Floresta e Ambiente 2022; 29(2): e20220018
https://doi.org/10.1590/2179-8087-FLORAM-2022-0018
ISSN 2179-8087 (online)

ORIGINAL ARTICLE – Conservation of Nature

Angiosperm Diversity in the Semiarid Region of Ceará State, Brazil, with Emphasis on Caatinga Species

Raimundo Luciano Soares Neto[1]
Maria Iracema Bezerra Loiola[1]

[1]Universidade Federal do Ceará, Fortaleza, CE, Brasil.

Abstract

We examined the taxonomic diversity of native angiosperms in the semiarid region of Ceará State, Brazil, emphasizing species occurring in Steppic Savanna. The diversity of native angiosperms comprises 120 families, 604 genera, and 1,443 species. Fabaceae was the most taxonomically diverse family, while *Croton* (Euphorbiaceae) was the most species rich genus (33 sp.). Steppic Savanna species account for 58% of all angiosperms recorded in Ceará State, and 41% of all species listed for that phytophysiognomy in Brazil. An update of the species richness within the Steppic Savanna of Ceará State phytogeographical area is provided, also indicating distribution data for other phytophysiognomies in Ceará.

Keywords: Sampling effort, flora, floristic list, Steppic Savanna, phytogeographical units.

1. INTRODUCTION AND OBJECTIVES

Steppic Savanna (known as "Caatinga" vegetation in Brazil) is considered the largest continuous SDTF area in the neotropics, covering approximately 900,000 km^2 (Queiroz, 2006, 2009), and it overlaps the Semiarid or Caatinga Domain (Velloso et al., 2002). The Caatinga domain is very heterogeneous, mainly due to local variations in climate and soil, and comprises many different associated vegetation types (Andrade-Lima, 1981).

Steppic Savanna occurs in a warm, semiarid climate, with an average rainfall of 1,000 mm/year, concentrated into only three to six months (Velloso et al., 2002; Leal et al., 2005). The vegetation is predominantly composed of a low, profusely branching forest with a discontinuous canopy showing high deciduousness, with many thorny and succulent shrubs (Velloso et al., 2002; Leal et al., 2005; Queiroz, 2006, 2009).

The predominant vegetation in Ceará is Steppic Savanna, including the Carrasco and Caatinga phytophysiognomies (with all of their variations – shrubby and arboreal), with Caatinga occupying approximately 70% of the total land area of the state (IPECE, 2017), although there are also areas of Neotropical Savanna (Cerrado), Forest Savanna (Cerradão), Dense Ombrophilous Forest (Mata úmida), Semideciduous Seasonal Forest (Mata seca), Vegetation under Fluvial and/or Lacustrine Influence, and Carnaubal (Riparian forests with *Copernicia prunifera* L. (Figueiredo, 1997; IBGE, 2012; Moro et al., 2015; MMA, 2016).

Botanical studies have been carried out in Ceará for at least two hundred years, with contributions from such renowned naturalists as João da Silva Feijó (1760-1824), Francisco Freire Alemão (1797-1874), Alberto Loefgren (1854-1918), and Phillip von Luetzelburg (1880-1946) (Freitas & Matias, 2010; Moro et al., 2015; Loiola et al., 2020). Those studies made it possible to recognize and establish different phytogeographic units in the state (Figueiredo, 1997; Moro et al., 2015), while others have concentrated on taxonomic studies (*e.g.*, Cactaceae – Menezes et al., 2013), descriptions of new species and those considered endemic to the state (Loiola, 2013; Ribeiro et al., 2017; Sampaio et al., 2019; Santos et al., 2020; Jardim et al., 2020), sampling efforts and analyses (Freitas & Queiroz, 2010), local floristic surveys (Loiola et al., 2015; Silveira et al., 2020a), and studies of protected areas (Araújo et al., 2005; Silveira et al., 2020b), among others.

This data set, built over the years, has allowed the flora of Ceará State to be published in an e-book format, providing a floristic inventory of 2,584 angiosperms species (Loiola, et al., 2020). That list was recently updated and recognizes 2,465 species belonging to 890 genera and 153 families (Loiola et al., 2021). Only the study of Reis et al. (2021) deals with a possible floristic list of species specifically from the Caatinga

of Ceará State, although based on a compilation of published data without actually providing a taxonomic list with the total number of recorded angiosperm species.

The present study is therefore the first attempt to provide data concerning the native species of angiosperms that constitute the flora of the Caatinga in Ceará State, Brazil. A floristic list of species is presented, in addition to information about endemism, endangered species (according to IUCN Red List of Threatened Species criteria), data concerning other vegetation types, and records of the occurrence of species in protected areas.

2. MATERIAL AND METHODS

2.1. Area of study

Among the states within the Brazilian semiarid region, Ceará (2°46'S-7°52'S × 41°24'W-37°14'W) has a territorial extension of 148.894 km^2 (IPECE, 2017), with a predominance of a BSh type (semiarid) climate according to the Köppen climate classification (Barreto et al., 2012). In addition to having areas under continental and maritime influences, the state harbors a great diversity of soils and landscapes, with elevations varying from sea level to 1,154 m at the Serra Branca Peak (IPECE, 2017). Those environmental variations are directly related to the wide diversity of vegetation types observed within the state (SUDENE, 1973; Araújo et al., 1998).

2.2. Assembling the floristic list

The floristic list considers only species classified as native according to the Flora of Brazil 2020 site (Flora do Brasil, 2020). We initially selected the species already surveyed for Ceará (Loiola et al., 2020, 2021), and subsequently updated the list with the inclusion of the taxa listed in Flora of Brazil 2020 but not included in the aforementioned lists. To confirm the occurrence of those species in Ceará, we performed a search of their respective specimens in the REFLORA Virtual Herbarium (http://floradobrasil.jbrj.gov.br/reflora/herbariovirtual), in the virtual herbaria with images available online at speciesLink-CRIA (http://inct.splink.org), and in the online database of the Botanical Garden of Rio de Janeiro – Jardim Botânico do Rio de Janeiro, JBRJ (http://jabot.jbrj.gov.br). The taxonomic classification system for families followed APG IV (2016), except for Passifloraceae and Turneraceae, which are considered here as distinct families. Scientific names, synonyms, and authorships are in accordance with the Flora of Brazil 2020 (Flora of Brasil, 2020). The life forms (habits) also follow the Flora of Brazil 2020 and Fernandes et al. (2020).

2.3. Occurrence of species in the Caatinga of Ceará, and the classification of the vegetation in this state

Species occurrence data were obtained from the online databases mentioned above. Information about the vegetation types was that provided by the collection descriptions and/or by the digitalized online exsiccate labels, and was used to plot their locations on the Ceará vegetation map adopted in this study; only specimens with geographic coordinates considered reliable were selected.

The nomenclature of the phytogeographic units is in accordance with Figueiredo (1997), IBGE (2012), and Moro et al. (2015), modified. Eight phytogeographic units were recognized for Ceará: Steppic Savanna - SS (Carrasco and Caatinga); Neotropical Savanna - NS (Cerrado); Forest Savanna - FS (Cerradão); Dense Ombrophilous Forest – DOF (Mata Úmida); Semideciduous Seasonal Forest – SSF (Mata Seca); Vegetation under Fluvial and/or Lacustrine Influence - VFLCI, Carnaubal - CARN (Riparian forest with *Copernicia prunifera* L.); and the Vegetation Complex of the Coastal Zone - VCCZ (Figure 1).

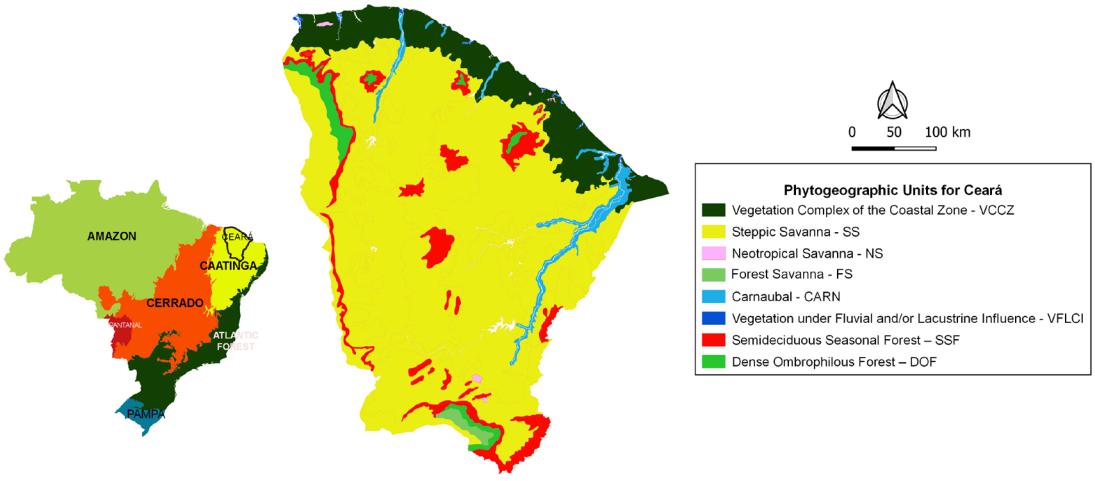

Figure 1. Map of phytogeographic areas in Ceará State, Brazil. Modified from Figueiredo et al. (1997).

2.4. Endemism, occurrence in extra-caatinga vegetation and conservation areas in Ceará

Information about the geographic distributions of species with regards to endemism and their occurrence in other Brazilian phytogeographic domains was obtained from the Flora of Brazil 2020 site and supplemented based on Fernandes et al. (2020). For distributions in other vegetation types occurring in Ceará, we used data from directly the exsiccate labels and plotted those points on the Ceará vegetation map.

The registration of species in designated conservation areas (CAs) of Ceará is in accordance with data from the digitized labels of specimens consulted online.

3. RESULTS

The inventory of angiosperms recorded in Caatinga vegetation in Ceará State indicated a flora composed of 1,443 species, 604 genera, and 120 families (Appendix 1 https://figshare.com/s/e09edf7a18199f117ffb). Fabaceae (235 species/84 genera) is the family with the greatest species diversity (Appendix 2 https://figshare.com/s/e09edf7a18199f117ffb), followed by Poaceae (83/36), Euphorbiaceae (77/21), Malvaceae (71/23), Convolvulaceae (58/9), Cyperaceae (56/7), Asteraceae (55/41), Bignoniaceae (52/18), Rubiaceae (48/28), Apocynaceae (33/18), and Malpighiaceae (33/16). The ten most representative genera in terms of the numbers of species (Appendix 3 https://figshare.com/s/e09edf7a18199f117ffb) are: *Croton* L. (33 spp.), *Cyperus* L. and *Ipomoea* L. (26 spp. each), *Chamaecrista* (L.) Moench (20 spp.), *Mimosa* L. (18 spp.), *Erythroxylum* P.Browne and *Senna* Mill. (17 spp. each), *Sida* L. (16 spp.), *Solanum* L. (15 spp.), and *Paspalum* L. (14 spp.).

Most of the plants encountered in our study (64.5%) are not endemic to Brazil (Appendix 1). One hundred and fifty-one species endemic to Brazil (10%) occur only in Caatinga, while 351 species (25%) occur in the Caatinga and at least one other Brazilian phytogeographic domain (Amazon, Atlantic Forest, Cerrado, Pampa, or Pantanal). Eight species are of undetermined endemism, because there are not data about it: *Dioscorea polygonoides* Humb. & Bonpl. ex Willd., *Esenbeckia pilocarpoides* Kunth, *Guapira opposita* (Vell.) Reitz, *Justicia sphaerosperma* Vahl, *Mascagnia sepium* (A.Juss.) Griseb., *Panicum stramineum* Hitchc. & Chase, *Sida ciliaris* L., *Strychnos rubiginosa* A.DC. Of the 1,443 species occurring in the Caatinga in Ceará, 15 are endemic to that state: *Aspidosperma confertiflorum* A.C.D.Castello, *Cranocarpus gracilis* Afr.Fern. & P.Bezerra, *Croton araripensis* Croizat, *C. cearenses* Baill., *C. kalkmannii* Müll.Arg., *Eremanthus arboreus* (Gardner) MacLeish, *Erythroxylum angelicae* Loiola, *Gaya grandiflora* Baker, *Lindackeria ovata* (Benth.) Gilg, *Mimosa niomarlei* Afr.Fern., *Mitracarpus fernandesii* E.L.Cabral, Sobrado & E.B.Souza, *Ocotea loefgrenii* Vattimo-Gil, *Pitcairnia limae* L.B.Sm., *Solanum graniticola* V.S.Sampaio & Gouvêa and *Vriesea baturitensis* Versieux & Tomaz.

Fully 59.6% of the caatinga species in Ceará are woody plants, including 228 subshrubs, 233 shrubs, 315 trees, and 83 lianas; 40.4% were non-woody species, including 427 herbs, 141 vines, 12 epiphytes, 3 parasites, and 1 scandent herb.

A total of 175 (12%) species occur only in Steppic Savanna (Appendix 4 https://figshare.com/s/e09edf7a18199f117ffb). The other species occur in at least one other phytophysiognomy found in Ceará, with 970 species also distributed in SSF; 867 in DOF; 803 in VCCZ; 514 in CARN; and 239 in AS (Appendix 4 https://figshare.com/s/e09edf7a18199f117ffb). No species were shared with Neotropical Savanna and Vegetation under Fluvial and/or Lacustrine Influence areas occurring in the state.

A total of 971 (67%) species were recorded in 25 CAs in Ceará State (Appendix 5 https://figshare.com/s/e09edf7a18199f117ffb). The Aiuaba Ecological Station (Estação Ecológica de Aiuaba - EEAiuaba), stood out with 453 species, followed by the Serra das Almas Private Natural Heritage Reserve (Reserva Particular do Patrimônio Natural – RPPN Serra das Almas), with 330 species; the Ubajara National Park (PARNA-Ubajara) with 247 species; and the Araripe-Apodi National Forest (Floresta Nacional Araripe-Apodi - FLONA Araripe-Apodi) with 224 species (Appendix 5).

Of the species listed, following the Flora of Brazil (Flora of Brasil, 2020) four are considered endangered (EN) – *Erythroxylum bezerrae* Plowman, *Griffinia gardneriana* (Herb.) Ravenna, *Pilocarpus jaborandi* Holmes and *P. trachylophus* Holmes, two as critically endangered (CR) – *Pitcairnia limae* and *Setaria parviflora* (Poir.) Kerguélen, and six as vulnerable (VU) – *Apuleia leiocarpa* (Vogel) J.F.Macbr., *Cattleya labiata* Lindl., *Cedrela odorata* L., *Discocactus bahiensis* Britton & Rose, *Wolffia brasiliensis* Wedd. and *Zeyheria tuberculosa* (Vell.) Bureau ex Verl.

4. DISCUSSION

Floristic inventories are primary sources for determining the plant biodiversity of an area, and data from these studies are important for conservation issues (Funk, 2006). As mentioned above, the flora of Ceará has been examined from a number of different perspectives, although in-depth studies of the floristic diversities of the different phytogeographic areas there are still incipient, and only a generalized study in that sense was carried out by Freitas & Matias (2010).

The species found in the Caatinga of Ceará represent 58% of the currently known species for its statewide flora (Loiola et al., 2021). That number is higher than previously reported

by Freitas & Matias (2010), who identified 19% of the species as found in shrubby caatinga (Shrubby Steppic Savanna *sensu* IBGE, 2012), 12% in arboreal caatinga (Arboreal Steppic Savanna), and 17% in Carrasco. As the division of the Steppic Savanna into shrubby and arboreal types was not recognized here, our data demonstrate a much higher number of species in Caatinga but a smaller percentage of species in Carrasco. This difference in the percentages of species is probably due to the total number of species included in the two studies: 2.465 species in our study (Loiola et al., 2021) and 1.209 in Freitas & Matias (2010).

Based on the list of Fernandes et al. (2020), Ceará State encompasses 41% of the 3,347 species recognized for the Caatinga. Those authors do not mention the occurrence of species by state and it is therefore not possible to compare the numbers of species found in the respective studies. However, the number of species recorded in our study is higher than that reported by Moro et al. (2014), who listed the occurrence of 586 species of angiosperms in the Caatinga of Ceará. Moro et al. (2014) used floristic lists of Caatinga published for different locations in Ceará in their methodology, without considering online records. The number of species recorded in our study was lower than that proposed by Flora of Brazil 2020, which considers 157 families, 819 genera, and 1,991 native species occurring in Caatinga vegetation in Ceará State. It is noteworthy that the Flora of Brazil 2020 methodology recognizes species from different types of vegetation inserted within the larger Caatinga domain (*e.g.*, *Avicennia schaueriana* Stapf & Leechm. ex Moldenke, a typical mangrove species found mainly in coastal regions) – thus generating significant differences in the number of species – as we considered here only those that occur in phytogeographic areas of Caatinga *sensu stricto*.

There is an historical belief that the Caatinga has only a low plant diversity, with no records of endemic species, although it actually has a rich flora with a relatively high proportion of endemism (23%) compared to other STDFs (Giulietti et al., 2004; Queiroz et al., 2017; Fernandes & Queiroz, 2018). Our botanical knowledge of the Caatinga Flora greatly advanced through studies of its ecological, floristic, phytogeographic, and taxonomic aspects, whether generalized or local, generating constantly updated floristic lists covering the taxonomic diversity of the region (Giulietti et al., 2002, Alves et al., 2009, Siqueira Filho, 2012, Moro et al., 2014, Fernandes et al., 2020) – and there are now more than three thousand recognized plant species (Fernandes et al., 2020).

In general, the families with the greatest species diversities were those identified in previous studies, with emphasis on Fabaceae, a taxon with a high diversity of life forms (habits) and wide distribution in the different phytophysiognomies present in Ceará (Freitas & Araújo, 2010; Moro et al., 2014; Fernandes et al., 2020). Our study corroborates the results of Freitas & Matias (2010), who likewise identified Poaceae as the second largest family in the state, and *Paspalum* as the tenth largest genus in terms of the number of species; Poaceae was ranked as the third and sixth family in terms of species diversity in the Caatinga by Fernandes et al. (2020) and Moro et al. (2014) respectively.

In terms of the taxonomic category of genus, our results corroborate the studies of Moro et al. (2014) and Fernandes et al. (2020), indicating *Croton* (Euphorbiaceae) as the genus with the highest number of species in the Caatinga (33 species for Ceará); *Croton blanchetianus* Baill. is notably the species with the highest number of occurrences recorded for the state (130), as documented by the National Forest Inventory floristic survey (MMA, 2016; Reis et al., 2021).

Woody taxa were more abundant than non-woody taxa. That high number of woody taxa is reflected by Fabaceae, the family with the greatest plant diversity in the state, as its representatives are mostly woody (81%: 83 species of trees, 34 shrubs, 69 subshrubs, and 5 lianas; *versus* 19% non-woody taxa: 31 vine species and 13 herbs). Non-woody species contribute significantly to the general taxonomic composition of the Caatinga flora (Moro et al., 2014; BFG, 2015; and Fernandes et al., 2020), being represented mainly by the families Poaceae and Cyperaceae, which significantly contribute to the formation of the herbaceous layer (with 83 and 56 species respectively), with *Cyperus* (Cyperaceae; 26 spp.) and *Paspalaum* (Poaceae; 14 spp.) appearing among the genera with high species diversity.

Data concerning the geographic distributions of the species listed for the Caatinga of Ceará indicate a great sharing of species between the different phytogeographic areas of that state, which is associated with its great heterogeneity of landscapes and vegetation associated with other biomes such as the Amazon, Cerrado, and Atlantic Forest surrounding and connecting the different phytophysiognomies and providing ecologically favorable environments for the wide distribution of many species (Fernandes et al., 2020).

Of the 11 Caatinga species recognized as endangered in Ceará according to IUCN criteria, *Cedrela odorata*, *Erythroxylum bezerrae*, *Griffinia gardneriana,* and *Setaria parviflora* were encountered in the EEAiuaba and RPPN Serra das Almas. *Cedrela odorata* was also recorded for the Ubajara National Park (PARNA Ubajara) in Dense Ombrophilous Forest (DOF) vegetation. There are no records of occurrence of the other endangered species in CAs in Ceará State based on the approach adopted here, that is, based only on herbaria specimens and not official lists. Greater collection efforts will be crucial to certifying the occurrences and distributions of those endangered species to be able to propose conservation actions in their favor.

The Aiuaba Ecological Station and the Serra das Almas RPPN are priority areas of environmental protection and biodiversity conservation in the Caatinga (Silva et al., 2003), and were the CAs with the highest numbers of recorded species. Both areas are proof that long-term sampling efforts are important for documenting the floristic composition of a given area. The first floristic surveys carried out in the two CAs showed a diversity of 160 species in the EEAiuaba (Lemos & Meguro, 2010) and 212 species in the RPPN Serra das Almas (Araújo et al., 2005), while the numbers of plants currently recorded have increased almost threefold in EEAiuaba and by at least 50% in RPPN Serra das Almas.

5. CONCLUSIONS

Our study demonstrates the importance of publishing floristic lists for better understanding and quantifying the biodiversity of a given area. We present here the first comprehensive list of the floristic diversity of Caatinga vegetation in Ceará State, and demonstrate that there has been a significant increase in our knowledge of the flora of this phytophysiognomy in just over a decade (as compared to the study of Freitas & Matias, 2010). Our expectation is that these data will be continually updated and new results will be compared and discussed to assess the true species richness of the Caatinga in Ceará State.

This study also provides a more accurate perspective of the floristic composition of Caatinga vegetation as compared to previously published data (Moro et al., 2014; Flora do Brasil, 2020), and this plant list can serve as a reference for academic or socio-environmental studies of the floristic composition of different areas of the state within the Caatinga domain to advance public policies favorable to the environment and society.

Continued commitments to greater sampling efforts in Caatinga areas has been evidenced by the increasing numbers of species recorded in protected areas (as can be seen in the EEAiuaba and RPPN Serra das Almas). We wish to emphasize the importance of depositing specimens collected in protected areas in existing herbarium in both Ceará State and Brazil, as they allow easy access for researchers, whether through *in loco* or online consultations. We believe that the plant diversity in other CAs in Caatinga areas within the state have much larger floristic compositions than recorded in our study, and that better assessments of those protected areas will contribute greatly to our knowledge of the geographic distributions of Caatinga species.

ACKNOWLEDGEMENTS

The authors are grateful to the anonymous reviewers who contributed to the improvement of this manuscript and made its publication possible, and to Roy Funch for translating and proofreading the text. The first author thanks the Fundação Cearense de Apoio ao Desenvolvimento Científico e Tecnológico – FUNCAP for the scholarship granted to the first author (Process n°: PD2-0175-00083.01.01 / 20). MIBL thanks CNPq for the productivity grant (Process nº: 308685 / 2020-2).

SUBMISSION STATUS

Received: 19 Feb. 2022
Accepted: 18 Apr. 2022
Associate editor: Bárbara Bomfim Fernandes

CORRESPONDENCE TO

Raimundo Luciano Soares Neto
Avenida Humberto Monte s/n, 60440-900, Fortaleza, CE, Brasil.
e-mail: lucianosoares.rdon@gmail.com

SUPPLEMENTARY MATERIAL

The following online material is available for this article:
Appendix 1. Floristic list of native angiosperms occurring in the Caatinga of Ceará State, Brazil.
Appendix 2. Taxonomic diversity of genera and species per family recorded in the Caatinga of Ceará State, Brazil.
Appendix 3. Number of species/genera registered in the Caatinga of Ceará State, Brazil.
Appendix 4. Geographic distribution data of species recorded in the Caatinga of Ceará State, Brazil, and in other phytogeographic areas of that state. The numbers indicate the presence of species in those phytogeographic units; empty cells indicate the absence of species in those phytogeographic units; * indicates species only occurring in Steppic Savanna.
Appendix 5. Occurrence data of species registered in Caatinga conservation Areas of Ceará State, Brazil. The numbers indicate the presence of species in those phytogeographic units; empty cells indicate the absence of species in those phytogeographic units. * indicates species only occurring in Steppic Savanna.

REFERENCES

Alves M, Araújo MF, Maciel JF, Martins S. Flora de Mirandiba. Recife: Associação Plantas do Nordeste; 2009.

APG IV – Angiosperm Phylogeny Group. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. Botanical Journal of the Linnean Society 2016; 181: 1–20.

Araújo FS, Costa RC, Figueiredo MA, Nunes EP. Vegetação e flora fanerogâmica da área Reserva Serra das Almas. In: Araújo FS, Rodal MJN & Barbosa MRV (orgs) Análise das variações da biodiversidade do bioma Caatinga: suporte a estratégias regionais de conservação. Brasília: Ministério do Meio Ambiente; 2005.

BFG – The Brazil Flora Group. Growing knowledge: an overview of seed plant diversity in Brazil. Rodriguésia 2015; 66(4): 1085–1113.

Fernandes MF, Queiroz LP. Vegetação e flora da Caatinga. Ciência e Cultura 2018; 70(4): 51-56.

Fernandes MF, Cardoso D, Queiroz LP. An updated plant checklist of the Brazilian Caatinga seasonally dry forests and woodlands reveals high species richness and endemism. Journal of Arid environments 2020; 174: 104079.

Figueiredo MA. A cobertura vegetal do Estado do Ceará (unidades fitoecológicas). In: Governo do Ceará (Org.). Atlas do Ceará, vol. 1. Fortaleza: Edições IPLANCE; 1997.

Flora do Brasil 2020. Jardim Botânico do Rio de Janeiro. Disponível em: < http://floradobrasil.jbrj.gov.br/ >.

Freitas RCA, Matias LQ. Situação amostral e riqueza de espécies das Angiospermas do estado do Ceará, Brasil. Acta Botanica Brasilica 2010; 24(4): 964-971.

Funk VA. Floras: a model for biodiversity studies or a thing of the past? Taxon 2006; 55(3): 581-588.

Giulietti AM, Harley RM, Queiroz LP, Barbosa MRV, Bocage Neta AL, Figueiredo MA. In: Sampaio EVSB, Giulietti AM, Virgínio J, Gamarra-Rojas CFL (eds.). Vegetação e Flora da Caatinga. Recife: Associação Plantas do Nordeste APNE; 2002.

Giulietti AM, Bocage Neta AL, Castro AAJF, Gamarra-Rojas CFL, Sampaio EVSB, Virgínio JF, Queiroz LP, Figueiredo MA, Rodal MJN, Barbosa MRV, Harley RM. Diagnóstico da vegetação nativa do bioma Caatinga. In: Silva JMC, Tabarelli M, Fonseca MS & Lins LV (eds) Biodiversidade da Caatinga: áreas e ações prioritárias para a conservação. Recife & Brasília: Universidade Federal de Pernambuco & Ministério do Meio Ambiente; 2004.

IBGE – Instituto Brasileiro de Geografia e Estatística. Manuais Técnicos em Geociências. n. 1. Manual técnico da vegetação brasileira. 2a ed. rev. ampl. Rio de Janeiro: IBGE; 2012. Disponível em: https://biblioteca.ibge.gov.br/visualizacao/livros/liv63011.pdf.

Jardim JG, Souza EB, Loiola MIB. *Faramea baturitensis* (Rubiaceae: Coussareae), a new species from the Serra de Baturité, Northeastern Brazil. Acta Botanica Brasilica 2020; 34(4): 778-782.

Leal IR, Silva JMC, Tabarelli M, Lacher Jr TE. Mudando o curso da conservação da biodiversidade na Caatinga do Nordeste do Brasil. Megadiversidade 2005; 1(1): 139–146.

Lemos JR, Meguro M. Florística e fitogeografia da vegetação decidual da Estação Ecológica de Aiuaba, Ceará, Nordeste do Brasil. Revista Brasileira de Biociências 2010; 8(1): 34-43.

Loiola MIB. A new species of *Erythroxylum* (Erythroxylaceae) from the Brazilian semiarid region. Phytotaxa 2013; 150(1): 61-64.

Loiola MIB, Araújo FS, Lima-Verde LW, Souza SSG, Matias LQ, Menezes MOT, Silva MAP, Souza MMA, Mendonça ACAM, Macedo MS, Oliveira SF, Sousa RS, Balcázard AL, Crepaldi CG, Campos LZO, Nascimento LGS, Cavalcanti MCB Tenório, Oliveira RD, Silva TC, Albuquerque UP. Flora da Chapada do Araripe. In: Albuquerque UP & Meiado MV. (Org.). Sociobiodiversidade na Chapada do Araripe v. 1. 1ed. Recife: NUPEEA; 2015.

Loiola MIB, Ribeiro RTM, Sampaio VS, Souza EB. Diversidade de angiospermas do Ceará: Herbário Prisco Bezerra – 80 anos de história. Sobral: Edições UVA; 2020.

Loiola MIB, Silva MAP, Ribeiro RTM, Sampaio VS, Soares Neto RL, Souza EB. Lista de Angiospermas do Ceará. Fortaleza: Secretaria do Meio Ambiente do Ceará; 2021. Disponível em https://www.sema.ce.gov.br/flora-do-ceara/.

MMA – Ministério do Meio Ambiente. Ceará: inventário florestal nacional: principais resultados. Brasília: Ministério do Meio Ambiente, Instituto Florestal Nacional; 2016.

Menezes MOT, Taylor NP, Loiola MIB. Flora do Ceará, Brasil: Cactaceae. Rodriguésia 2013; 64(4): 757-774.

Moro MF, Lughadha EN, Filer DL, Araújo FS, Martins FR. A catalogue of the vascular plants of the Caatinga Phytogeographical Domain: a synthesis of floristic and phytosociological surveys. Phytotaxa 2014; 160(1): 1-118.

Moro MF, Macedo MB, Moura-Fê MM, Castro ASF, Costa RC. Vegetação, unidades fitoecológicas e diversidade paisagística do estado do Ceará. Rodriguésia 2015; 66(3): 717-743.

Queiroz LP. The Brazilian Caatinga: phytogeographical patterns inferred from distribution data of the Leguminosae. In: Pennington RT, Lewis GP, Ratter JA (eds). Neotropical savannas and dry forests: Diversity, Biogeography, and Conservation. Boca Raton: Taylor & Francis CRC Press; 2006.

Queiroz LP. Leguminosas da Caatinga. Feira de Santana: Editora da Universidade Estadual de Feira de Santana; 2009.

Queiroz LP, Cardoso D, Fernandes MF, Moro MF. Diversity and evolution of flowering plants of the Caatinga dominium. In: Silva JMC, Leal IR, Tabarelli M (eds). Caatinga – The largest tropical dry forest region in South America. Springer Nature, Cham. 2017.

Reis APL, Silva MAFS, Maia ALV, Silva Júnior JMT, Sabóia LRM. Levantamento florístico das espécies nativas da caatinga do estado do Ceará. Brazilian Journal of Animal and Environmental Research 2021; 4(3): 3060-3078.

Ribeiro RTM, Soares Neto RL, Loiola MIB. *Phyllanthus carmenluciae*, a supreme species of *Phyllanthus* (Phyllanthaceae) from Brazil. Phytotaxa 2017; 305(1): 35-40.

Sampaio VS, Gouvêa YF, Souza EB, José-Silva L, Eisenlohr P, Loiola MIB. Description of a new species of spiny *Solanum* (Solanaceae) from rocky outcrops of Northeastern Brazil, with modeling of its environmental suitability. Systematic Botany 2019; 44(2): 415-423.

Siqueira Filho JA. Flora das Caatingas do Rio São Francisco, História natural e conservação. Rio de Janeiro: Andrea Jakobsson; 2012.

Silveira AP, Loiola MIB, Gomes VS, Lima-Verde LW, Oliveira TO, Silva EF, Otutumi AT, Ribeira KA, Xavier FAS, Bruno MMA, Souza SSG, Araújo FS. Flora of Baturité, Ceará: a wet island in the Brazilian semiarid. Floresta e Ambiente 2020a; 27(4): e20180320.

Silveira AP, Menezes BS, Loiola MIB, Lima-Verde LW, Zanina DN, Carvalho ECD, Souza BC, Costa RC, Mantovani W, Menezes MOT, Flores LMA, Nogueira FCB, Matias LQ, Barbosa LS, Gomes FM, Cordeiro LS, Sampaio VS, Batista MEP, Soares Neto RL, Silva MAP, Campos NB, Oliveira AA, Araújo FS. Flora and annual distribution of flowers and fruits in the Ubajara National Park, Ceará, Brazil. Flora e Ambiente 2020b; 27(2): e20190058.

Velloso AL, Sampaio EVSB, Pareyn FGC. Ecorregiões propostas para o Bioma Caatinga. Recife: Associação Plantas do Nordeste: Instituto de Conservação Ambiental The Nature Conservancy do Brasil; 2002.