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Original Paper

Does the carnauba-palm riverine vegetation constitute a different type of plant community in the Brazilian semiarid? An analysis of the floristic composition

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Abstract
Floristic surveys are the main source of information about species composition of different vegetation types and a fundamental input of information for biogeographical studies. Within the Caatinga Domain, there are many vegetation types, of which the most conspicuous is the deciduous caatinga *s.s.* vegetation. However, along the watercourses of this region, one can find a type of riparian forest called *Carnaubais*, characterized by a larger presence of evergreen species with access to underground water and a conspicuous occurrence of the endemic "carnauba" palm (*Copernicia prunifera*). The present study aimed at making a floristic survey on a *Carnaubal* riverine habitat and a nearby caatinga *s.s.* site in Ceará, and perform a biogeographical comparison with other sites within the Caatinga Domain. In our study site, we identified 186 species, distributed in 135 genera and 52 families. Of the 186 species recorded, we found 123 species uniquely in the caatinga *s.s.* phytophysiognomy, 40 uniquely in *Carnaubal* and 23 in both phytophysiognomies. The most representative families were Fabaceae (31 spp.), Poaceae (15 spp.), and Euphorbiaceae (13 spp.). The UPGMA and NMDS analyses supported the idea that the *Carnaubal* is a habitat with distinct flora within the Caatinga Domain.
Key words: dry forest, carnaubal, riparian forest, *caatinga*, semiarid, vegetation.

Resumo
Os levantamentos florísticos são a principal fonte de informação sobre a composição das espécies de diferentes fitofisionomias e um fator fundamental para estudos biogeográficos. Dentro do Domínio da Caatinga, existem muitos tipos de vegetação, dos quais o mais evidente é a vegetação decídua de caatinga s.s. No entanto, ao longo dos cursos d'água dessa região, pode-se encontrar um tipo de vegetação ripária denominada Carnaubais, caracterizada pela maior presença de espécies perenes com acesso a águas subterrâneas e pela ocorrência evidente da endêmica carnaúba (Copernicia prunifera). O presente estudo teve como objetivo fazer um levantamento florístico em um habitat ribeirinho de Carnaubal e uma caatinga s.s. no Estado do Ceará, e realizar uma comparação biogeográfica com outros estudos realizados dentro do Domínio Caatinga. Em nosso local de estudo, identificamos 186 espécies, distribuídas em 135 gêneros e 52 famílias. Das 186 espécies registradas, 123 foram encontradas somente na fitofisionomia de Caatinga s.s., 40 somente em Carnaubal e 23 em ambas as fitofisionomias. As famílias mais representativas foram Fabaceae (31 spp.), Poaceae (15 spp.) e Euphorbiaceae (13 spp.). As análises do UPGMA e do NMDS corroboraram a ideia de que o Carnaubal é um habitat com flora distinta dentro do Domínio da Caatinga.
Palavras-chave: mata seca, carnaubal, mata ciliar, caatinga, semiárido, vegetação.

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Introduction

South America's seasonally dry forests cover an area of 1.811.741 km² and occur disjointly at the margins of tropical forests and savannas in Colombia, Venezuela, Ecuador, Peru, Bolivia, Argentina, Paraguay, and Brazil (Pennington *et al.* 2000; Silva *et al.* 2017). In Brazil, the Caatinga Phytogeographic Domain (from now on CPD) has extensive areas of deciduous dry forests, the caatinga *s.s.* vegetation, which covers about 800.000 km². CPD is the largest area of continuous tropical dry forest in the Americas (Pennington *et al.* 2000; Moro *et al.* 2016; Queiroz *et al.* 2017).

The CPD covers the states of Ceará, the large part of Rio Grande do Norte, Paraíba and Pernambuco, southeast of Piauí, west of Alagoas and Sergipe, northern and central Bahia, and a small part of northern Minas Gerais (Andrade-Lima 1981; Olson *et al.* 2001; Moro *et al.* 2016; Silva *et al.* 2017). Two major floristic subgroups can be distinguished: the flora present in the crystalline basement, called crystalline caatinga or caatinga *s.s.*, and the flora on sandy terrains of the sedimentary basins, called sedimentary caatinga, sandy caatinga or "carrasco" (Moro *et al.* 2016; Queiroz *et al.* 2017). Caatinga *s.s.* is the dominant habitat of CPD and comprises a range of physiognomies varying from low vegetation, with discontinuous canopy, to tall, well-developed dry forests, both physiognomies with deciduous foliage in the dry season and commonly armed with thorns (Queiroz 2009).

The CPD has an extensive fluvial network composed of many intermittent and a few perennial rivers. While the caatinga is strongly deciduous we can find riverine vegetation along the riversides with a larger proportion of evergreen plants. Functioning as a refuge for plants and animals and ecologically maintaining the riparian forests during the two main seasonal periods, the dry and the rainy (Silva *et al.* 2017). Naiman *et al*. (1998) and Ribeiro & Walter (2008) define vegetative formations that occur along watercourses as riparian forests. Along the watercourses of the northern Caatinga, one can find a specific type of riparian forest called c*arnaubais*, which are characterized by many evergreen species with access to underground water and a strong occurrence of the endemic 'carnaúba' palm [*Copernicia prunifera* (Mill.) E.H. Moore]. According to Andrade-Lima (1981), in a paper that now has become classic, the *carnaubais* are a particular subtype of caatinga (vegetation type 12: Copernicia-Geoffroea-Licania community). He says "this is another restricted unit, represented by a fringe forest along the main rivers […] within the caatingas of the states of Piauí, Ceará and Rio Grande do Norte, and also along most of their tributaries and humid valleys which are flooded during the rainy season" (Andrade-Lima 1981).

This type of vegetation has a typical flora under the influence of the great abundance of Carnaúba individuals. This fact makes the environment quite peculiar when the floristic composition is compared with other semiarid phytophysiognomies and even riparian forests without the occurrence of *C. prunifera*. In addition to the habitat created by carnaubas, the diversity of species is directly influenced by seasonal periods, as in the rainy season, several small "lagoons" are formed along the carnauba trees, providing the occurrence of species typical of this vegetation.

The *Carnaubais* are bordered by Caatinga *s.s.*, where these two phytophysiognomies share the occurrence of some species, mainly in the transition zone. However, soil characteristics, as well as temperature and humidity, are conditions for the occurrence of certain species. In relation to riparian forests without the occurrence of carnauba, this phytophysiognomy is considered different because they are directly linked to the main channel of a certain river, with part of their composition determined by the physical-climatic conditions of the lotic environments, such as the height of the water column, current speed, depth and soil characteristics, light, organic matter and nutrient availability, being some of the determining factors for the floristic composition of riparian forests (Schneck & Hepp 2010; Staes *et al.* 2010). Riparian forests and *Carnaubais* are subject to different anthropic actions. While the *Carnaubais* suffer degradation due to the fact that other species are removed from the environment for the permanence only of *C. prunifera* in order to facilitate livestock activities and extraction of carnauba wax and other raw materials produced by this plant (Vieira *et al.* 2016; Almeilda *et al.* 2021), riparian forests suffer environmental impacts related to monoculture plantations, illegal extraction of water from the river and even real estate developments, often leading to the silting of rivers (Oliveira *et al.* 2011).

Historically, the Caatinga *s.s.* had been neglected by biologists in the study of its biodiversity (Moro *et al.* 2015b). However, since the early 2000s, the number of studies on its diversity has been increasing, especially floristic studies (Moro *et al.* 2015b). These studies help taxonomic and

ecological research, as well as support the creation of policies for sustainable management and conservation of flora (Lemos & Meguro 2010).

Given these considerations, this study aimed to carry out the floristic survey in a riparian *Carnaubal* and a nearby caatinga *s.s.* site and compare their biogeographical affinities with other habitats that typically occur in the Caatinga Domain, as well as verify the level of endemism and threat of the recorded species. We hypothesize that the carnaubal forms a vegetation subgroup within the Caatinga *s.s.*, with a flora distinguishable from surrounding caatinga *s.s.*

Materials and Methods

Study area

The floristic study was carried out at the Experimental Farm (FAEX) of the State University Vale do Acaraú, which is in the municipality of Massapê, state of Ceará, at coordinates 03º37'01''S and 40º18'22''W (Fig. 1a-b). FAEX has about 150 ha of extension and altitudes varying from 40 to 70 m. It is on the west bank of the Acaraú River, which has 315 km long, from the source to the estuary. Its hydrographic basin has 14,427 km², covering 25 municipalities (Claudino-Sales *et al.* 2020).

The farm is in an area with bot Thorny Deciduous Forest (caatinga *s.s.*) (Fig. 1c-f), in the Depressão Sertaneja basement, and *carnaubal* vegetation (Fig. 1c-f), in the fluvial plains of the Acaraú river (Moro *et al.* 2015a). As an area of experimental agricultural studies, it has significant levels of anthropization. The studied *carnaubal* has been exposed to human impacts and represents the *carnaubais* in Ceará are usually exposed to many interferences for agriculture and grazing. The *carnaubais* of Ceará are part of the fluvial plains (Moro *et al.* 2015a), being that of the Acaraú

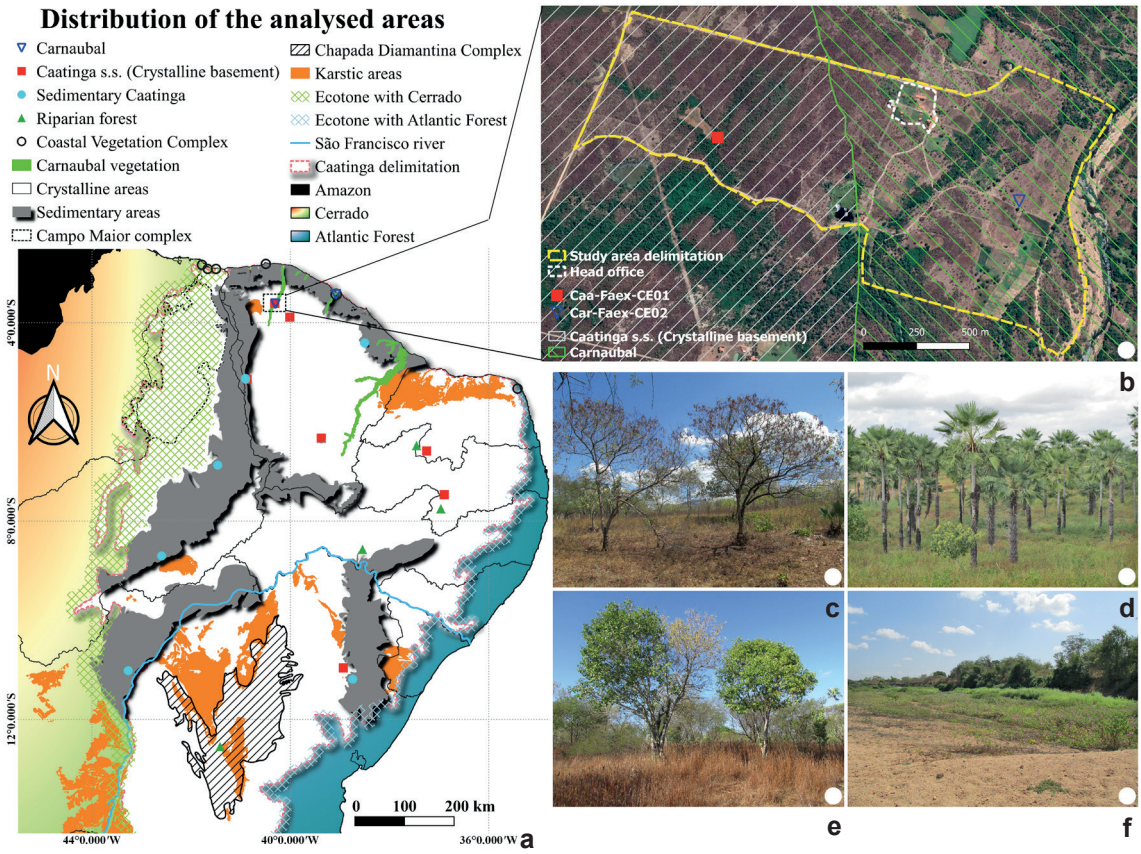

Figure 1 – a-f. The geographic location of the carnaubal and caatinga *s.s.* vegetation sampled by this study in Sobral, Ceará state, Brazil – a. geographic distribution of the areas compared in the UPGMA and NMDS analyses; b. delimitation of the geographical limits of the study area; c. *Caatinga s.s.* dry season; d. population of *Copernicia prufinera*; e. *Caatinga s.s.* at the end of the rainy season; f. *Carnaubal* near the left bank of the Acaraú river.

River one of the most important. These areas have Quaternary age sediment with fluvial neossols that can reach larger depths than the soil in the surrounding caatinga. The caatinga *s.s.* studied here is established on the crystalline basement, which is of the Precambrian age with shallow livisols and superficial pebble stone (Moro *et al.* 2015a). Images of the study area are available at <https://figshare.com/s/a8091537de4d1f888cd5>.

Field and laboratory studies

Collection expeditions for floristics were carried out monthly, starting in July/2014 and ending in April/2022. The botanical material was herborized according to usual botanical methods (Peixoto & Maia 2013). The specimens were identified using specialized literature (Longhi-Wagner *et al.* 2001; Alves *et al.* 2009; Queiroz 2009; Souza & Lorenzi 2012) and taxonomic databases (Flora do Brasil 2020, continuously updated), and the exsiccates were incorporated into the collection of the Herbarium of the Universidade Estadual Vale do Acaraú (HUVA). Duplicates were sent to the EAC, HDELTA, and HUEFS herbaria (acronyms according to Thiers, continuously updated).

The circumscription of families is according to APG IV (2016), and scientific names and author respective follows IPNI (continuosly updated). We considered endemic species those listed as restricted to Caatinga in the checklist published to the whole CPD by Fernandes *et al.* (2020) and in the database of the Flora do Brasil 2020 (continuously updated). The threat status of each species was examined in CNC Flora (2021) database. The distribution of each species across the Brazilian phytogeographic domains was verified in Flora do Brasil 2020 (continuously updated). The habit of the species in the two habitats surveyed here was obtained in the field.

Biogeographical analyses

To understand the floristic affinities of the vegetation of the *carnaubal* and caatinga *s.s.* in the study area, and with other phytophysiognomies in the Brazilian semiarid, we created a database of species present in other sites. Our database had 27 sites with caatinga vegetation (both caatinga *s.s.* and sedimentary caatinga), *carnaubal*, coastal vegetation, and riparian vegetation (Tab. S1, available on supplementary material <https://doi.org/10.6084/m9.figshare.21948092>; Fig. 1a). To compare other floristic lists with our study, we chose from the literature published works that presented in their list plants of all habits, from small herbaceous plants to large trees. In addition, we emphasize that the database focuses on lists published mainly for the Carnaubais and, in the background, for the crystalline Caatinga, since it would not be feasible, at the moment, to carry out statistical analyzes with all the published lists for the five types of vegetation mentioned in this study. To compare the sites, we excluded the exotic species reported in each study and used UPGMA grouping analysis and NMDS ordination with Jaccard distance (Legendre & Legendre 2012), using package Vegan in R software (Oksanen *et al.* 2019; R Core Team 2019). The map which shows the study area and geographic location of the analyzed areas was prepared in QGIS 3.4.8.

Results and Discussion

In our study site, 185 species were recorded, distributed in 135 genera and 52 families (Tab. S2, available on supplementary material <https://doi.org/10.6084/m9.figshare.21948092>; Figs. 3-5). Of this total, 40 were found exclusively for the *carnaubal* area (63.5% of the species that are registered in the Carnaubal), and 122 were recorded exclusively in the Caatinga *s.s.* area and 23 species in both phytophysiognomies (Fig. 2a). Of all recorded plants, 21 were trees, 22 shrubs, 44 subshrubs, 82 herbs, eight herbaceous climbers, and seven woody climbers (Fig. 2b). Photographs of some flora species in the study area can be seen in Figs. 3-5.

In total, the richest families were Fabaceae (30 spp.), Poaceae (15 spp.), and Euphorbiaceae (13 spp.), and the richest genera were *Cyperus* L., *Ipomoea* L., and *Mimosa* L., with five species each, and *Alternanthera* Forssk, *Portulaca* L. and *Sida* L., with four species each. Analyzing the numbers by type of vegetation, in *Carnaubal* the most representative families were Fabaceae (14 spp.), Rubiaceae (6 spp.), and Cyperaceae (4 spp.), and among the genera, none stood out according to the number of species, with seven genera (*Borreria* G. Mey., *Crotalaria* L., *Cyperus* L., *Echinochloa* P., Beauv., *Eleocharis* R.Br., *Ludwigia* L. and *Tephrosia* Pers.) represented by two species and the other by one species each. For the Caatinga *s.s.*, the most diversified families were Fabaceae (19 spp.), Poaceae (13 spp.), and Euphorbiaceae (11 spp.), while the genera *Ipomoea* L. and *Mimosa* L. with five species each, and *Alternanthera* Forssk., *Portulaca* L. and *Sida* L. with four species each, were the richest.

Among the registered species, 34 are endemic to Brazil, of which 16 occur only in the Caatinga phytogeographic domain, being *Tragia cearensis* Pax. & K. Hoffm. (Euphorbiaceae) endemic to Ceará. We also recorded 13 exotic species (Fernandes *et al.* 2020; Flora do Brasil 2020, continuously updated). The species *Aspidosperma castroanum* A.C.D. Castello (Apocynaceae) was recently described for science (Castello *et al.* 2018) and occurs in the states of Ceará and Piauí.

According to CNCFlora (2021), of the species found in FAEX, only 13 have their conservation status assessed, eleven being classified as of Least Concern (LC); *Amburana cearensis* (Allemão) A.C.Sm. as Near Threatened (NT); and *Aspidosperma castroanum* A.C.D. Castello as Endangered (EN) (Castello *et al.* 2018). The remaining 173 species have no assessment of their conservation status. These data corroborate the fact that the knowledge about the flora of the Caatinga domain is still incipient, especially Carnaubal vegetation, which has practically no published data on their biodiversity, resulting in a few species evaluated regarding their conservation status, as well public policies aimed at preserving the vegetation in the Caatinga and its water bodies.

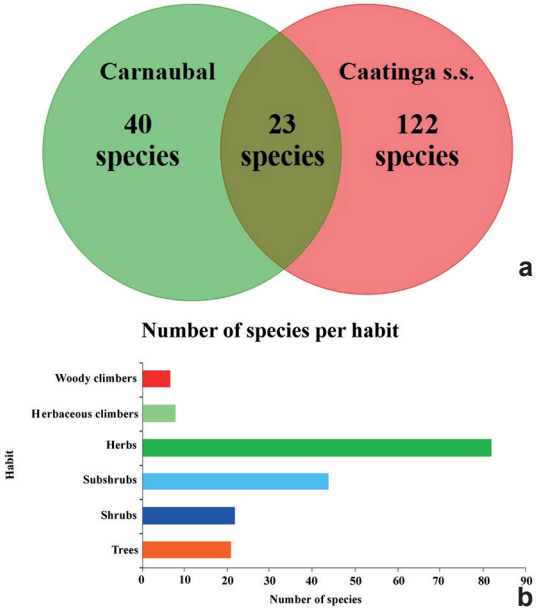

Figure 2 – a-b. Data on the number of species in the study area – a. number of exclusive and shared species of *Carnaubal* and Caatinga *s.s.*; b. number of species per habit.

The cluster (UGPMA) (cophenetic value ~0.89) (Fig. 6) and ordination (NMDS) (stress value ~0.18) analyses (Fig. 7) confirmed the distinction of the floristic composition of the *carnaubal* and other habitats of the CPD analyzed here.

The NMDS analysis also corroborated the results for the vegetation groups evidenced in the UPGMA analysis. Although some areas are outside the 95% confidence ellipse, the vegetation groups are cohesive, since no ellipsis is superimposed. The caatinga *s.s.* from FAEX (Caa-Faex-CE01) appears to be associated with the flora of other caatinga *s.s.* on the crystalline basement and the caatinga, except for a small sedimentary basin in Ceará (Iguatu basin - Csd-Igt-CE08) positioned within the Caatinga *s.s.* group, grouping together with the nearby crystalline caatinga site (Caa-Igt-CE07). Thus, despite being based at different geological basements, the flora of Csd-Igt-CE08 and Caa-Igt-CE07 had a great similarity. A probable hypothesis for this grouping is the short geographical distance, since both areas can share the same environmental and geographical variations, and the small size of the Iguatu sedimentary basin, surrounded by caatinga *s.s.* vegetation.

Regarding the flora of our studied *carnaubal* (Car-Faex-CE02), its flora was closer to the second area of *carnaubal* in the coastal region of Ceará (Car-Pecém-CE04), revealing that the plant composition of riparian forests, associated with the carnaúba palm, is configured as a different type of plant community when compared with both crystalline and sedimentary caatinga (Ribeiro-Filho *et al.* 2009; Souza & Rodal 2010; Silva *et al.* 2015; Farias *et al.* 2017). Thus, this result reveals the dissimilarity between the *carnaubal* and Riparian Forest and corroborates with Figueiredo (1997) and Moro *et al.* (2015a), reinforcing the idea of Andrade-Lima (1981) that the *carnaubais* constitute a particular floristic subgroup within the Caatinga Domain.

In axis one, we can see the separation of the composition of crystalline areas (crystalline caatinga and c*arnaubal*) and sedimentary areas (sedimentary Caatinga and coastal vegetation complex), although the sedimentary caatinga area of Iguatu, which is on a small sedimentary basin in Ceará, is inserted within the ellipse of crystalline caatinga. This shows that there is only insertion in the sediment domain, the area has a strong floristic similarity with the areas of the crystalline caatinga,

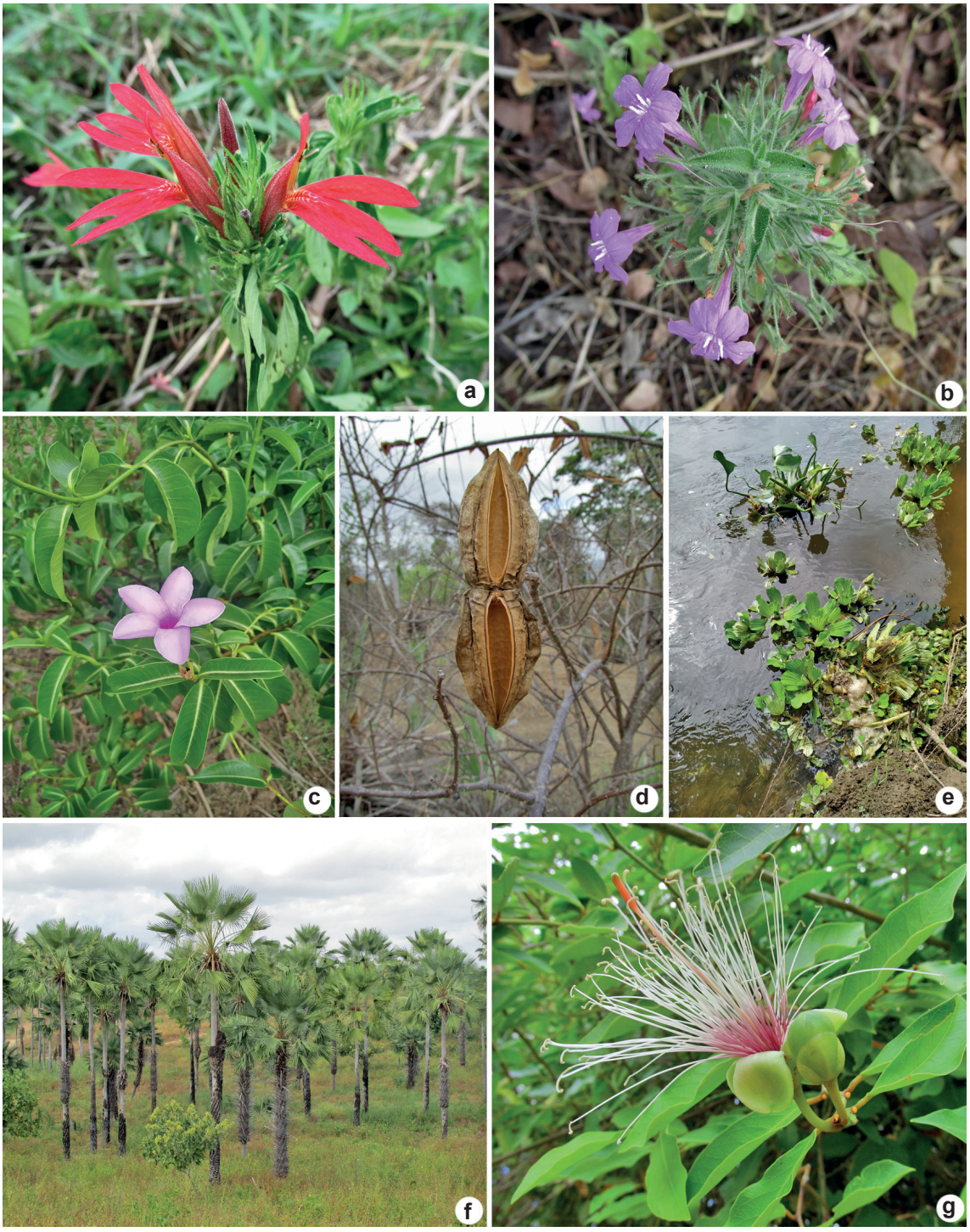

Figure 3 – a-g. Examples of local flora – a-b. Acanthaceae – a. *Anisacanthus trilobus*; b. *Ruellia paniculata*; c-d. Apocynaceae - *Cryptostegia madagascariensis* *; e. Araceae - *Pistia stratiotes*, and Pontederiaceae - *Eichhornia azurea*; f. Arecaceae - *Copernicia prunifera*; g. Caparaceae - *Cynophalla flexuosa*. (* = invasive species very common in *carnaubais*, mainly on *Copernicia prunifera*, where it suffocates and prevents the photosynthetic process until the death of Carnauba).

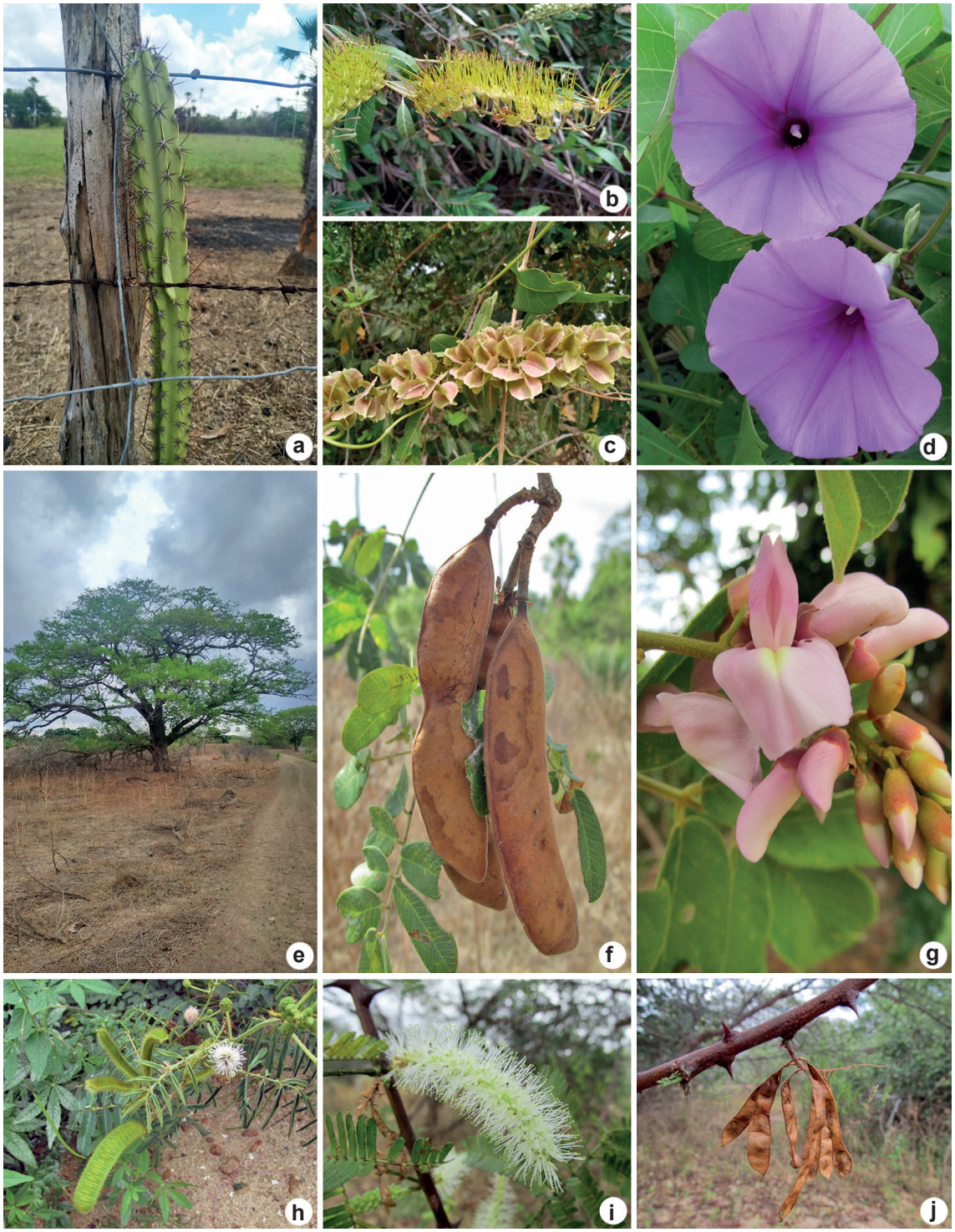

Figure 4 – a-j. Examples of local flora – a. Cactaceae - *Cereus jamacaru*; b-c. Combretaceae - *Combretum lanceolatum*; d. Convolvulaceae - *Ipomoea asarifolia*; e-j. Fabaceae – e. *Geoffrea spinosa*, f. *Libidibia ferrea*, g. *Lonchocarpus sericeus*, h. *Mimosa pigra*, i-j. *Mimosa tenuiflora*.

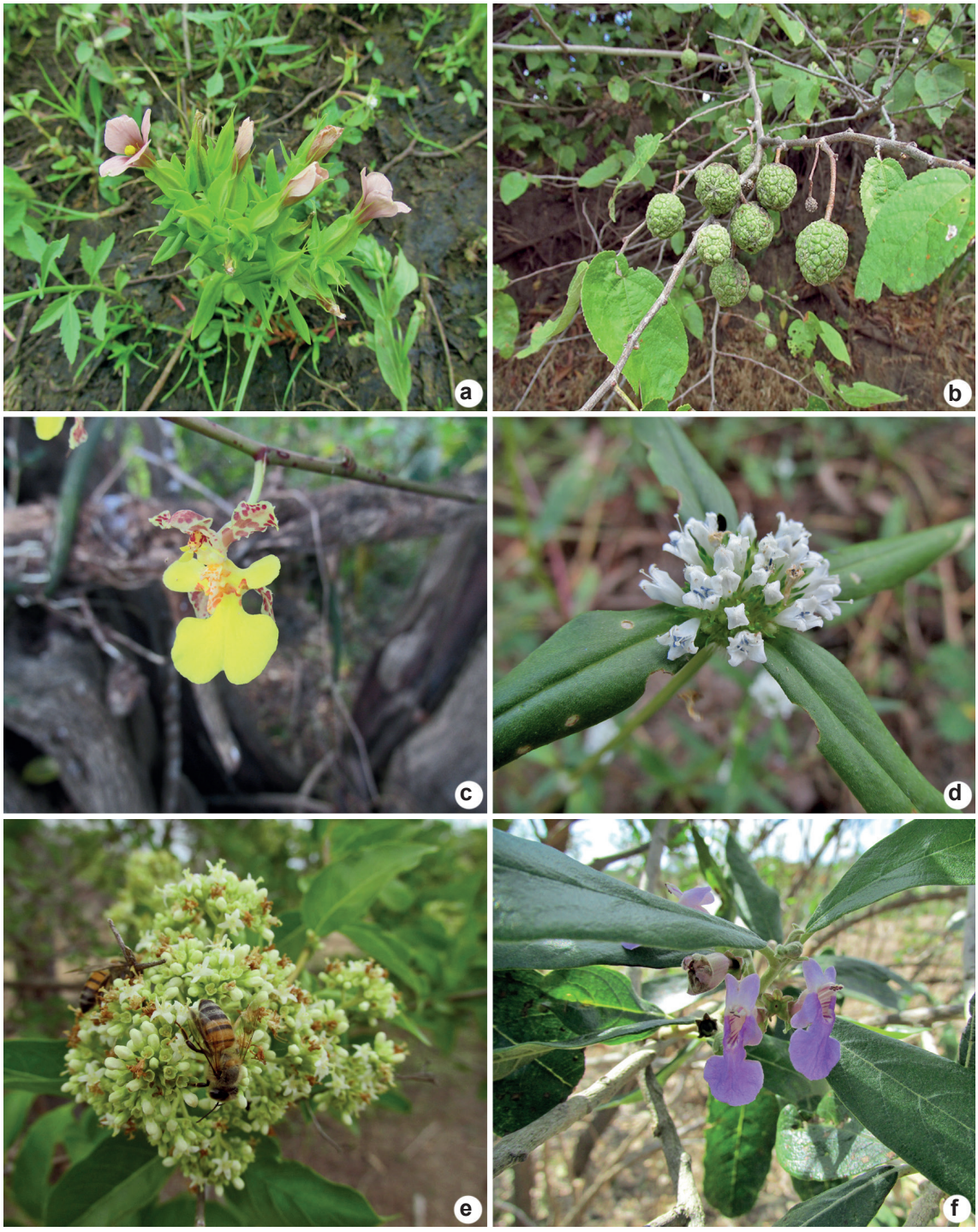

Figure 5 – a-f. Examples of local flora – a. Gentianaceae - *Schultesia guianensis*; b. Malvaceae - *Guazuma ulmifolia*; c. Orchidaceae - *Trichocentrum cepula*; d-e. Rubiaceae – d. *Borreria scabiosoides*; e. *Machaonia acuminata*; f. Lamiaceae - *Vitex gardneriana*.

as shown by the UPGMA analysis. Still on the same axis, among the analyzed riparian forest areas, only one composition of the study carried out in the Chapada Diamantina National Park, in Bahia, is positioned next to the sedimentary areas, despite being geographically positioned in an ecotonal zone between crystalline areas, and the Chapada Diamantina complex.

In the second axis, we can observe the separation of three vegetation groups, the areas of riparian forests, those of Caatinga (crystalline and sedimentary) and *Carnaubal*, and the coastal vegetation complex. In this analysis of NMDS, it is on this axis that the difference in plant composition between the areas of *carnaubal*, riparian forest, and crystalline caatinga is clear.

The flora of the *carnaubal* habitat was floristically distinguishable from all other habitats, including other riparian forests inside the Caatinga Domain (Ribeiro-Filho *et al.* 2009; Souza & Rodal 2010; Silva *et al.* 2015; Farias *et al.* 2017) that do not harbor the carnauba-palm (Figs. 6-7). It has characteristics that distinguish it from other types of phytoecological units, as they occur in sedimentary soils that border the river of the Brazilian semiarid region.

Indeed, the flora of riverine forests in the Cerrado Domain Regarding the flora of our studied *carnaubal* (Car-Faex-CE02), its flora was closer to the second area of *carnaubal* in the coastal region of Ceará (Car-Pecém-CE04), revealing that the plant composition of riparian forests, associated with the carnaúba palm, is configured as a different type of plant community when compared with both crystalline and sedimentary caatinga (Ribeiro-Filho *et al.* 2009; Souza & Rodal 2010; Silva *et al.* 2015; Farias *et al.* 2017). In Moro *et al.* (2015a), twelve characteristic species of the carnaubal vegetation were cited: *Combretum laxum* Jacq., *Copernicia prunifera*, *Erythrina velutina* Willd., *Ficus elliotiana* S. Moore, *Geoffroea Spinosa* Jacq., *Guazuma ulmifolia* Lam., *Microdesmia rigida* (Benth.) Sothers & Prance (= *Licania rigida* Benth.), *Monteverdia obtusifolia* (Mart.) Biral (= *Maytenus obtusifolia* Mart.), *Sapindus saponaria* L., *Sebastiania macrocarpa* Müll.Arg., *Tarenaya longicarpa* Soares Neto & Roalson and *Sarcomphalus joazeiro* (Mart.) Hauenschild (= *Ziziphus joazeiro* Mart.), from which seven registered in this study (Tab. S2, available on supplementary material <https://doi.org/10.6084/m9.figshare.21948092>). However, besides these, we also highlight here some characteristic species of the studied Carnaubal: *Coccoloba obtusifolia* Jacq., *Echinodorus pubescens* (Mart.) Seub. *ex* Warm., *Lonchocarpus sericeus* (Poir.) Kunth *ex* DC, *Ludwigia helminthorrhiza* (Mart.) H. Hara and *Vitex gardneriana* Schauer.

The riparian forest without association with Carnaúba formed a cohesive group since all areas with this type of vegetation were grouped. However, two areas of the Caatinga *s.s.* positioned themselves within the riparian forest group without association with Carnaúba. Caa-Ara-CE05 is a study in which a flora of a water body inserted in a crystalline basement was analyzed, and has greater floristic similarity with the grouping RiF-Sben-PB03 and RiF-RPje -PE01, which are also in the crystalline basement. Caa-Car-PB02 is a floristic study of RPPN Fazenda Almas, inserted in Cariri Paraíba, in the Borborema Plateau, and has a greater floristic similarity with RiF-Car-PB01, which is also inserted in Cariri Paraíba,

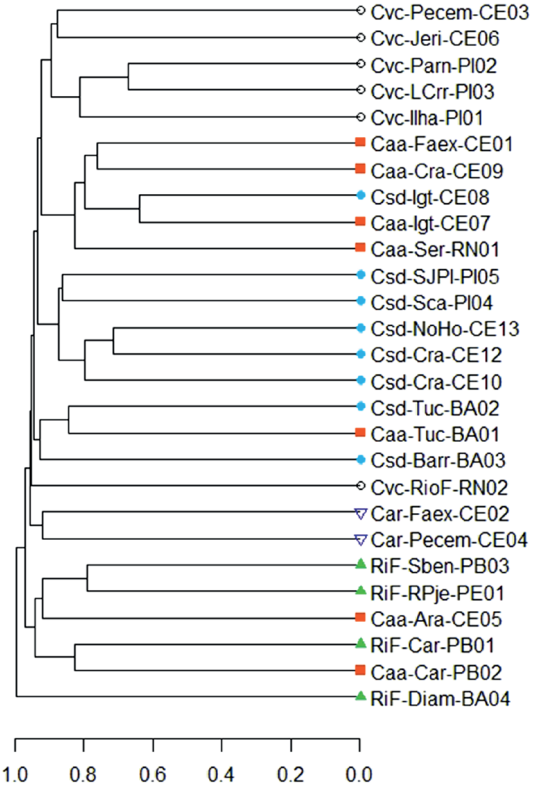

Figure 6 – UPGMA cluster analysis. The cophenetic correlation was ~0.88. Car = *Carnabual*; Caa = crystalline Caatinga; Csd = sedimentary caatinga; Cvc = coastal vegetation; RiF = riparian forest.

being - geographically speaking - areas that share practically the same environmental and geographical variations. Among the analyzed riverside forest areas, RiF-Diam-BA04 is the riparian forest area without association with Carnaúba, which has the most different floristic composition, despite being under the crystalline basement, like all other areas of the Riparian Forest, the plant composition is directly influenced by the surrounding karst areas, besides being inserted in the plateau of Chapada Diamantina.

The Sedimentary of Caatinga areas also formed a cohesive group, with three subgroups (Bahia, Ceará, and Piauí), showing the floristic composition between the Caatinga *s.s.* and Caatinga of the sedimentary is considerably dissimilar, as demonstrated in Moro *et al.* (2016). However, despite being on the crystalline basement, Caa-Tuc-BA01 shows greater floristic similarity to the geographically very close Csd-Tuc-BA02, an area of sedimentary caatinga, since the two lists were made in nearby areas on the edge between sedimentary and crystalline substrates (Costa *et al.* 2015). In addition, these two areas are grouped with another area in Bahia (Csd-Barr-BA03), forming a subgroup of areas in Bahia. Like other areas, Csd-Cra-CE10, Csd-Cra-CE12, and Csd-NoHo-CE13 form a subgroup of areas in Ceará, and Csd-Sca-PI04 and Csd-SJPI-PI05 a subgroup of areas in Piauí.

The Coastal Vegetation Complex areas also formed a cohesive group with two subgroups, one comprising the areas of Ceará (Cvc-Pecém-CE03 and Cvc-Jeri-CE06) and the other of the Piauí areas (Cvc-Parn-PI02, Cvc -LCrr-PI03 and Cvc-Ilha-PI01). This shows that the coastal, littoral zone bordering the Caatinga Domain has a different flora when compared with typical caatinga *s.s.* and sedimentary caatinga. Castro *et al.* (2012) and Moro *et al.* (2015) have recorded this pattern, showing that the flora of coastal areas bordering the Caatinga Domain has not only species from caatinga vegetation but also many species from the Cerrado Domain and even some from the Atlantic Forest and Amazon, plus typical coastal species, never found inside the continent (e.g. mangrove or Restinga species). Unlike the Coastal Vegetation Complex areas of Ceará and Piauí, the plant composition of the study carried out in Rio Grande do Norte was more associated with the Caatinga areas, especially the Sedimentary of Caatinga. This grouping is justified by the fact it is an area of coastal savannah influenced by restingas in the domain of the Atlantic Forest.

Finally, *Carnaubal* seems to be a particular floristic subgroup within the Caatinga domain, being floristically distinct from the caatingas *s.s.* and riparian forests without carnauba. However, it is worth noting that the two detailed floristic studies in published *Carnaubal* are located in Ceará, one

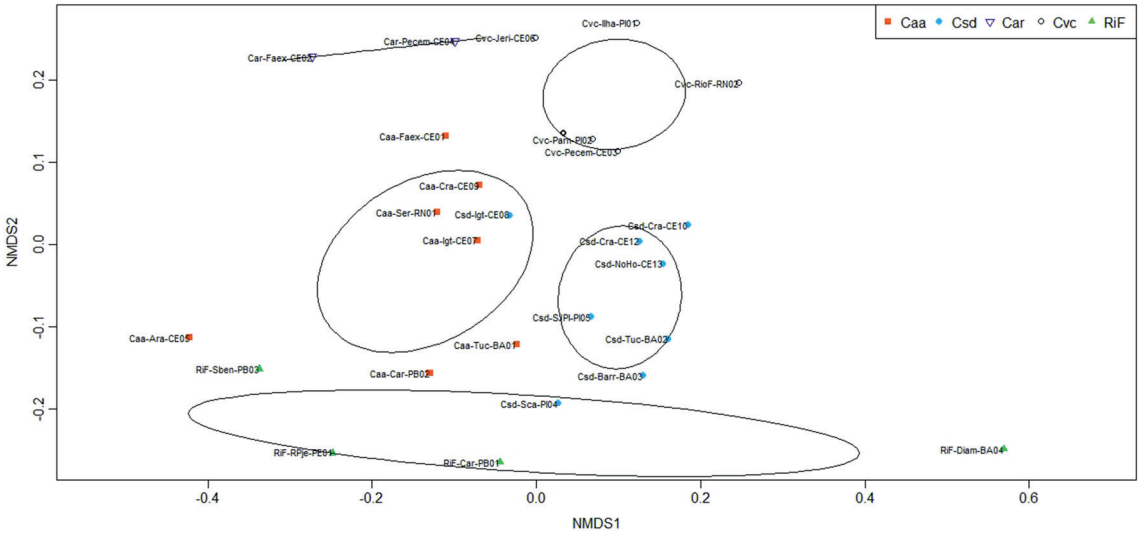

Figure 7 – NMDS ordination analysis. The stress was ~0.18. Car = *Carnabual*; Caa = crystalline Caatinga; Csd = sedimentary caatinga; Cvc = coastal vegetation; RiF = riparian forest.

inland and the other in the coastal zone, where both suffer different environmental, climatic, and anthropogenic pressures. Localities in the coastal zone are subject to higher levels of precipitation, wind speed, and lower levels of aridity and relative temperature, while areas in the interior have lower levels of precipitation, low-speed wind, and higher levels of aridity, temperature, and desertification (Dinpashoh *et al.* 2004; Silva *et al.* 2012; Sales *et al.* 2015). Therefore, these abiotic factors can interfere with the vegetation dynamics of carnauba trees, acting mainly on the dispersion of fruits and seeds, as well as influencing the phenology and geographic distribution of the species.

Extensive *carnaubais* are also in other states, such as Piauí, in areas of the Parnaíba sedimentary basin, and Rio Grande do Norte, besides the other Carnaubal areas in Ceará that have not been studied yet, and that data from these *carnaubais* would be important to properly understand the floristic diversity of vegetation type and to investigate the relationship between carnaubals in the interior of the semiarid region and those in coastal areas, in addition to testing the hypothesis that carnauba forests are in fact a different phytophysiognomy within the Phytogeographic Domain of the Caatinga.

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