Acta Botanica Brasilica - 35(3): 361-380. July-September 2021.
doi: 10.1590/0102-33062020abb0259

Savannas of the Brazilian semiarid region: what do we learn from floristics?

Izaíra Vasconcelos Nepomuceno[1,7*], Elnatan Bezerra de Souza[2,5], Daniela Cristina Zappi[3,4], Marcela Cruz Moreira[5], Francisco Álvaro Almeida Nepomuceno[6] and Marcelo Freire Moro[7]

Received: June 3, 2020
Accepted: November 16, 2020

ABSTRACT

The Cerrado represents the largest extension of savanna in South America. It occupies large stretches of central Brazil, being fragmented towards the Northeast, Southeast, and South regions of the country. Examples of disjunct patches of vegetation with savanna physiognomy within the Caatinga can be found in the Chapada Diamantina, the Chapada do Araripe, in small areas of southern Ceará State, and also in the coastal plains. This study recorded the floristic composition of four savannas within the Caatinga in northern Ceará State and evaluated the floristic relationships between these and other savannas, Cerrado and Caatinga sites. Periodic floristic collections recorded 247 species distributed among 162 genera and 55 families. Fifty-seven percent of the recorded species were of herbaceous or subshrubby habit, while the majority of the flora was of the therophytic life-form. Biogeographic analyses revealed that the study sites differ from typical Cerrado in flora and life-form spectra and have closer floristic relationships with Caatinga vegetation. The presence of floristic elements from the Cerrado, together with species from the Caatinga, in the study sites allows us to conclude that these savanna enclaves in the Caatinga are composed of a mixed flora with typical elements of these two Brazilian biomes.

Keywords: Brazil, Cerrado, floristics, savanna, semiarid, therophytes, vegetation comparisons

Introduction

Savannas are a group of phytophysiognomies dominated by open habitats, where trees and shrubs are found sparsely distributed in the landscape and the ground is covered by a continuous herbaceous layer, often associated with natural fires (Eiten 1982; Pennington *et al.* 2006; Walter *et al.* 2008; Townsend *et al.* 2009). This vegetation typically occurs under seasonal climate where rainfall is more regular and the dry season is less strong than in deciduous Seasonally Dry Forests (Pennington *et al.* 2006). In South America there are large expanses of savannas: the central Brazilian Cerrado, the Llanos between Venezuela and Colombia, the Gran Sabana in Venezuela, and the savannas of Northern Brazil and the Southern Guianas. The second largest biome in Brazil, the Cerrado, is represented by savannas with large numbers of endemic plant taxa (Eiten 1982; Ratter

1 Programa de Pós-Graduação em Sistemática, Uso e Conservação da Biodiversidade, Universidade Federal do Ceará, 60455-760, Fortaleza, CE, Brazil
2 Centro de Ciências Agrárias e Biológicas, Universidade Estadual Vale do Acaraú, 62040-370, Sobral, CE, Brazil
3 Programa de Pós-Graduação em Botânica, Instituto de Ciências Biológicas, Universidade de Brasília, 70910-970, Brasília, DF, Brazil
4 Universidade Federal Rural da Amazônia / Museu Paraense Emílio Goeldi, Programa de Pós-Graduação em Ciências Biológicas - Botânica Tropica, 66077-830, Belém, PA, Brazil
5 Herbário Professor Francisco José de Abreu Matos, Universidade Estadual Vale do Acaraú, 62040-370, Sobral, CE, Brazil
6 Laboratório de Sistemática e Genética de Plantas, Universidade Federal do Espírito Santo, 29932-540, São Mateus, ES, Brazil
7 Laboratório de Biogeografia e Estudos da Vegetação, Instituto de Ciências do Mar, Universidade Federal do Ceará, 60165-081, Fortaleza, CE, Brazil

* Corresponding author: nepomucenoiv@gmail.com

et al. 1997; Pennington *et al.* 2006; BFG 2015). The families with the largest number of species in the Cerrado flora are Fabaceae, Malpighiaceae, Myrtaceae, Melastomataceae, Poaceae and Rubiaceae. Nevertheless, in some localities, the vegetation can be dominated by species of *Vochysiac*eae (Ratter *et al.* 1997). The Brazil Flora Group´s current data (BFG 2018) listed 33,099 angiosperm species for the whole of Brazil and, of these, 12,113 were recorded for the Cerrado biome, with 7,800 species listed for the cerrado *s.s.* vegetation (Souza *et al.* 2018).

The Brazilian Cerrado occupies a large area of central Brazil, also extending to Bolivia and Paraguay. It has very diversified and dynamic vegetation types and, according to the fire regime and substrate in each locality, physiognomies can vary from open grasslands (*campos limpos*, *campos sujos*, *campos brejosos*) to ecotonal forests known as *cerradão* and gallery forests (Eiten 1972; Gibbs *et al.* 1983; Ratter *et al.* 1997; Harley *et al.* 2005; Coutinho 2016). The most characteristic vegetation of the Cerrado domain is the cerrado *sensu stricto* (referred to as cerrado *s.s.* from here onwards), represented by a savanna with widely spaced shrubs and trees usually between 2-8 m height, displaying twisted and thickened, corky trunks, while the soil is covered by an herbaceous layer with a predominance of Poaceae and Cyperaceae and dicotyledoneous shrubs often with lignotuberous root systems (Eiten 1982; Gibbs *et al.* 1983; Ratter *et al.* 1997).

Apart from the 'core' area, savannas with species typical of the cerrado *s.s.* vegetation also occur in disjunct patches in other biomes in the Northern, Northeastern, Southeastern and Southern regions of Brazil (Eiten 1972; Ratter *et al.* 2003). Along the coastal environments of Brazil, the coastal savannas (Castro 1994; Castro & Martins 1999; Moro *et al.* 2011) appear to be associated with the tablelands of the *Formação Barreiras*, a flat 400 mya deposit in the coastal geomorphological unit found from Amapá to Rio de Janeiro states (Arai 2006; Balsamo *et al.* 2010) that is sometimes referred to as the *tabuleiros costeiros* (Castro 1994).

The best studied disjunct patches of savanna are those embedded within the Amazonian Rainforest biome (Devecchi *et al.* 2020). Biogeographical studies have shown that, although these sites have a typical savanna physiognomy and share very characteristic species with the cerrado vegetation of Central Brazil (like species of *Byrsonima*, *Qualea*, *Salvertia* and other genera), these patches of open habitats within the rainforest differ floristically from core cerrado sites, with a predominance of widespread and Amazonian species and a high species turnover from site to site (Devecchi *et al.* 2020).

Less studies are available for the savanna enclaves found within the semiarid Caatinga biome (caatinga-savannas hereafter). In Northeastern Brazil, savannas are found in the Chapada Diamantina (Bahia State), Chapada do Araripe (Ceará State) and in other areas of Bahia, Piauí, Ceará, Rio Grande do Norte and Paraíba states (Figueiredo 1989; Costa *et al.* 2004; Juncá *et al.* 2005; Oliveira *et al.* 2012; Moro *et al.* 2015; 2016; Queiroz *et al.* 2017). While these caatinga-savannas appear to have floristic ties with the Cerrado of central Brazil, they also have species typical of the semiarid Caatinga (Castro 1994; Castro & Martins 1999).

Despite sharing the same macroclimate of the Caatinga, where the mean annual precipitation is less than 1000 mm with a longer, less predictable and more dramatic dry season than the Cerrado core area, the caatinga-savannas found in Northeastern Brazil develop on poor and acidic soils and are subject to wild fires (Moro *et al.* 2016; Queiroz *et al.* 2017). For example, the Chapada Diamantina and the Chapada do Araripe present a variety of substrates that support diverse plant physiognomies. In the Chapada Diamantina the areas of cerrado occur on clay soils while in the Chapada do Araripe the *cerradão* forests are found on oxisols, a class of soil constituted from mineral material that ranges from imperfectly to heavily drained, and that are naturally acidic and variable in depth (Costa *et al.* 2004; Rocha *et al.* 2005; Ribeiro-Silva *et al.* 2012; Santos *et al.* 2018).

Among the characteristic species commonly found between the typical cerrado and these caatinga savanna sites are *Bowdichia virgilioides*, *Curatella americana*, *Byrsonima crassifolia*, *Hancornia speciosa*, *Hymenaea*, *Salvertia convallariodora* and *Vatairea macrocarpa* (Costa *et al.* 2004; Moro *et al.* 2011; Oliveira *et al.* 2012; Moro *et al.* 2015; Silva-Moraes *et al.* 2018). All of these were listed as very widespread Cerrado species by Ratter & Dargie (1992) and Ratter *et al.* (2003). On the other hand, these Northeastern cerrados are also home to species that are commonly found in the Caatinga, such as *Centrosema brasilianum*, *Chamaecrista flexuosa*, *Cochlospermum vitifolium* and *Pityrocarpa moniliformis* (Castro 1994; Moro *et al.* 2011; Oliveira *et al.* 2012; Moro *et al.* 2014).

Mentions of Cerrado enclaves in Northeastern Brazil were made by several authors (Eiten 1982; Castro 1994; Castro & Martins 1999; Ratter & Dargie 1992; Ratter *et al.* 2003), together with putative floristic elements that might characterize them. Castro (1994) attempted to establish a relationship between such 'Cerrado areas' in Northeastern Brazil with the core Cerrado biome and showed floristic and phytosociological differences between cerrado areas from Piauí and São Paulo. While analysing the Cerrado as a whole, Ratter *et al.* (2003) have shown that the Northeastern Brazilian areas formed a cohesive group; however, the relationship between the caatinga vegetation with caatinga-savannas and the cerrado vegetation was not investigated further. The present work aims to document the flora of four caatinga-savanna enclaves and increase our understanding of the biogeographical links of these caatinga-savannas with typical cerrado and caatinga sites, evaluating their biogeographical relationships.

Materials and methods

Study area

The caatinga-savannas sampled by this study are located in the northeastern region of Ceará state, in the municipalities of Granja and Martinópole (Fig. 1). The coordinates of the localities studied are listed in Table 1. The predominant climate in the municipalities is hot tropical mild semiarid, varying to hot tropical sub-humid at the limits of Granja with the Ibiapaba highlands, and hot tropical semiarid in Martinópole, close to the central Ceará lowlands (IPECE 2007). The average annual temperature is around 27°C with an average annual precipitation of 1.115 mm in Granja and 1.009 in Martinópole (FUNCEME 2019).

The localities studied in Granja (S1, S2 and S3) (Figs. 2A-C), comprise sandy, clay and stony soils. The vegetation physiognomies of these localities vary from open savannas similar to the cerrado *sensu stricto* (cerrado *s.s.*), according to the classification of Walter *et al.* (2015), from transition zones between Caatinga-Cerrado, to forested physiognomies similar to more densely woody, ecotonal *cerradão* forests. S1 has soils ranging from sandy to clay, the herbaceous layer is well developed, and the trees and shrubs are sparsely distributed throughout the landscape. S2 is located over a quartzitic rock outcrop and it is a principal area of Caatinga-Cerrado ecotone studied. S3 is characterised by sandy and stony, lateritic soil with rocks formed in a process of intense weathering from the mother-rock, and rich in Fe and Al (Costa 1991). The study area in Martinópole (S4) (Fig. 2D) has predominantly sandy soils that are stony in some sections, and support arboreal vegetation resembling a *cerradão*.

Floristic survey

Fertile plant specimens were collected in the four caatinga-savannas in expeditions carried out between May 2016 and August 2019. Appropriate herborization techniques were followed (Mori *et al.* 1989) and the herbarium samples were deposited in the Herbarium 'Professor Francisco José de Abreu Matos' (HUVA) of

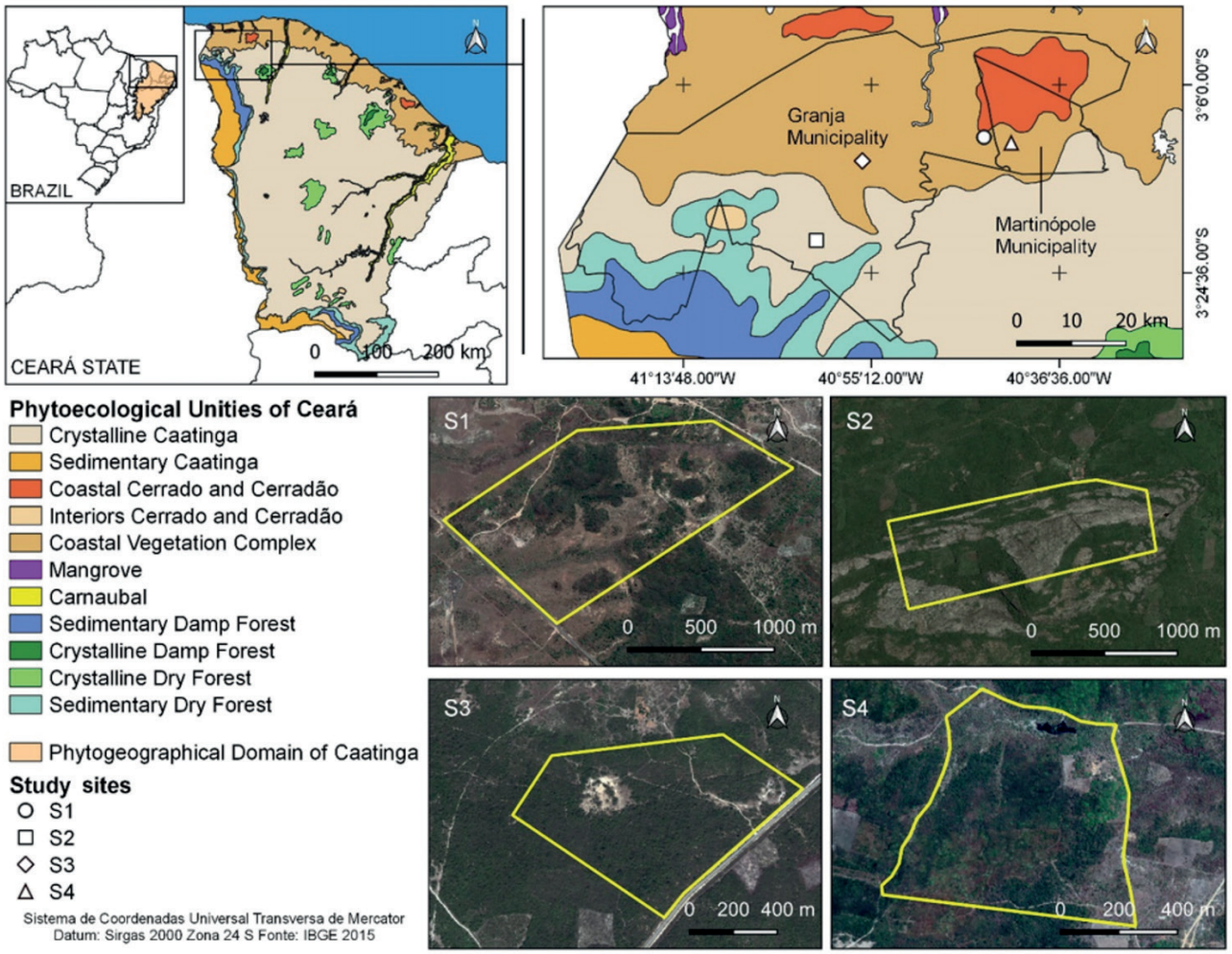

Figure 1. Location of the study areas in the municipalities of Granja and Martinópole in Northern Ceará, Brazil. Source of satellite images: Google Earth 2020.

the Vale do Acaraú State University (UVA). Duplicates, when available, were sent to the herbaria EAC and HUEFS (herbarium acronyms according to Thiers 2021, continuously updated).

We consulted the relevant literature, such as the monographs of the Flora of Ceará (Menezes *et al.* 2013; Soares-Neto *et al.* 2014; Lima *et al.* 2018; Nepomuceno *et al.* 2018) and specialized taxonomic databases - Flora do Brasil 2020 (Flora do Brasil 2020 2019) and CRIA (2019), to identify the specimens. Plant specialists in the families Asteraceae, Bignoniaceae, Cyperaceae, Euphorbiaceae, Poaceae and Rubiaceae were consulted. Family circumscriptions follow the classification proposed by APG IV (2016), except for the Turneraceae, which was recognised as distinct from Passifloraceae (see Tokuoka 2012). Species names, their respective authors, geographic distribution and endemism are in accordance with BFG (2018). In addition, we classified each species into Raunkiaer life-forms to obtain the biological spectrum of the areas (Martins & Batalha 2011). The classification of Raunkier's life-forms follows the classification of Martins & Batalha (2011) and was observed in the field. When the life-form could not be defined *in situ*, data from the literature were consulted to determine the appropriate life-form.

To compare the life-form spectra of our sites with other vegetation types, we used an ordination analyses (NMS – non-metric multidimensional scaling using Eucliden distances) to contrast the spectra we compiled in our study sites with the spectra of other biomes, as compiled by Costa *et*

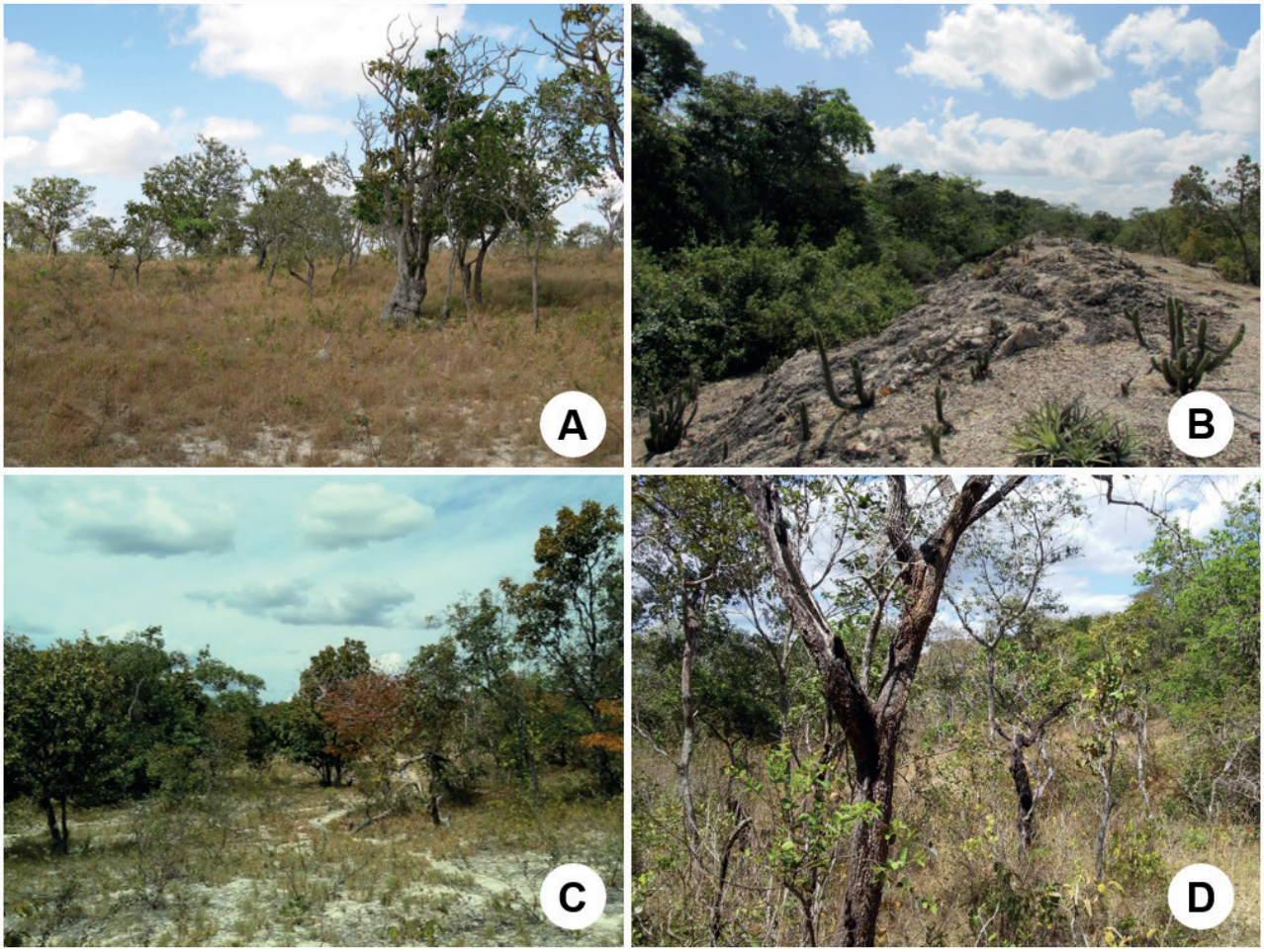

Figure 2. Landscapes of the study areas in Granja (**A, B, C**) and Martinópole (**D**) in Northern Ceará. Granja, CE **A**) S1; **B**) S2; **C**) S3, Martinópole **D**) S4. Photographs: **A-B**) E.B. Souza, **C-D**) I.V. Nepomuceno.

Table 1. Location, acronyms, vegetation type and geographical coordinates of the study areas.

Municipality	Location	Acronym	Vegetation	Coordinates
Granja	Papagaios	S1	Open savanna	03°11'11" S, 40°44'35" W
	São Miguel	S2	Ecotone between a savanna and typical caatinga vegetation	03°21'32" S, 41°01'24" W
	Vereda dos Tomás	S3	Savanna (both open and arboreal)	03°13'33" S, 40°55'49" W
Martinópole	Bom Princípio	S4	Tall savanna (similar to arboreal cerrado, the *cerradão*)	03°11'51" S, 40°41'04" W

al. (2016) (https://doi.org/10.6084/m9.figshare.12755876, Tab. S1 in supplementary material).

Biogeographical analyses

We built a database with floristic lists of sites harbouring caatinga-savannas, typical caatinga and typical cerrado vegetation (https://doi.org/10.6084/m9.figshare.12755876, Tab. S2 in supplementary material). We only selected from the literature studies that included both woody (trees and shrubs) and non-woody (herbs and subshrubs) plant species. We then performed grouping (UPGMA - unweighted arithmetic average) analyses using Bray-Curtis distance (Gotelli & Ellison 2011; Legendre & Legendre 2012) to compare the general floristic resemblance between sites.

We made the UPGMA analyses for the woody component and also for the non-woody component in order to evaluate whether each vegetation layer has or has not different floristic affinities (https://doi.org/10.6084/m9.figshare.12755876, Tab. S2 in supplementary material). Lianas were removed from the analyses, because it was not possible to differentiate between woody and non-woody climbers using the Flora do Brasil 2020 (2019) database. We also compared the flora of caatinga-savannas, caatinga and cerrado sites using Venn diagrams for the woody and non-woody components using Venny 2.1 (https://bioinfogp.cnb.csic.es/tools/venny/).

Results

We recorded 246 species in the four sites, comprised of 162 genera and 55 families (Tab. 2, Fig. 3). The family Fabaceae (49 spp.), Rubiaceae (19 spp.), Convolvulaceae (17 spp.), Poaceae (11 spp.), Cyperaceae (10 spp.), Asteraceae (9 spp.), Lamiaceae (9 spp.) and Malvaceae (8 spp.) were the richest families, and represented 53.4 % of the flora. The genera *Ipomoea* and *Mimosa*, each with seven species, stood out as the most diverse, followed by *Borreria*, with six species and *Chamaecrista* and *Combretum* with five species each. Within the general flora, we found *Borreria* sp. nov., a new species yet to be described and 76 species endemic to Brazil, of which six are recorded only for Northeastern Brazil: *Stilpnopappus cearensis*, *Croton anisodontus*, *Mimosa ulbrichiana*, *Schultesia angustifolia*, *Hexasepalum gardneri* (and *Mitracarpus fernandesii* (BFG 2018).

Only six species were recorded in all four study areas: *Combretum laxum*, *Ipomoea eriocalyx*, *Cyperus schomburgkianus*, *Curatella americana*, *Bauhinia ungulata* and *Qualea parviflora*. In contrast with the small number of species occurring in the four areas, 158 species were collected only in one locality, 53 exclusive to S1, 52 in S2, 20 in S3 and 33 in S4.

The non-woody component represented 56.9 % of the total flora, with 113 herbaceous species and 27 subshrubby species (Fig. 4). The woody component, with trees and shrubs, is constituted by 82 species. The shrubs vary between 1-6 m in height and mostly belong to the Fabaceae (6 spp.), Combretaceae (5 spp.) and Rubiaceae (5 spp.), while the trees, ranging in size from 2-12 m height, belong to the Fabaceae (15 spp.), Ochnaceae (4 spp.) and *Vochysia*ceae (4 spp.). Significant numbers of vines were recorded in our sites, 24 species in total, mainly Bignoniaceae (9 spp.) and Convolvulaceae (7 spp.).

Analysing the composition of the vegetation of each area separately, we observed the high richness of herbaceous species in the open habitats S1, S2, and S3, where herbs and subshrubs represent the majority of the flora (Fig. 4). Only in S4 it is possible to observe a similar number of herbaceous and tree species, 33 and 38 species, respectively, because this site has more closed vegetation. The climbers are divided between woody (9 spp.) and herbaceous climbers (15 spp.) and were recorded in higher numbers in S3.

The UPGMA analyses of separate life-forms has demonstrated that the flora of the savannas in the Caatinga is more closely related to the Caatinga biome than to the Cerrado biome. The grouping analysis of the woody component showed that all these caatinga-savannas formed a group, and that this group was closer to the caatinga vegetation than to the cerrado vegetation. An exception was the caatinga-savanna of the Chapada do Araripe, where the woody flora shares more species with the Cerrado (Fig. 5). The non-woody species displayed a similar pattern, with the caatinga-savannas being closer to the caatinga vegetation than to the cerrado vegetation, despite sharing some species with the cerrado (Fig. 6).

The Venn diagram shows that the savannas in the Caatinga have more species in common with the caatinga vegetation than with the cerrado (Fig. 7). In the database used here the caatinga-savannas shared 39 woody species with the cerrado vegetation, while 60 species are exclusive to these areas and 38 are shared with the caatinga vegetation (either on crystalline or sedimentary substrates) (Fig. 7A). In the Venn diagram for non-woody species, only 13 species from the caatinga-savannas are shared with the cerrado, while 22 species are shared with the caatinga and 90 are exclusive from the latter (Fig. 7B).

In order to document the structure of these sites, we recorded the Raunkier life-forms and observed that the therophytes, plants survive the drought in the form of seeds (Martins & Batalha 2011), represent the majority of the local flora (42.2 %), with 104 species (Fig. 8). The phanerophytes, species with buds exposed over 50 cm above the ground (Martins & Batalha 2011), represented the second largest group of species: 72 in total (29.3 %). Hemicryptophytes, plants that protect their buds at ground level, had 36 records totalling 14.6 %. A total of 25 species was classified as chamaephytes, individuals with buds that are protected between 50 cm and just above ground level (Martins & Batalha 2011), representing 10.2 % of the total.

Table 2. Lists the species recorded in the caatinga savannas in the Caatinga of Northern Ceará. Th – Therophytes, Cr – Cryptophytes, He – Hemicryptophytes, Ch – Chamaephytes, Ph – Phanerophytes, PN - Popular Name, END – Endemism, BR – Endemic from Brazil, NE – Endemic from Northeastern Brazil, S1, S2 and S3 - Areas situated in the municipality of Granja - CE, S4 - Area situated in the municipality of the Martinópole - CE. Collectors: EBS – Elnatan Bezerra de Souza, FAAN – Francisco Álvaro Almeida Nepomuceno, IVN – Izaíra Vasconcelos Nepomuceno.

Family	Species	Habit	Life-forms	PN	End	Occurrence				Voucher
						S1	S2	S3	S4	
Acanthaceae	*Elytraria imbricata* (Vahl.) Pers.	Herb	Th	-	-				X	EBS 5819
	Ruellia paniculata L.	Shrub	Th	melosa-roxa	-			X	X	EBS 5799, 4728
Amaranthaceae	*Gomphrena gardneri* Moq.	Herb	He	-	BR				X	EBS 5144
Amaryllidaceae	*Habranthus sylvaticus* Herb.	Herb	Cr	cebola-de-calango	BR	X				EBS 3754
Anacardiaceae	*Anacardium occidentale* L.	Tree	Ph	cajú	-		X	X		EBS 3159, 5790
	Astronium fraxinifolium Schott.	Tree	Ph	-	-				X	EBS 5818
Annonaceae	*Ephedranthus pisocarpus* R.E.Fr.	Tree	Ph	conduru	BR				X	EBS 4715
Apocynaceae	*Allamanda blanchetii* A.DC.	Tree	Ch	alamanda-roxa	BR	X				EBS 5044
	Aspidosperma multiflorum A.DC.	Tree	Ph	-	BR		X			EBS 5439
	Himatanthus drasticus (Mart.) Plumel.	Tree	Ph	janaguba	BR				X	EBS 3741
	Mandevilla tenuifolia (J.C. Mikan) Woodson	Subshrub	Th	jalapa-do-campo	-		X			EBS 3400
	Tabernaemontana catharinensis A.DC.	Tree	Ph	leiteiro	-		X			EBS 4471
Araceae	*Philodendron acutatum* Schott.	Herb	Ep	imbis	-		X			EBS 5758
	Taccarum ulei Engl. & K. Krause	Herb	Th	milho-de-cobra	BR				X	EBS 5163
Arecaceae	*Bactris major* Jacq.	Tree	Ph	tucum	-		X			EBS 5761
	Copernicia prunifera (Mill.) H.E.Moore	Tree	Ph	carnaúba	BR	X			X	IVN 99, EBS 5839
Asteraceae	*Aspilia bonplandiana* (Gardner) S.F.Blake	Herb	Th	margarida	BR		X	X		EBS 5752, 3621
	Bidens pilosa L.	Herb	Th	picão-preto	-		X			EBS 3398
	Elephantopus hirtiflorus DC.	Herb	He	língua-de-vaca	BR	X	X	X		EBS 3588, 5753, 3622
	Lepidaploa sp.	Herb	Th	-			X			EBS 4145
	Pectis brevipendunculata (Gardner) Sch.Bip.	Herb	Th	chá-de-moça	BR		X			EBS 3379
	Praxelis diffusa (Rich.) Pruski	Herb	Th	cambará	-		X			EBS 4103
	Stilpnopappus cearensis Huber	Herb	Th	-	NE	X				EBS 3605
	Stilpnopappus pratensis Mart. ex DC.	Herb	Th	-	BR	X		X	X	EBS 3485, 3487, 4730
	Stilpnopappus trichospiroides Mart. ex. DC.	Herb	Th	-	BR			X		EBS 3629
Bignoniaceae	*Adenocalymma subsessilifolium* DC.	Shrub	Ph	-	BR			X		EBS 3628
	Adenocalymma validum L.G. Lohmann	Climber	Ph	-	-				X	EBS 4713
	Fridericia dispar (Bureau ex K.Schum) L.G. Lohmann	Shrub	Ch	cipó-de-boi	BR		X			EBS 4126
	Fridericia limae (A.H. Gentry) L.G.Lohmann	Climber	Ch	cipó-de-bola	NE		X	X	X	EBS 5742, 5769, 5828
	Fridericia platyphylla (Cham.) L.G.Lohmann	Climber	Ch	cipó-una	-		X			EBS 3382
	Fridericia subverticillata (Bureau & K. Schum.) L.G. Lohmann	Climber	Ch	-	BR				X	EBS 4714
	Fridericia triplinervia (Mart. ex. DC.) L.G.Lohmann	Climber	Ch	-	-			X		EBS 3643
	Neojobertia candolleana (Mart. ex. DC.) Bureau & K. Schum.	Climber	Ph	-	BR			X		EBS 3635
Bixaceae	*Cochlospermum vitifolium* (Willd) Spreng	Tree	Ph	pacotê	-		X		X	FAAN 43, EBS 5809
Boraginaceae	*Cordia rufescens* A.DC.	Shrub	Ph	grão-de-galo	-	X				EBS 4926
Bromeliaceae	*Bromelia laciniosa* Mart. ex Schult. f.	Herb	He	macambira	BR		X			EBS 5762
	Encholirium spectabile Mart. ex Schult. & Schult.f.	Herb	He	macambira-de-flecha	BR		X			EBS 3158

Table 2. Cont.

Family	Species	Habit	Life-forms	PN	End	Occurrence				Voucher
						S1	S2	S3	S4	
Cactaceae	*Cereus jamacaru* DC.	Tree	Ph	mandacaru	BR				X	EBS 5840
	Pilosocereus catingicola (Gürke) Byles & Rowley	Shrub	Ph	facheiro	BR				X	EBS 5841
	Xiquexique gounellei (F.A.C.Weber) Lavor & Calvente	Shrub	Ph	xique-xique	BR		X			EBS 5720
Chrysobalanaceae	*Hirtella ciliata* Mart. & Zucc	Tree	Ph	-	-	X			X	EBS 3164, 5836
Combretaceae	*Buchenavia tetraphylla* (Aubl.) R.A.Howard	Tree	Ph	periquiteira	-		X			EBS 4158
	Combretum glaucocarpum Mart.	Shrub	Ph	sipaúba, vaqueta	-		X			EBS 3385
	Combretum hilarianum D. Dietr.	Shrub	Ph	imbiridiba	-	X				EBS 3464
	Combretum laxum Jacq.	Shrub	Ph	cipó-de-bugio	-	X	X	X	X	EBS 4184, 5440, 5768, 4725
	Combretum leprosum Mart.	Shrub	Ph	mufumbo	-		X		X	EBS 4147, 5821
	Combretum mellifluum Eichler	Shrub	Ph	sipaúba	-		X			FAAN 37
Convolvulaceae	*Cuscuta racemosa* Mart.	Herb	He	cipó-chumbo	-	X		X		EBS 5222, 3466
	Distimake cissoides (Lam.) A.R. Simões & Staples	Climber	Th	-	-			X		EBS 3632
	Evolvulus ericifolius Mart. ex. Schrank.	Herb	Th	-	BR	X		X		EBS 5051, 3748
	Evolvulus glomeratus Ness. & Mart.	Subshrub	Th	azulzinha	-	X				EBS 5052
	Evolvulus gypsophiloides Moric.	Herb	Th	-	BR	X				EBS 4186
	Evolvulus ovatus Fernauld	Herb	Th	azulzinha	-	X	X	X		EBS 5684, 4112, 3499
	Ipomoea asarifolia (Ders.) Roem. & Schult.	Climber	Th	salsa	-			X	X	EBS 3496, 5810
	Ipomoea bahiensis Willd ex. Roem. & Schult.	Climber	Th	jetirana	BR		X			EBS 4107
	Ipomoea bignonioides Sims	Climber	Th	-	-				X	EBS 5164
	Ipomoea calyptrata Dammer	Climber	Th	-	BR			X	X	EBS 5058, 5162
	Ipomoea eriocalyx (Mart. ex. Choisy) Meisn.	Climber	Th	-	BR	X	X	X	X	EBS 5246, 4138, 3618, 5812
	Ipomoea piurensis O'Donell	Climber	Th	-	-			X		EBS 3497
	Ipomoea subincana (Choisy) Meisn.	Climber	Ph	-	BR	X		X		EBS 3423, 3620
	Jacquemontia gracillima Choisy	Herb	Th	jetirana	BR	X	X			EBS 3471, 4162
	Jacquemontia gracilis Choisy	Herb	Th	-	BR	X				EBS 3579
	Jacquemontia tamnifolia (L.) Griseb.	Herb	Th	-	-		X			EBS 4106
	Operculina hamiltonii (G. Don.) D.F.Austin & Stalpes	Climber	Cr	batatão	-			X		EBS 3498
Cyperaceae	*Bulbostylis capillaris* (L.) C.B. Clarke	Herb	He	-	-				X	EBS 5155
	Bulbostylis conifera (Kunth) C.B. Clarke	Herb	He	-	-	X				EBS 4930
	Bulbostylis junciformis (Kunth) C.B. Clarke	Herb	He	-	-	X				EBS 5041
	Cyperus amabilis Vahl.	Herb	Th	-	-				X	EBS 5134
	Cyperus sesquiflorus (Torr.) Mattf. & Kük.	Herb	He	junquinho	-				X	EBS 5137
	Cyperus schomburgkianus Ness.	Herb	He	tiririca	-	X	X	X	X	EBS 3477, 5348, 3492, 5145
	Fimbristylis dichotoma (L.) Vahl	Herb	He	-	BR	X			X	EBS 5239, 5169

Table 2. Cont.

Family	Species	Habit	Life-forms	PN	End	Occurrence				Voucher
						S1	S2	S3	S4	
Cyperaceae	*Rhynchospora holoschoenoides* (Rich.) Herter	Herb	He	-	-	X				EBS 3476
	Rhynchospora nervosa (Vahl) Boeckeler	Herb	Cr	capim-estrela	BR	X				EBS 4916
	Scleria hirtella Sw.	Herb	Cr	-	-	X				EBS 5248
Dilleniaceae	*Curatella americana* L.	Tree	Ph	lixeira	-	X	X	X	X	IVN 100, EBS 5434, 5770, 4718
	Davilla cearensis L.	Climber	Ch	-	BR		X			EBS 3160
Droseraceae	*Drosera sessilifolia* A.St.-Hil.	Herb	Th	-	-		X			EBS 5355
Eriocaulaceae	*Paepalanthus lamarckii* Kunth.	Herb	Th	-	-		X			EBS 4141
	Paepalanthus cf. tortilis (Bong.) Mart.	Herb	Th	-	BR		X			EBS 5345
Erythroxylaceae	*Erythroxylum laetevirens* O.E. Schulz.	Shrub	Ch	-	BR			X		EBS 5061
Euphorbiaceae	*Croton anisodontus* Müll.Arg.	Shrub	Ch	-	NE	X	X	X		EBS 5047, 4464, 5795
	Croton glandulosus L.	Herb	Th	carvão-branco	-				X	EBS 5156
	Dalechampia scandens L.	Climber	Th	-	-			X		EBS 3640
	Euphorbia bahiensis (Klotzsch & Garke) Boiss.	Herb	Th	-	-		X			EBS 3394
	Microstachys corniculata (Vahl.) Griseb.	Herb	Th	-	-	X				EBS 4483
	Microstachys hispida (Mart. & Zucc.) Govaerts	Herb	Th	-	-	X				EBS 3417
Fabaceae	*Aeschynomene benthamii* (Rudd.) Afr.Fern.	Subshurb	Th	-	BR	X				EBS 3592
	Aeschynomene filosa Mart.	Subshurb	He	-	-	X				EBS 5243
	Aeschynomene histryx Poir.	Herb	Th	-	-	X	X	X		EBS 3457, 3374, 3615
	Aeschynomene mollicula Kunth.	Subshurb	Th	-	-	X				EBS 5242
	Amburana cearensis (Allemão) A.C. Sm.	Tree	Ph	cumaru	-		X			EBS 5354
	Andira cordata Arroyo ex R.T. Penn. & H.C. Lima	Tree	Ph	-	BR				X	EBS 5830
	Arachis dardani Kaprov. & W.C. Greg.	Herb	Th	amendoim-de-carcará	BR	X				EBS 3375
	Arachis pusilla Benth.	Herb	Th	-	BR		X			EBS 4458
	Bauhinia acuruana Moric.	Shrub	Ch	-	BR		X			EBS 5357
	Bauhinia cheilantha (Bong.) Steud.	Shrub	Ch	-	-		X			EBS 5366
	Bauhinia ungulata L.	Shrub	Ph	pata-de-vaca	-	X	X	X	X	EBS 3155, 5743, 5775, 4721
	Bowdichia virgilioides Kunth.	Tree	Ph	sucupira	-	X				EBS 3152
	Calopogonium mucunoides Desv.	Climber	Th	-		X				EBS 5321
	Centrosema brasilianum (L.) Benth.	Climber	Th	centrosema	-	X	X			EBS 3601, 5749
	Centrosema pascuorum Mart. ex. Benth.	Climber	Th	centrosema, jetirana	-	X		X		EBS 5335, 3490
	Chamaecrista diphylla (L.) Greene	Herb	Th	-	-	X				EBS 3369
	Chamaecrista flexuosa (L.) Greene	Subshrub	He	-	-	X	X	X		EBS 5228, 3373, 5801
	Chamaecrista linearis (H.S. Irwin & Barneby) Afr.Fern. & E.P. Nunes	Subshrub	Te	-	-	X				EBS 5319

Table 2. Cont.

Family	Species	Habit	Life-forms	PN	End	Occurrence				Voucher
						S1	S2	S3	S4	
Fabaceae	*Chamaecrista rotundifolia* (Pers.) Greene	Herb	Th	-	-	X	X			EBS 5240, 4457
	Chamaecrista supplex (Benth.) Britton & Ross ex Britton & Killip.	Herb	Th	-	-		X			EBS 4117
	Chloroleucon foliolosum (Benth.) G.P.Lewis	Tree	Ph	arapiraca	-		X			EBS 5721
	Copaifera martii Hayne	Tree	Ph	pau-d'óleo	-				X	EBS 5820
	Dalbergia cearensis Ducke.	Shrub	Ph	jacarandá-violeta	BR				X	EBS 5148
	Dimorphandra mollis Benth.	Tree	Ph	fava-danta	-			X		EBS 5779
	Galactia jussiaeana Kunth	Subshrub	He	-	-	X	X	X		EBS 4488, 4462, 3624
	Hymenaea stigonocarpa Mart. ex Hayne	Tree	Ph	jatobá-do-cerrado	-				X	EBS 5714
	Machaerium acutifolium Vogel.	Tree	Ph	jacarandá-do-campo	-				X	EBS 5817
	Macroptilium lathyroides (L.) Urb.	Climber	Ch	feijão-de-rola	-	X				EBS 5241
	Mimosa camporum Benth.	Subshurb	Th	-	-	X				EBS 4487
	Mimosa hirsutissima Mart.	Subshurb	Th	-	-	X			X	EBS 5229, 5153
	Mimosa misera Benth.	Subshurb	Th	-	BR	X				EBS 3467
	Mimosa modesta Mart.	Subshurb	Ch	-	BR	X				EBS 3450
	Mimosa pigra L.	Subshurb	Th	calumbi-d'água	-				X	EBS 5158
	Mimosa somnians Humb. & Bonpl. ex. Willd.	Subshurb	Ch	malícia	-	X				EBS 4484
	Mimosa ulbrichiana Harms	Subshurb	Th	-	NE	X		X		EBS 3463, 3489
	Peltogyne confertiflora (Mart. ex Hayne) Benth.	Tree	Ph	jatobá-de-brinco	-		X			EBS 5437
	Piptadenia stipulacea (Benth.) Ducke	Tree	Ph	jurema-branca	BR		X			EBS 5347
	Pityrocarpa moniliformis (Benth) Luckow & R.W.Jobson	Tree	Ph	angico-de-bezerro	BR	X	X	X		EBS 4914, 4467, 5763
	Plathymenia reticulata Benth.	Tree	Ph	candeia	-	X			X	EBS 5236, 5827
	Senna alata (L.) Roxb.	Shrub	Ch	fedegoso-gigante, mat-apastão	-		X			EBS 5721
	Senna gardneri (Benth.) H.S.Irwin & Barneby	Subshrub	Ch	-	-	X				EBS 3608
	Senna splendida (Vogel) H.S.Irwin & Barneby	Shrub	Ch	-	-			X		EBS 5787
	Senna trachypus (Benth.) H.S.Irwin & Barneby	Shrub	Ch	besouro	BR	X	X	X		EBS 5245, 4120, 3634
	Stryphnodendron coriaceum Benth.	Tree	Ph	barbatimão-do-cerrado	BR				X	EBS 5824
	Stylosanthes angustifolia Vogel	Herb	Th	-	-	X	X			EBS 3448, 4120
	Stylosanthes scabra Vogel	Herb	Th	-	-			X		EBS 3627
	Tephrosia purpurea (L.) Pers.	Herb	He	-	-			X		EBS 3500
	Vatairea sericea (Ducke) Ducke	Tree	Ph	angelim-amargoso	-				X	EBS 5815
	Zornia reticulata Sm.	Herb	He	-	-	X				EBS 4922
Gentianaceae	*Chelonanthus purpurascens* (Aubl.) Struwe, S.Nilsson & V.A.Albert	Herb	Th	-	-	X				EBS 4181
	Schultesia angustifolia Griseb	Herb	Th	-	NE	X				EBS 5225
	Schultesia guianensis (Aubl.) Malme	Herb	Th	mata-zombando	-	X				EBS 5223

Table 2. Cont.

Family	Species	Habit	Life-forms	PN	End	Occurrence				Voucher
						S1	S2	S3	S4	
Iridaceae	*Cipura paludosa* Aubl.	Herb	Cr	alho-do-mato	-	X				EBS 5033
	Trimezia martinicensis (Jacq.) Herb.	Herb	Cr	íris-amarela	-	X			X	EBS 5034, 5131
Krameriaceae	*Krameria tomentosa* A.St.-Hill.	Subshrub	Ch	carrapicho-de-cavalo	-	X	X		X	EBS 5036, 4463 5146
Lamiaceae	*Amasonia campestris* (Aubl.) Moldenke	Subshurb	Ch	flor-de-urubu	-	X			X	EBS 4485, 5143
	Cyanocephalus rugosus (Benth.) Harley & J.F.B.Pastore	Subshrub	Ch	-	-	X				EBS 4177
	Eriope macrostachya Mart. ex. Benth.	Herb	He	-	-			X		EBS 3633
	Hypenia salzmannii (Benth.) Harley	Subshrub	He	canela-de-urubu	-	X				EBS 5336
	Hyptis atrorubens Poit.	Subshrub	He	mentinha	-	X	X		X	EBS 5331, 5757, 5833
	Hyptis lanceolata Poir.	Subshrub	He	-	-	X				EBS 5233
	Marsypianthes montana Benth.	Herb	He	alfavaca-de-cheiro	BR	X	X		X	EBS 3475, 4459, 5140
	Rhaphiodon echinus Schauer	Herb	Th	betônica, falsa-menta	BR	X	X	X		EBS 3447, 4176, 3638
	Vitex polygama Cham.	Tree	Ph	tarumã	BR				X	EBS 5838
Lythraceae	*Ammannia auriculata* Willd.	Herb	Th	-	-	X				EBS 5317
	Cuphea campestris Koehne	Herb	Th	-	-	X	X		X	EBS 4475, 3406, 5138
	Cuphea impatientifolia A.St.-Hill	Herb	Th	-	BR	X			X	EBS 4477, 5154
Malpighiaceae	*Byrsonima coccolobifolia* Kunth.	Subshrub	Ph	murici-rosa	-		X	X		EBS 5744, 5805
	Byrsonima crassifolia (L.) Kunth.	Tree	Ph	murici-da-praia	-	X		X	X	EBS 4929, 3750, 5268
	Janusia sp.	Shrub	Ph	-			X			EBS 4128
	Peixotoa sp.	Climber	Ch	-			X			EBS 4146
	Stigmaphyllon paralias A.Juss.	Shrub	Ph	-	BR		X	X		EBS 5358, 5063
Malvaceae	*Helicteres heptandra* L.B.Sm.	Shrub	Ch	saca-rolha	-	X				EBS 5318
	Pavonia cancellata (L.) Cav.	Herb	He	-	-			X	X	EBS 3639, 5808
	Sida ciliaris L.	Herb	Th	-	-	X	X	X		EBS 3442, 4156, 3495
	Sida cordifolia L.	Subshrub	Th	-	-	X	X			EBS 4169, 4123
	Sida linifolia Cav.	Subshurb	Th	-	-			X	X	EBS 5796, 5834
	Sterculia striata A.St.-Hill & Naudin	Tree	Th	chichá	BR		X			EBS 3156
	Waltheria indica L.	Subshrub	He	douradinha	-	X	X	X		EBS 3611, FAAN 40, EBS 3641
	Waltheria operculata Rose	Herb	Th	-	-	X	X	X		EBS 3472, 3381, 3493
Melastomataceae	*Comolia villosa* (Aubl.) Triana	Herb	He	-	-		X			EBS 4461
	Pterolepis perpusilla (Naudin) Cogn.	Herb	Th	-	BR	X	X			EBS 5322,5751
Myrtaceae	*Campomanesia aromatica* (Aubl.) Griseb	Shrub	Ph	guabiraba	-			X		EBS 5057
	Campomanesia dichotoma (O. Berg.) Mattos	Shrub	Ph	guabiraba	BR	X				EBS 4918
	Myrcia guianensis (Aubl.) DC.	Shrub	Ph	araçazinho	-	X			X	EBS 3755, 4726
	Myrcia splendens (Sw.) DC.	Shrub	Ph	guamirim-miúdo	BR		X	X	X	EBS 5435, 5804, 5829
Moraceae	*Ficus* sp.	Tree	Ph	-			X			EBS 4470

Table 2. Cont.

Family	Species	Habit	Life-forms	PN	End	Occurrence				Voucher
						S1	S2	S3	S4	
Ochnaceae	*Ouratea castaneifolia* (DC.) Engl.	Tree	Ph	farinha-seca	-				X	IVN 89
	Ouratea cuspidata (A. St.-Hil.) Engl	Tree	Ph	-	BR				X	IVN 77
	Ouratea fieldingiana (Garnder) Engl.	Tree	Ph	batiputá	-				X	IVN 81
	Ouratea glaucescens (A.St.-Hil.) Engl.	Tree	Ph	flor-de-ouro	BR			X	X	EBS 3749, 3735
Olacaceae	*Ximenia americana* L.	Tree	Ph	ameixa	-		X	X	X	EBS 5729, 5786, 3740
Orchidaceae	*Habernaria* sp.	Herb	Th	-				X		EBS 5054
	Trichocentrum cepula (Hoffmanns.) J.M.H.Shaw	Herb	Ep	dama-dançante	-		X			EBS 5759
Orobanchaceae	*Agalinis hispidula* (Mart.) D'Arcy	Herb	Th	-	-	X	X			EBS 5329, 4132
	Buchnera rosea Kunth	Herb	Th	-	-	X		X		EBS 5325, 3491
Oxalidaceae	*Oxalis divaricata* Mart. ex Zucc.	Herb	Th	azedinha	BR		X			EBS 4104
	Oxalis psoraleoides Kunth	Herb	Th	trevo	-	X	X			EBS 3670, 4460
Passifloraceae	*Passiflora foetida* L.	Climber	Th	maracujá-de-cheiro	-	X				EBS 4923
Phytolacaceae	*Microtea paniculata* Moq.	Herb	Th	-	-		X			EBS 3392
Plantaginaceae	*Bacopa angulata* (Benth.) Edwall	Herb	Th	-	BR	X	X			EBS 5237, 5360
	Bacopa sessiliflora (Benth.) Edwall	Herb	Th	-	-		X			EBS 5748
	Tetraulacium veroniciforme Turcz.	Herb	Th	-	BR	X	X			EBS 3441, 5756
Poaceae	*Andropogon angustatus* (J. Presl). Steud	Herb	He	-	-		X			EBS 4122
	Aristida longifolia Trin.	Herb	He	-	-	X				EBS 5320
	Axonopus marginatus (Trin.) Chase	Herb	He	capim-mimoso	-				X	EBS 5157
	Isachne sp.	Herb	Th	-			X			EBS 4152
	Mesosetum annuum Swallen	Herb	Th	-	-	X			X	EBS 5038, 5152
	Paspalum maculosum Trin.	Herb	He	canafístula	-	X				EBS 5037
	Paspalum sp.1	Herb	Th	-					X	EBS 5135
	Paspalum sp.2	Herb	Th	-					X	EBS 5147
	Paspalum sp.3	Herb	Th	-					X	EBS 5150
	Streptostachys asperifolia Desv.	Herb	Th	-	-			X	X	EBS 5055, 5159
	Trachypogon spicatus (L. f.) Kuntze	Herb	He	-	-	X				EBS 5050
Polygalaceae	*Asemeia* cf. *monticola* (Kunth.) J.F.B. Pastore & J.R. Abbott.	Herb	Th	-	-			X		EBS 5060
	Bredemeyera floribunda Willd.	Tree	Th	botica-inteira	-				X	EBS 4723
	Polygala boliviensis A.W.Benn.	Herb	Th	-	-	X	X			EBS 3488, 3363
	Polygala glochidata Kunth	Herb	Th	-	BR	X				EBS 3407
	Polygala longicaulis Kunth	Herb	Th	-	BR	X				EBS 5049
	Polygala trichosperma Jacq.	Herb	Th	-	-		X		X	EBS 4115, 5167
Rhamnaceae	*Gouania colurnifolia* Reissek	Climber	Ph	-	-		X			EBS 5350
Rubiaceae	*Borreria latifolia* (Aubl.) K.Schum.	Herb	Th	-	-		X			EBS 4153
	Borreria scabiosoides Cham. & Schltdl.	Herb	He	-	-	X				EBS 5343
	Borreria spinosa Cham. et Schltdl.	Herb	He	vassourinha-de-botão	-	X		X		EBS -, 3503

Table 2. Cont.

Family	Species	Habit	Life-forms	PN	End	Occurrence				Voucher
						S1	S2	S3	S4	
Rubiaceae	*Borreria verticillata* (L.) G. Mey.	Subshrub	He	falsa-poaia	-	X			X	EBS 4479, 4724
	Borreria tenella (Kunth) Cham. & Schltdl.	Herb	Th	-	-		X	X		EBS 4150, 3612
	Borreria sp.nov.	Subshurb	He	-	-	X				EBS 5341
	Cordiera myrciifolia (K. Schum.) C. Press. & Deplrete	Shrub	Ph	-	-				X	EBS 3737
	Cordiera rigida (K. Schum.) Kuntze	Shrub	Ph	-	BR				X	EBS 3733
	Guettarda viburnoides Cham. & Schlltdl.	Shrub	Ph	angislica	-			X	X	EBS 5783, 5161
	Hexasepalum apiculatum (Willd.) Delprete & J.H. Kirkbr.	Herb	Th	-	-	X		X		EBS 3478, 3614
	Hexasepalum gardneri (K. Schum.) J.H. Kirkbr.	Subshrub	Th	-	NE		X	X	X	EBS 4119, 3619, 4720
	Hexasepalum teres (Walter) J.H. Kikbr.	Herb	Th	-	-		X			EBS 4143
	Mitracarpus fernandesii E.L. Cabral, Sobrado & E.B. Souza	Herb	Th	-	NE	X	X	X		EBS 5323, 5356, 3646
	Oldenlandia filicaulis K.Schum.	Herb	Th	-	-		X			EBS 5351
	Richardia grandiflora (Cham & Schltdl.) Steud	Herb	Th	-	-		X			MCPT 14
	Richardia scabra L.	Herb	Th	-	-			X		EBS 3630
	Rosenbergiodendron longiflorum (Ruiz & Pav.) Fagerl.	Shrub	Ch	estrela-do-norte	-	X				EBS 5332
	Staelia virgata (Link ex. Roem. & Schult.) K.Schum.	Herb	Th	-	-	X	X	X		EBS 3598, 4116, 3623
	Tocoyena sellowiana (Cham. & Schltdl.) K.Schum.	Shrub	Th	jeniparana	BR		X		X	EBS 4468. 4719
Santalaceae	*Phoradendron* sp.	Herb	Th	erva-de-passarinho				X		EBS 3752
Simaroubaceae	*Homalolepis cedron* (Planch.) Devecchi & Pirani	Shrub	Ph	-	-			X		EBS 5789
	Simarouba versicolor A. St.-Hil.	Tree	Ph	mata-cachorro	-				X	EBS 5816
Solanaceae	*Brunfelsia uniflora* (Pohl.) D.Don.	Shrub	Ch	manacá-de-jardim	-			X		EBS 5056
	Schwenckia americana Rooyen ex L.	Herb	Th	-	-		X			EBS 5731
	Solanum crinitum L.	Shrub	Ph	-	-		X			EBS 5740
	Solanum paniculatum L.	Shrub	Ph	jurubeba	-		X			EBS 5734
Turneraceae	*Turnera coerulea* DC.	Herb	Th	-	-	X	X			EBS 5231, 4455
	Piriqueta sp.	Herb	Th	-		X				EBS 5235
Urticaceae	*Cecropia concolor* Willd.	Tree	Ph	embaúba	BR		X			EBS 5738
Verbenaceae	*Lantana camara* L.	Shrub	Ph	camará-chumbinho	-	X				EBS 4925
	Stachytarpheta cayennensis (Riech.) Vahl.	Herb	He	gervão-azul	-	X				EBS 3456
	Stachytarpheta coccinea Schauer	Herb	He	-	BR	X				EBS 3482
Violaceae	*Hybanthus albus* (A. St.-Hill) Baill	Herb	Th	-	BR	X				EBS 3410
	Pombalia calceolaria (L.) Paula-Souza	Herb	Th	ipeca-da-praia	-				X	EBS 5161
Vochysiaceae	*Callisthene minor* Mart.	Tree	Ph	pau-de-pilão	BR		X		X	EBS 5738, 5822
	Qualea grandiflora Mart.	Tree	Ph	pau-terra-de-folha-larga			X	X		EBS 5723, 5778
	Qualea parviflora Mart.	Tree	Ph	pau-terra	-	X	X	X	X	EBS 5417, 5438, 3751, 3738
	Salvertia convallariodora A.St.-Hill.	Tree	Ph	pau-de-colher	-	X			X	EBS 5415, 3746
Xyridaceae	*Xyris cf. paradisiaca* Wand	Herb	Cr	-	BR		X			EBS 5353

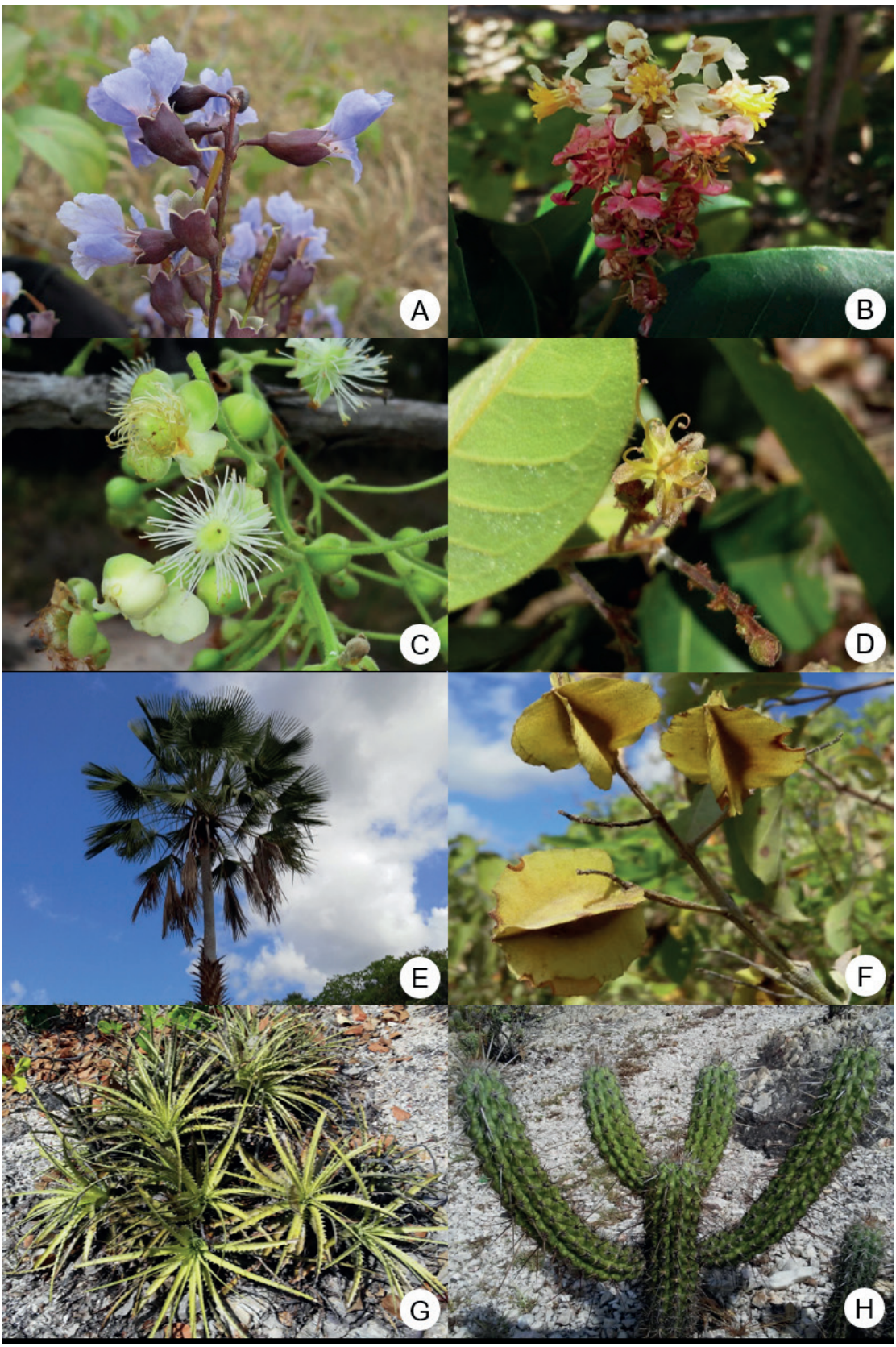

Figure 3. Some species collected in the caatinga savanna studied. **A-D**) Species in common with the Cerrado, **E-H**) Species in common with the Caatinga. **A**) Bowdichia virgilioides Kunth., **B**) *Byrsonima coccolobifolia* Kunth., **C**) *Curatella americana* L., **D**) *Hirtella ciliata* Mart. & Zucc, **E**) *Copernicia prunifera* (Mill.) H.E. Moore, **F**) *Combretum leprosum* Mart., **G**) *Encholirium spectabile* Mart. ex Schult. & Schult.f., **H**) *Xiquexique gounellei* (F.A.C. Weber) Lavor & Calvente. *Photographs:* ***A****) E.B. Souza,* ***B-H****) I.V. Nepomuceno.*

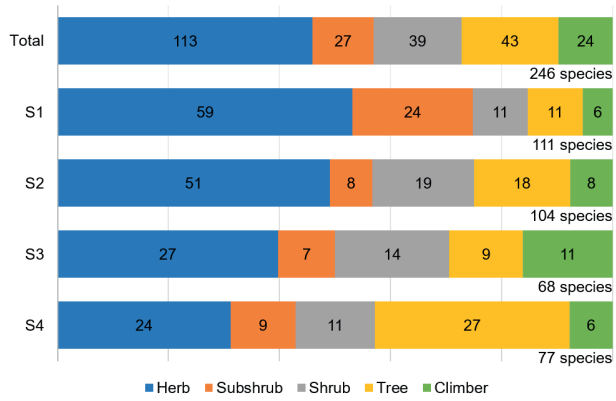

Figure 4. Spectrum of habit of the species recorded in each study area in Northern Ceará.

When we compared the Raunkiaer life-form spectra of our four sites with the spectra of other Brazilian biomes (Costa *et al.* 2016), we noted that these caatinga-savannas had spectra similar to the caatinga on crystalline substrates (Fig. 9), with a predominance of therophytes over other life-forms for most areas (Fig. 8). Therophytic species dominate in all areas, with the exception of S4, where we found a predominance of phanerophytes (39 spp.). Therophytes, phanerophytes, hemicryptophytes and chamaephytes are present in all the areas as the main life-forms, however other types are also found in smaller numbers. Cryptophytes, species that possess underground storage structures (Martins & Batalha 2011), were recorded in S1, S3 and S4. Only in S2 did we find epiphytic species, *Philodendron acutatum* and *Trichocentrum cepula* (Tab. 2).

For the NMS analyses performed with the Raunkiaer life-form spectra (Fig. 9) we observed that, while the standard biological specrum of Raunkiaer is dominated by the phanerophytes, the caatinga-savanna and the caatinga in crystalline terrains are both composed of a majority of therophytes. The cerrado areas had a predominance of hemicryptophytes, as previously reported by other studies (Batalha & Martins 2002; Martins & Batalha 2011).

Discussion

The species richness in typical cerrado areas is variable, with a relatively low alpha diversity (number of species) while, in a few cases, it is possible to encounter more than 100 woody species occurring in a determined area (Felfili *et al.* 1992; Ratter & Dargie 1992; Ratter *et al.* 2003). When considering the four study areas we found a significant number of 82 species in the woody component, even though with low alpha diversity per area, with 22 species in S1, 35 in S2, 23 in S3 and 38 in S4. These numbers are in accordance with the average species per area that Ratter *et al.* (2003) obtained with the compilation of data from 376 localities of Cerrado vegetation in Brazil.

The Vochysiaceae is probably one of the more characteristic families of cerrado vegetation (Goodland & Ferri 1979). Six genera of this family occur in Brazil, with *Callisthene* Mart., *Qualea* Aubl. and *Vochysia* Aubl. being strongly associated with the cerrado and occurring in the surrounding biomes, whilst *Salvertia* A.St.-Hil. is typical of cerrado vegetation (Goodland & Ferri 1979; BFG 2018), but although our sites are many kilometres distant from the core Cerrado domain, we recorded *Callisthene* minor, *Qualea grandiflora* and *Salvertia convallariodora* in our caatinga-savannas. *Qualea grandiflora*, *Q. parviflora* and *Salvertia convallariodora* are commonly cited as widely distributed species in the Cerrado domain (Goodland & Ferri 1979; Felfili *et al.* 1992; Ratter & Dargie 1992; Ratter *et al.* 2003; Castro *et al.* 2007). These same species are also recorded in the Amazonian savannas (Miranda *et al.* 2006; Magnusson *et al.* 2008). Other examples of very common species in typical cerrado sites that were recorded in the studied caatinga-savannas were *Bouwdichia virgilioides*, *Byrsonima coccolobifolia*, *Curatella americana* and *Hirtella ciliata* (Tab. 2, Fig. 3), but typical caatinga species like *Cereus jamacaru*, *Encholirium spectabile*, *Copernicia prunifera* and *Combretum leprosum* were also found in our sites, making them a mixture of floristic elements from both the Cerrado and Caatinga biomes (Moro *et al.* 2011).

The woody (shrubs + trees) component of our study sites is composed by many species common in cerrado vegetation of the core Cerrado biome. We recorded in our study sites *Astronium fraxinifolium*, *Bowdichia virgilioides*, *Byrsonima coccolobifolia*, *B. crassifolia*, *Curatella americana*, *Dimorphandra mollis*, *Hymenaea stigonocarpa*, *Machaerium acutifolium*, *Plathymenia reticulata*, *Qualea grandiflora*, *Q. parviflora* and *Salvertia convallariodora*, that are widely distributed in the core Cerrado areas, and compiled as common species by Ratter & Dargie (1992) and Ratter *et al.* (2003) and recorded in Souza *et al.*'s (2018) species list. Other species also common in the cerrado, such as *Anacardium occidentale*, *Copaifera martii*, *Hirtella ciliata* and *Ouratea castaneifolia*, were also recorded.

In the herbaceous layer we found the repeated occurrence of species that are commonly listed in Cerrado floras, such the Asteraceae *Elephantopus hirtiflorus*, the Cyperaceae *Bulbostylis junciforme*, *Rynchospora nervosa*, *Scleria hirtella*, the Fabaceae *Chamaecrista diphylla*, *C. flexuosa*, *Zornia reticulata* and the Poaceae *Aristida longifolia*, *Axonopus marginatus* and *Trachypogon spicatus* (Batalha *et al.* 1997; Mantovani & Martins 1993; Costa *et al.* 2004; Tannus & Assis 2004; Magnusson *et al.* 2008; Moro *et al.* 2011; Oliveira *et al.* 2012; Ribeiro-Silva *et al.* 2012; Souza *et al.* 2018). We also flag here the occurrence of species typical of the Cerrado as abundant in the areas studied, with *Trachypogon spicatus* being widely recorded in the floristic lists of Brazilian Cerrado (Mantovani & Martins 1993; Oliveira *et al.* 2012; Souza *et al.* 2018) and in Ceará (Costa *et al.* 2004; Moro *et al.* 2011; Ribeiro-Silva *et al.* 2012).

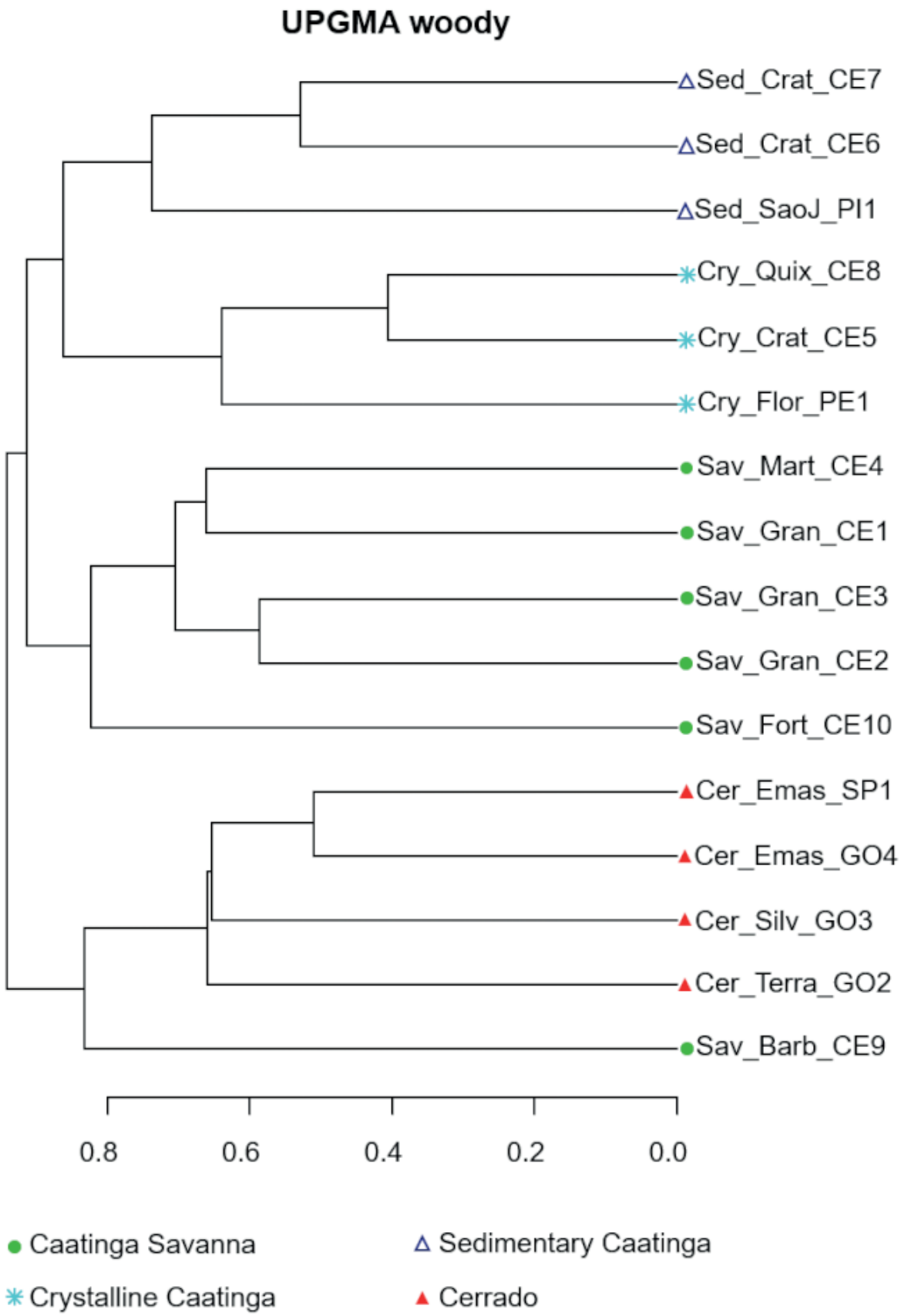

Figure 5. Dendrogram obtained in grouping analysis UPGMA with Bray-Curtis distance for woody component (cophenetic correlation coefficient = 0.910).

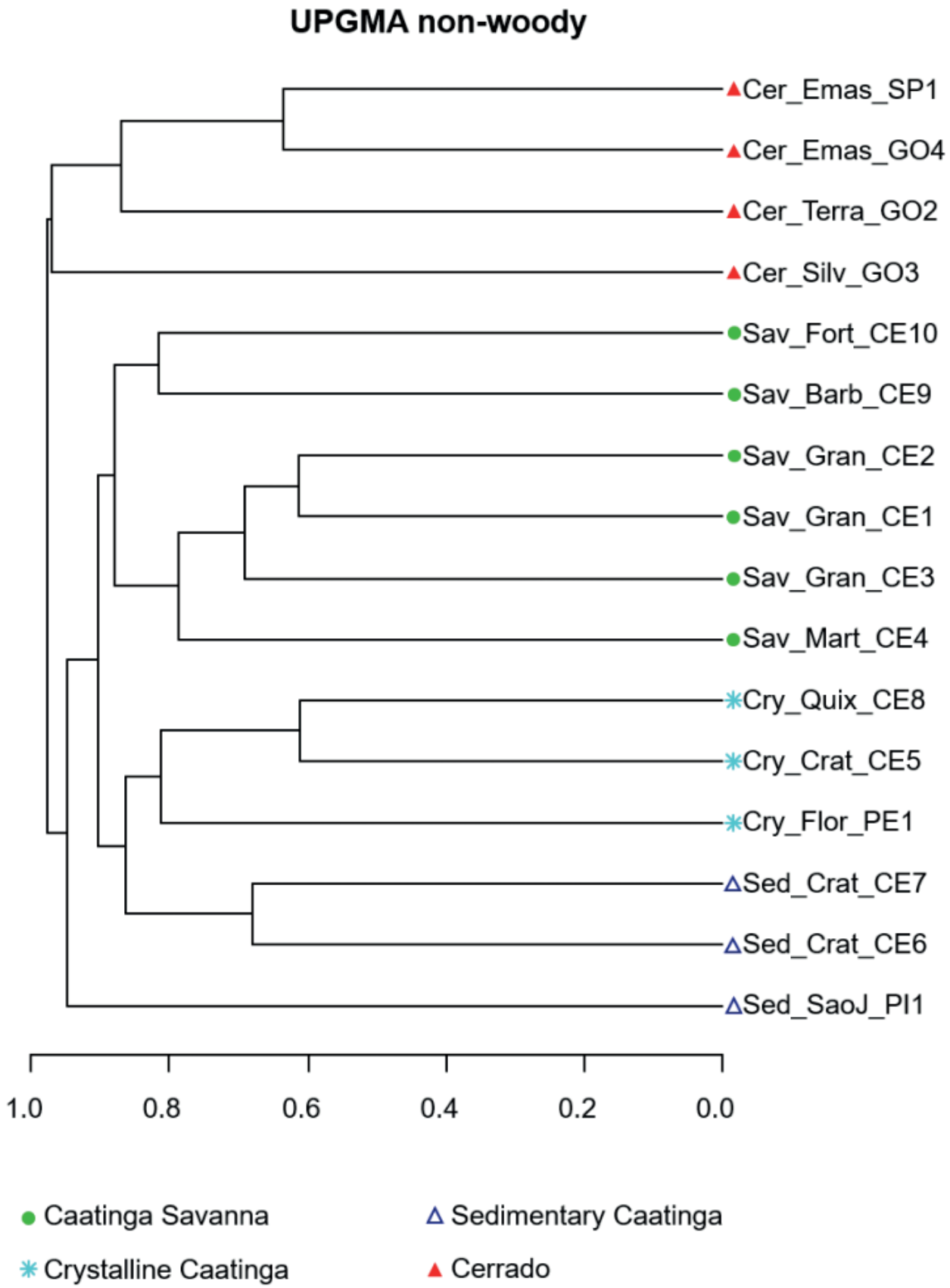

Figure 6. Dendrogram obtained in grouping analysis UPGMA with Bray-Curtis distance for non-woody component (cophenetic correlation coefficient = 0.920).

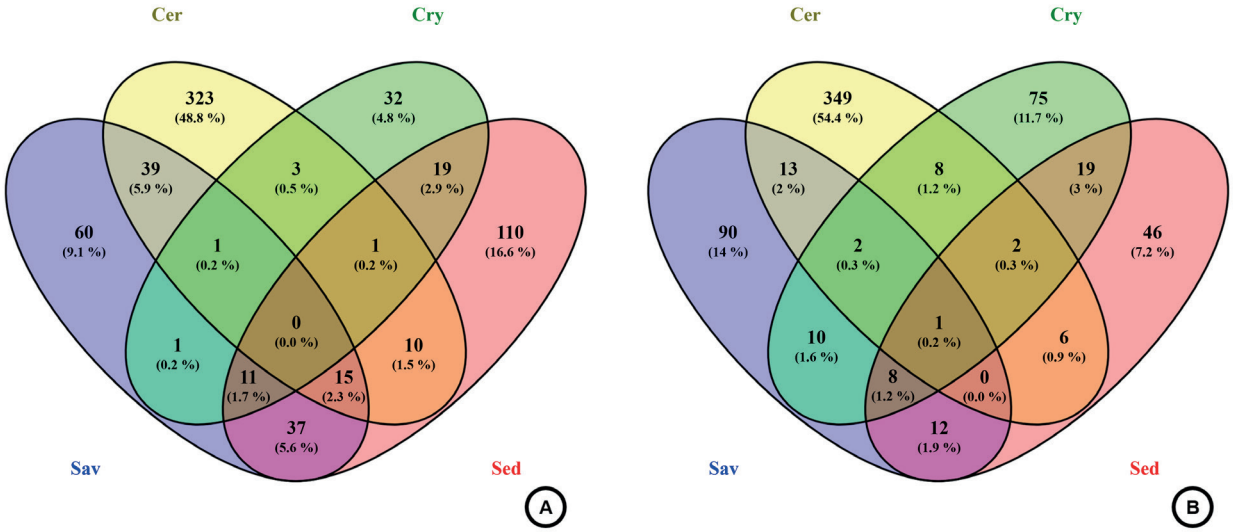

Figure 7. Veen diagrams showing the number species per area. **A)** Veen diagram for woody component. **B)** Venn diagram for non-woody component.

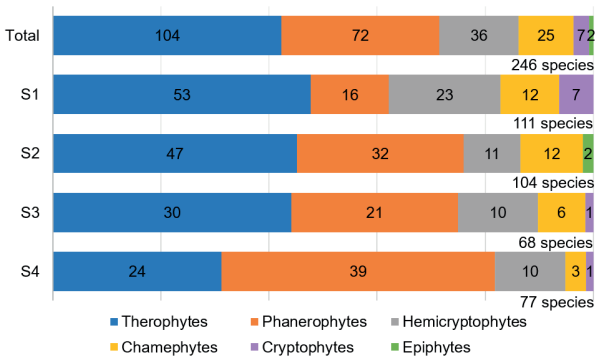

Figure 8. Spectrum of life-forms of the 246 species from the study area in Northern Ceará.

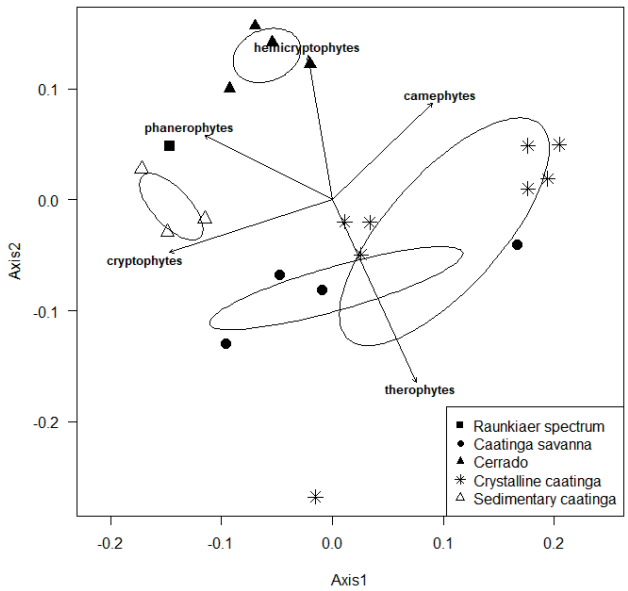

Figure 9. Non-metric multidimensional scaling (NMS) of caatinga-savannas, Caatinga and Cerrado (stress = 0.128).

In S1, the area with the highest richness of herbaceous plants, we observed trees and shrubs distributed sparsely in the environment with an herbaceous layer dominating the landscape (Fig. 2A). This configuration resembles the cerrado *s.s.* of central Brazil (Walter *et al.* 2015). In S2, we note a transition area between Caatinga and Cerrado, with shared species typical of both biomes, such as *Amburana cearensis*, *Combretum leprosum*, *Encholirium spectabile*, *Xiquexique gounellei* and *Ruellia paniculata*, common in the Caatinga (Araújo *et al.* 2011; Moro *et al.* 2014), and *Anacardium occidentale*, *Curatella americana*, *Byrsonima coccolobifolia*, *Qualea grandiflora* and *Q. parviflora* (Ratter & Dargie 1992; Ratter *et al.* 2003; Moro *et al.* 2011) common in the Cerrado (Fig. 2B). S3 presents a woody vegetation with trees reaching approximately 10 m in height, such as *Campomanesia aromatica*, *Curatella americana*, *Dimorphandra mollis*, *Qualea grandiflora* and *Q. parviflora*. In this sense it is similar to the cerradão, the forest facies of the Cerrado (Walter *et al.* 2015). However, in other stretches of the same study area, we found open areas with widely spaced trees and shrubs, such as *Anacardium occidentale*, *Byrsonima coccolobifolia* and *Myrcia splendens*, and a more continuous herbaceous layer, composed principally by the species *Elephantopus hirtiflorus*, *Cyperus schomburgkianus*, *Galactia jussiaeana* and *Streptostachys asperifolia*, a physiognomy which resembles that of cerrado *s.s.* (Fig. 2C) (Walter *et al.* 2015). S4 also presents a physiognomy similar to that of the cerradão at some sites and dense cerrado *s.s.* in others, (Fig. 2D), with many trees, namely *Andira cordata*, *Astronium fraxinifolium*, *Curatella americana*, *Himatanthus drasticus*, *Hirtella ciliata*, *Hymenaea stigonocarpa*, *Salvertia convallariodora* and *Stryphnodendron coriaceum* composing the landscape. Herbaceous species like the Poaceae *Axonopus marginatus*, *Mesosetum annum* e *Streptostachys asperifolia* and the Cyperaceae *Bulbostylis capilaris*, *Cyperus schomburgkianus* and *Fimbristylis dichotoma* are common in the herbaceous component of S4.

Despite sharing woody and non-woody species with the core Cerrado biome the total flora of caatinga-savanas is more similar to the surrounding caatinga vegetation. The typical savanna physiognomy that can be observed in these caatinga-savannas did not mean that typical caatinga species were excluded from these areas. We found here that most caatinga-savanna sites were floristically closer to the caatinga than to the cerrado. A remarkable exeption was the woody community in the Chapada do Araripe savanna enclave, which presented a woody flora that is more similar to geographically distant cerrado areas of Goiás and São Paulo than to the surrounding Caatinga. It is possible that the deep, acidic soils from this region, together with higher rainfall and altitude may be the cause of this similarity (Costa *et al.* 2004; Ribeiro-Silva *et al.* 2012; Santos *et al.* 2018).

Batalha & Martins (2002 and 2004) compiled data from Raunkiaer life-forms in seven areas of Cerrado in Brazil and observed the predominance of hemicryptophytes, followed by phanerophytes and chamaephytes (Costa *et al.* 2004; Martins & Batalha (2011)), recording the largest occurrence of phanerophytes and hemicyptophytes in the Chapada do Araripe (CE) and in Itirapina (SP), respectively, and Tannus & Assis (2004) who established that hemicryptophytes were dominant in an area with open grassland. In our study areas, phanerophytes (29.3 %) and hemicryptophytes (15 %) have significant representativeness, although they are less rich than the therophytic life-form, which represented 42.3 % of the plant species. Therophytes are predominant in desertic areas according to the Raunkiaer spectrum (Martins & Batalha 2011), whilst in Brazilian biomes they are more representative of the caatinga vegetation (Pennington *et al.* 2000; Costa *et al.* 2016), as seen in studies by Araújo *et al.* (2011) and Queiroz *et al.* (2015).

Despite being classified as phygsionomically similar to the cerrado vegetation, our study areas had biological spectra different from other cerrado areas in Brazil and closer to the caatinga, with a high number of therophytic species. This fact could be related to the environmental conditions of the Caatinga biome, where these sites are located, with high temperatures and erratic rain regime and distribution, which favours therophytes, having short life-cycles that are adapted to water restriction and short or unpredictable growing seasons (Martins & Batalha 2011). Thus, the flora of the four studied caatinga-savannas is more similar to the caatinga vegetation than to the cerrado. Of the 247 species recorded in our areas, 150 are listed as occurring in the Caatinga biome as compiled by Moro *et al.* (2014). Also, we found that the therophytic life-form predominates, a similar situation with that recorded in caatinga vegetation (Araújo *et al.* 2011; Costa *et al.* 2016; Queiroz *et al.* 2015). The large number of therophytes found in the caatinga-savannas is very likely connected to the semiarid climate of the region with lower, less predictable precipitation in these savannas than in cerrados of central Brazil. Nevertheless, these caatinga-savannas share a significant number of typical cerrado species do not present in typical caatinga sites.

Conclusion

The caatinga-savanna enclaves studied here are not fragments of typical cerrado vegetation, although possessing savanna physiognomy. The proximity of caatinga vegetation, which surrounds the patches, and the influence of the semiarid climate explain the larger number of therophytic species in relation to the phanerophytes and hemicryptophytes, since therophytes are the dominant life-form in the caatinga. Many species typical of the cerrado vegetation were found in our study areas. Apart from presenting a physiognomy similar to the cerrado *s.s.* and the taller and more closed *cerradão*, these areas have various typical species that occur in the 'core' Cerrado domain. Nevertheless, the local flora as a whole is closer to the caatinga vegetation than to the cerrado, with the exception of the Araripe savanna enclave. The flora of these enclaves is therefore characterised by a mixture of species typical of the Brazilian cerrado, widespread species and species typical from the caatinga vegetation.

Acknowledgements

We would like to thank the specialists Nádia Roque, Regina Célia, Daniela Carneiro-Torres, Cassio van den Berg and Rubens Queiroz for taxonomic identifications. We are very grateful to Nigel Taylor for reviewing the English language and improving the manuscript. EBS and IVN thank the FUNCAP for financing the Projeto Inventário Florístico do Noroeste do Estado do Ceará: Diversidade e Potencialidades do Bioma Caatinga (processo: BP2-0107-00081.01.02/16.) and the MSC grant for IVN. DCZ is a holder of a CNPq productivity grant.

References

Arai M. 2006. A grande elevação eustática do Mioceno e sua influência na origem do Grupo Barreiras. Geologia USP, Série Científica 6: 01-06.

Araújo FS, Costa RC, Lima JR, *et al.* 2011. Floristics and life-forms along a topographic gradient, central-western Ceará, Brazil. Rodriguésia 62: 341-366.

Balsamo F, Storti F, Salvini F, Silva AT, Lima CC. 2010. Structural and petrophysical evolution of extensional fault zones in low-porosity, poorly lithified sandstones of the Barreiras Formation, NE Brazil. Journal of Structural Geology 32: 1806-1826.

Batalha MA, Aragaki S, Mantovani W. 1997. Florística do Cerrado em Emas (Pirassununga, SP). Boletim de Botânica da Universidade de São Paulo16: 49-64.

Batalha MA, Martins FR. 2002. Life-form spectra of Brazilian cerrado sites. Flora 197: 452-460.

Batalha MA, Martins FR. 2004. Floristic, frequency and vegetation life-form of a Cerrado site. Brazilian Journal of Biology 64: 203-209.

BFG - The Brazil Flora Group. 2015. Growing knowledge: An overiew of Seed Plant diversity in Brazil. Rodriguésia 66: 1085-1113.

BFG - The Brazil Flora Group. 2018. Brazilian flora 2020: Innovation and collaboration to meet target 1 of the global strategy for plant conservation (GSPC). Rodriguésia 69: 1513-1527.
Castro AAJF. 1994. Comparação florística-geográfica (Brasil) e Fitossociológica (Piauí-São Paulo) de amostras de cerrado. PhD Thesis, Universidade Estadual de Campinas, Campinas.
Castro AAJF, Castro NMCF, Costa JM, *et al.* 2007. Cerrados Marginais do Nordeste e Ecótonos Associados. Revista Brasileira de Biociências 5: 273-275.
Castro AAJF, Martins FR. 1999. Cerrados do Brasil e do Nordeste: caracterização, área de ocupação e considerações sobre a sua fitodiversidade. Pesquisa em Foco 7: 147-178.
Costa ACM, Moro MF, Martins FR. 2016. Raunkiaerian life-forms in the Atlantic forest and comparisons of life-form spectra among Brazilian main biomes. Brazilian Journal of Botany 39: 833-844.
Costa IR, Araújo FS, Lima-Verde LW. 2004. Flora e aspectos auto-ecológicos de um encrave de cerrado na chapada do Araripe, Nordeste do Brasil. Acta Botanica Brasilica 18: 759-770.
Costa ML. 1991. Aspectos geológicos dos lateritos da Amazônia. Revista Brasileira de Geociências 21: 146-160.
Coutinho LM. 2016. Biomas brasileiros. 1st. edn. São Paulo, Oficina de Textos.
CRIA - Centro de Referência e Informação Ambiental. 2019. SpeciesLink. http://www.splink.org.br. 14 Jun. 2019.
Devecchi M, Lovo J, Moro M, *et al.* 2020. Beyond forests in the Amazon: biogeography and floristic relationships of the Amazonian savannas. Botanical Journal of the Linnean Society 193: 478-503.
Eiten G. 1972. The Cerrado Vegetation of Brazil. The Botanical Review 38: 201-341.
Eiten G. 1982. Brazilian "Savannas". In: Huntley HJ, Walker BH. (eds.) Ecology of Tropical Savannas. Berlin, Heidelberg, Springer-Verlag. p. 25-47.
Felfili JM, Silva-Júnior MC, Rezende AV, *et al.* 1992. Análise comparativa da florística e fitossociologia da vegetação arbórea do Cerrado *sensu stricto* na Chapada Pratinha, DF-Brasil. Acta Botanica Brasilica 6: 27-46.
Figueiredo MA. 1989. Nordeste do brasil: relíquias vegetacionais no semi-árido cearense (cerrado). Coleção Mossoroense, Série B 646: 3-13.
Flora do Brasil 2020. 2019. Jardim Botânico do Rio de Janeiro. http://floradobrasil.jbrj.gov.br/. 14 Jun. 2019.
FUNCEME – Fundação Cearense de Meteorologia e Recursos Hídricos. 2019. Dados Históricos. http://www.funceme.br/produtos/script/chuvas/Download_de_series_historicas/DownloadChuvasPublico.php. 27 Jul. 2019.
Gibbs PE, Leitão-Filho HF, Sheperd G. 1983. Floristic Composition and Community Structure in an Area of Cerrado in SE Brazil. Flora 173: 433-449.
Goodland RJA, Ferri MG. 1979. Ecologia do Cerrado. São Paulo, Editora Itatiaia.
Gotelli NJ, Ellison AM. 2011. Princípios de Estatística em Ecologia. Porto Alegre, Artmed.
Harley RM, Giulietti AM, Grilo AS, *et al.* 2005. Cerrado. In: Juncá F, Funch L, Rocha W. (eds.) Biodiversidade e Conservação da Chapada Diamantina. Brasília, Ministério do Meio Ambiente. p. 121-152.
IPECE – Instituto de Pesquisa e Estratisgia Econômica do Ceará. 2007. http://www2.ipece.ce.gov.br/atlas/lista/index.htm. 14 Jun. 2019.
Juncá FA, Funch L, Rocha W. 2005. Biodiversidade e conservação da Chapada Diamantina. Brasília, Ministerio do Meio Ambiente.
Legendre P, Legendre L. 2012. Numeral Ecology. 3rndn. Oxford, Elsevier.
Lima IG, Albuquerque AML, Dias ACA, Loiola MIB. 2018. Flora do Ceará, Brasil: Polygalaceae. Rodriguésia 69: 673-692.
Magnusson WE, Lima AP, Albernaz ALKM, Sanaiotti TM, Guillaumet JL. 2008. Composição florística e cobertura vegetal das savannas na região de Alter do Chão, Santarém - PA. Revista Brasileira de Botânica 31: 165-177.
Mantovani W, Martins FR. 1993. Florística do Cerrado na Reserva Biológica de Moji Guaçu, SP. Acta Botanica Brasilica 7: 33-60.
Martins FR, Batalha MA. 2011. Formas de vida, espectro biológico de Raunkiaer e fisionomia da vegetação. In: Felfili JM, Eisenlohr PV, Melo MMRF, Andrade LA, Meira-Neto JAA. (eds.) Fitossociologia no Brasil – Métodos e estudos de caso. Vol. 1. Viçosa, Editora UFV. p. 44-85.
Menezes MOT, Taylor NP, Loiola MIB. 2013. Flora do Ceará, Brasil: Cactaceae. Rodriguésia 64: 757-774.
Miranda IS, Almeida SS, Dantas PJ. 2006. Florística e estrutura de comunidades Shróreas em cerrados de Rondônia, Brasil. Acta Amazonica 36: 419-430.
Mori SA, Silva LAM, Lisboa G, Coradin L. 1989. Manual de manejo do herbário fanerogâmico. 2nd. edn. Ilhéus, Bahia, CEPLAC.
Moro MF, Castro ASF, Araújo FS. 2011. Composição florística e estrutura de um fragmento de vegetação savânica sobre os tabuleiros pré-litorâneos na zona urbana de Fortaleza, Ceará. Rodriguésia 62: 407-423.
Moro MF, Macedo MB, Moura-Fé MM, Castro ASF, Costa RC. 2015. Vegetação, unidades fitoecológicas e diversidade paisagística do estado do Ceará. Rodriguésia 66: 717-743.
Moro MF, Lughadha EN, Araújo FS, Martins FR. 2016. A Phytogeographical Metaanalysis of the Semiarid Caatinga Domain in Brazil. The Botanical Review 82: 91-148
Moro MF, Lughadha EN, Filer DL, Araújo FS, Martins FR. 2014. A catalogue of the vascular plants of the Caatinga Phytogeographical Domain: a synthesis of floristic and phytosociological surveys. Phytotaxa 160: 1-118.
Nepomuceno FAA, Souza EB, Nepomuceno IV, Miguel LM, Cabral EL, Loiola MIB. 2018. The genus *Borreria* (Spermacoceae, Rubiaceae) in the state of Ceará, Brazil. Rodriguésia 69: 715-731.
Oliveira ACP, Penha AS, Souza RF, Loiola MIB. 2012. Composição florística de uma comunidade savânica no Rio Grande do Norte, Nordeste do Brasil. Acta Botanica Brasilica 26: 559-569.
Pennington RT, Prado DE, Pendry CA. 2000. Neotropical seasonally dry forests and Quaternary vegetation changes. Journal of Biogeography 27: 261-273.
Pennington RT, Lewis GP, Ratter JA. 2006. An Overview of the Plant Diversity, Biogeography and Conservation of Neotropical Savannas and Seasonally Dry Forests. In: Pennington RT, Lewis GP, Ratter JA. (eds.) Neotropical Savannas and Seasonally Dry Forests. Boca Raton, CRC Press. p. 1-24.
Queiroz RT, Moro MF, Loiola MIB. 2015. Evaluating the relative importance of woody versus non-woody plants for alpha-diversity in a semiarid ecosystem in Brazil. Plant Ecology and Evolution 148: 361-376.
Queiroz LP, Cardoso D, Fernandes MF, Moro MF. 2017. Diversity and Evolution of Flowering Plants of the Caatinga Domain. In: Silva JMC, Leal IR, Tabarelli M. (eds.) Caatinga: The Largest Tropical Dry Forest Region in South America. Switzerland, Springer International Publishing AG. p. 23-63.
Ratter JA, Bridgewater S, Ribeiro JF. 2003. Analysis of the Floristic Composition of the Brazilian Cerrado Vegetation III: Comparison of the Woody Vegetation of 376 Areas. Edinburgh Journal of Botany 60: 57-109.
Ratter JA, Dargie TCD. 1992. An analysis of the floristic composition of 26 Cerrado areas in Brazil. Edinburgh Journal of Botany 49: 235-250.
Ratter JA, Ribeiro JF, Bridgewater S. 1997. The Brazilian Cerrado Vegetation and Threats to its Biodiversity. Annals of Botany 80: 223-230.
Ribeiro-Silva S, Medeiros MB, Gomes BM, Naiana E. 2012. Angiosperms from the Araripe National Forest, Ceará, Brazil. Check List 8: 744-751.
Rocha WJSF, Chaves JM, Rocha CC, Funch L, Juncá FA. 2005. Avaliação ecológica rápida da Chapada Diamantina. In: Juncá F, Funch L, Rocha W. (eds.) Biodiversidade e Conservação da Chapada Diamantina. Brasília, Ministisrio do Meio Ambiente. p. 29-45.
Santos HG, Jacomine PKT, Anjos LHC, *et al.* 2018. Sistema brasileiro de classificação de solos. 5th. edn. Brasília, DF, Embrapa Solos.
Silva-Moraes HG, Cordeiro I, Figueiredo N. 2018. Flora and floristic affinities of the Cerrados of Maranhão state, Brazil. Edinburgh Journal of Botany 76: 1-21.
Soares-Neto RL, Cordeiro LS, Loiola MIB. 2014. Flora do Ceará, Brasil: Combretaceae. Rodriguésia 65: 685-700.
Souza VC, Flores TB, Colletta GD, Coelho RL. 2018. Guia das Plantas do Cerrado. 1st. edn. Piracicaba, Taxon Brasil.

Tannus JLS, Assis MA. 2004. Composição de espiscies vasculares de campo sujo e campo úmido em área de cerrado, Itirapina - SP, Brasil. Revista Brasileira de Botânica 27: 489-506.

Townsend CR, Begon M, Harper JL. 2009. Fundamentos em Ecologia. Porto Alegre, Artmed.

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

Thiers B. 2021; continuously updated.. Index Herbariorum: A global directory of public herbaria and associated staff. http://sweetgum.nybg.org/science/ih/. 10 Aug. 2019.

Tokuoka T. 2012. Molecular phylogenetic analysis of Passifloraceae sensu lato (Malpighiales) based on plastid and nuclear DNA sequences. Journal of Plant Research 125: 489-497.

Walter BMT, Carvalho AM, Ribeiro JF. 2008. Conceito de Savanna e de seu Componente Cerrado. In: Ribeiro JF, Almeida SP, Sano SM. (eds.) Cerrado: ecologia e flora. Brasília, Embrapa. p.21-45.

Walter BMT, Durigan G, Munhoz CBR, Ribeiro JF. 2015. Fitofisionomias do Cerrado: classificação, métodos e amostragens fitossociológicas. In: Eisenlohr PV, Felfili JM, Melo MMRF, Andrade LA, Neto JAAM. (eds.) Fitossociologia no Brasil: mistodos e estudos de casos. Vol. 2. Viçosa, Editora UFV. p.183-212.