na América do Sul, por ocasião dos períodos glaciais quaternários. Instituto de Geografia/USP, São Paulo (Série Paleoclimas, 3).

Alcoforado-Filho, F.G., 1993. Composição florística e fitossociologia de uma área de *caatinga* arbórea no município de Caruarú—PE. M.Sc. Thesis, Universidade Federal Rural de Pernambuco, Recife, Pernambuco, Brazil.

Alcoforado-Filho, F.G.A., Sampaio, E.V.S.B., Rodal, M.J.N., 2003. Florística e fitossociologia de um remanescente de vegetação caducifólia espinhosa arbórea em Caruarú, Pernambuco. Acta Botanica Brasilica 17 (2), 287–303.

Andrade-Lima, D., 1981. The *caatinga*s dominium. Revista Brasileira de Botânica 4, 149–153.

Araújo, E.L., Sampaio, E.V.S.B., Rodal, M.J.N., 1995. Composição florística e fitossociologia de três áreas de *caatinga* de Pernambuco. Revista Brasileira de Biologia 55 (4), 595–607.

BRASIL, 1972. Mapa exploratório-reconhecimento de solos: estado do Ceará, escala 1:600.000, SUDENE, Recife, Brazil.

Cain, S.A., 1950. Life forms and phytoclimate. Botanical Review 16, 1–32.

Camacho, R.G.V., 2001. Estudo fitofisiografico da *caatinga* do seridó- Estação Ecológica do Seridó, RN. Ph.D. Thesis, Universidade de São Paulo, São Paulo, Brazil.

Cody, M.L., 1986. Structural niches in plant communities. In: Diamond, J., Case, T. (Eds.), Community Ecology. Harper and Row, San Francisco, pp. 381–405.

Crosswhite, F., Crosswhite, C., 1984. A classification of life forms of the Sonoran desert with emphasis on seed plants and their survival strategies. Desert Plants 5, 131–161.

Ferraz, E.M.N., Rodal, M.J.N., Sampaio, E.V.S.B., Pereira, R.C.A., 1998. Composição florística em trechos de vegetação de *caatinga* e brejo de altitude na região do Vale do Pajeú, Pernambuco. Revista Brasileira de Botânica 21 (1), 7–15.

Figueiredo, M.A., 1983. A região dos Inhamuns-CE no domínio das caatingas. Coleção Mossoroense B-411.

Figueiredo, M.A., 1987. A microregião salineira norte-riograndense no domínio das *caatinga*s. Coleção Mossoroense 353.
Fonseca, M.R., 1991. Análise da vegetação arbustivo-arbórea da *caatinga* hiperxerófila do noroeste do estado de Sergipe. Ph.D. Thesis, Universidade Estadual de Campinas, São Paulo, Brazil.
Gomes, M.A.F., 1980. A vegetação dos Carirís Velhos no estado da Paraíba. Vegetalia 14.
IBGE, 1998. Fundação Instituto Brasileiro de Geografia e Estatística. Anuário Estatístico do Brasil. IBGE, Rio de Janeiro, Brazil.
Kovács-Lang, E., Kroel-Dulay, G., Kertész, M., Fekete, G., Bartha, S., Mika, J., Dobi-Wantuch, I., Rédei, T., Rajkai, K., Hahn, I., 2000. Changes in composition of sand grasslands along a gradient in Hungary and implications for climate change. Phytocoenologia 30 (3–4), 385–407.
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 (1), 22–23.
Lima, P.C., Lima, J.L.S., 1998. Composição florística e fitossociologia de uma área de *caatinga* em Contendas do Sincorá, Bahia, microregião homogênea da Chapada Diamantina. Acta Botânica Brasilica 12 (3), 431–440.
Mann, P.S., 1998. Introductory Statistics. Wiley, New York.
Mueller-Dombois, D., Ellenberg, H., 1974. Aims and Methods of Vegetation Ecology. Wiley, New York.
Nascimento, C.E.S., Rodal, M.J.N., Cavalvanti, A.C., 2003. Phytossociology of the remaining xerophytic woodland associated to an environmental gradient at the banks of the São Francisco river-Petrolina, Pernambuco, Brazil. Revista Brasileira de Botanica 26 (3), 271–287.
Nimer, E., 1989. Climatologia do Brasil, second ed. IBGE-SUPREN (Fundação IBGE-SUPREN), Recursos Naturais e Meio Ambiente, Rio de Janeiro.
Oliveira, M.E.A., 1995. Vegetação e flora de uma área de transição *caatinga*-carrasco Padre Marcos. Piauí. M.Sc. Thesis, Universidade Federal de Pernambuco, Recife, Brazil.
Oliveira, J.G.B., Quesado, H.L.C., Nunes, E.P., Figueiredo, M.A., Bezerra, C.L.F., 1988. Vegetação da estação ecológica de Aiuaba, Ceará. Coleção Mossoroense 537B.
Pereira, I.M., Andrade, L.A., Barbosa, M.R.V., Sampaio, E.V.S.B., 2002. Composição florística e análise fitossociológica do componente arbustivo-arbóreo de um remanescente florestal no Agreste Paraibano. Acta Botanica Brasilica 16 (3), 241–369.
RADAMBRASIL. 1983. Folhas SC 24/25. Aracajú/Recife—Geologia, geomorfologia, pedologia, vegetação, uso potencial da terra, RADAMBRASIL, Rio de Janeiro, Brazil.
Raunkiaer, C., 1934. The Life forms of Plants and Statistical Plant Geography. Clarendon Press, Oxford.
Rizzini, C.T., 1997. Tratado de Fitogeografia do Brasil. Âmbito Cultural, Rio de Janeiro, Brazil.
Rodal, M.J.N., 1992. Fitossociologia da vegetação arvbustivo-arbórea em quatro áreas de *Caatinga* em Pernambuco. Ph.D. Thesis, Universidade Estadual de Campinas, Campinas, Brazil.
Sampaio, E.V.S.B., 1995. Overview of the Brazilian *caatinga*. In: Bullock, S.H., Mooney, H.A., Medina, E. (Eds.), Seasonally Tropical Dry Forests. Cambridge University Press, Cambridge.
Santos, M.F.A., 1987. Características dos solos e da vegetação em sete áreas de Parnamirim, Pernambuco. M.Sc. Thesis, Universidade Federal Rural de Pernambuco, Recife, Brazil.
Silva, A.Q., 1985. Flora e vegetação das depressões inundáveis da região de Ouricuri-PE. M.Sc. Thesis, Universidade Federal Rural de Pernambuco, Recife, Brazil.
Tavares, S., Paiva, F.A.F., Tavares, E.J.S., Lima, J.L.S., 1969a. Inventário florestal do Ceará-Estudo preliminar das matas remanescentes do município de Quixadá. Boletim de Recursos Naturais—SUDENE 7 (1–4), 93–111.
Tavares, S., Paiva, F.A.F., Tavares, E.J.S., Carvalho, G.H., e Lima, J.L.S., 1969b. Inventário florestal Pernambuco-Estudo preliminar das matas remanescentes do município de São José de Belmonte. Boletim de Recursos Naturais—SUDENE 7 (1–4), 113–139.
Tavares, S., Paiva, F.A.F., Tavares, E.J.S., Carvalho, G.H., e Lima, J.L.S., 1970. Inventário florestal Pernambuco-Estudo preliminar das matas remanescentes dos municípios de Ouricurí, Bodocó, Santa Maria da Boa Vista e Petrolina. Boletim de Recursos Naturais—SUDENE 8, 14.
Tavares, S., Paiva, F.A.F., Tavares, E.J.S., Lima, J.L.S., 1974. Inventário florestal do Ceará-estudo preliminar das matas remanescentes do município de Tauá. Boletim de Recursos Naturais—SUDENE 12 (2), 5–19.
van Rooyen, M.W., Theron, G.K., Grobbelaar, N., 1990. Life forms and spectra of flora of Namaqualand, South Africa. Journal of Arid Environments 19, 133–145.
Veloso, H.P., Rangel-Filho, A.L.R., Lima, J.C.A., 1991. Classificação da vegetação brasileira, adaptada a um sistema universal. IBGE—Departamento de Recursos Naturais e Estudos Ambientais, Rio de Janeiro.