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REGULAR PAPER

Evaluating the relative importance of woody versus non-woody plants for alpha-diversity in a semiarid ecosystem in Brazil

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Background and aims – Floristic surveys in tropical ecosystems are strongly biased towards collecting woody plants, overlooking the non-woody component even in semiarid ecosystems, where they can be predominant. This has led to an undervaluation of plant biodiversity in semiarid ecosystems because, as we show here, these areas have a high diversity of herbaceous species, sometimes much higher than that of woody plants. The semiarid Caatinga, in Northeastern Brazil, is one of such areas. Previously thought to be a species poor biome, these ecosystems are now understood as having a diverse flora, well adapted to dry conditions, including many therophytic species.
Methods – We performed an extensive survey on plant diversity in a semiarid Caatinga site paying special attention to the non-woody component and compared it with the previously available data on woody plants for the same site. We used rarefied and extrapolated sampling curves to evaluate to what extent woody species are well sampled, based on the published data for trees and shrubs. We also constructed habit spectra to compare the relative importance of woody versus non-woody species in our site and across different Caatinga sites.
Key results – Although the asymptotic richness for woody species is low when compared to other areas within Caatinga, the total alpha-diversity in the region is high if non-woody plants are considered in the study. We present habit and life form spectra to show that in this semiarid area most of the local biodiversity is composed by short-lived, usually under sampled, therophytes.
Conclusion – We discuss how the focus on woody plants has underestimated the total alpha diversity of semiarid ecosystems. We call the attention of ecologists and phytosociologists collecting in semiarid ecosystems to focus not only on large trees and shrubs, but also to look down and collect the usually neglected, but very rich non-woody component.

Key words – Brazil, Caatinga, habit spectrum, Raunkiaer life forms, seasonally dry tropical forests.

INTRODUCTION

A common source of data on plant distribution is floristic papers, which bring information on local plant communities. These studies can be integrated into larger meta-analytical studies seeking for biogeographical patterns (Oliveira-Filho & Fontes 2000, Ratter et al. 2003, Cardoso & Queiroz 2007, Linares-Palomino et al. 2011, Moro et al. 2015b). But a common limitation of biogeographical studies is that most of them explore only the patterns of woody plant distribution due to lack of data about non-woody plant communities (Oliveira-Filho & Fontes 2000, Ratter et al. 2003, Linares-Palomino et al. 2011). This seems reasonable when one needs to analyze biogeographical patterns in rainforests, because this vegetation is dominated by woody plants. But when it comes to seasonally dry tropical vegetation, like the semiarid Caatinga, the proportion of non-woody plants in the local communities can be much more significant (Costa et al. 2007, 2009). In this case, the lack of data on non-woody plants imposes a problem when one tries to understand the plant diversity patterns of these areas.

Many South American biomes are richer in non-woody plants that in woody ones, including the The Brazilian cerra-

do savannas, very rich in herbs and subshrubs belonging to the chamaephytic and hemicryptophytic life forms (Batalha & Martins 2002, Sano et al. 2008); deserts, rich in therophytes (Raunkiaer 1934, Batalha & Martins 2002); and the semiarid caatinga vegetation, where both woody and non-woody plants are important, but where non-woody plants, especially therophytes, can be the most common life form in some sites (Costa et al. 2007, 2009, Araújo et al. 2011). Nevertheless, herbaceous plants are usually overlooked by researchers publishing floristic surveys in the Brazilian semiarid Caatinga and most collectors that published floristic studies have focused only on woody plants, ignoring the rich non-woody component (Moro et al. 2014a, 2015a).

In a synthesis of the plant diversity in the semiarid Caatinga Phytogeographical Domain, Moro et al. (2015a) have shown that within Caatinga there is a region with a very small number of recorded species. This region, called Seridó, represents one of the driest sites of Caatinga and has received little governmental attention regarding the establishment of nature reserves. The data available up to date in the floristic literature suggest that this region is of least concern regarding biodiversity conservation due to its extremely low alpha diversity.

Here we defy this vision, showing that the flora of Seridó is not extremely poor in species number, but simply concentrated in the non-woody component. We show that the recorded plant diversity is currently underestimated because most studies have overlooked non-woody plants, focusing only on the woody component. We present here a botanical survey for the caatinga vegetation of Seridó, aiming to evaluate the proportional importance of woody versus non-woody plants for Caatinga. We also calculated the proportion of woody versus non-woody species in other Caatinga sites to evaluate the role of non-woody plants for alpha diversity across the biome. We call here the attention of researches sampling the flora of semiarid ecosystems to give more attention to herbs and subshrubs when performing floristic surveys, as this component can be richer than the woody component in seasonally dry tropical vegetation.

MATERIAL AND METHODS

Study site

This study was carried out in the Seridó Ecological Station (Estação Ecológica do Seridó – ESEC Seridó 6°34′–6°37′S and 37°15′–37°17′W) in Serra Negra do Norte municipality, Rio Grande do Norte State, Northeastern Brazil (fig. 1). The ESEC Seridó is a Federal nature reserve comprising 1,166 hectares, a very small protected area, if we consider the Brazilian context. The area is subjected to a semiarid and

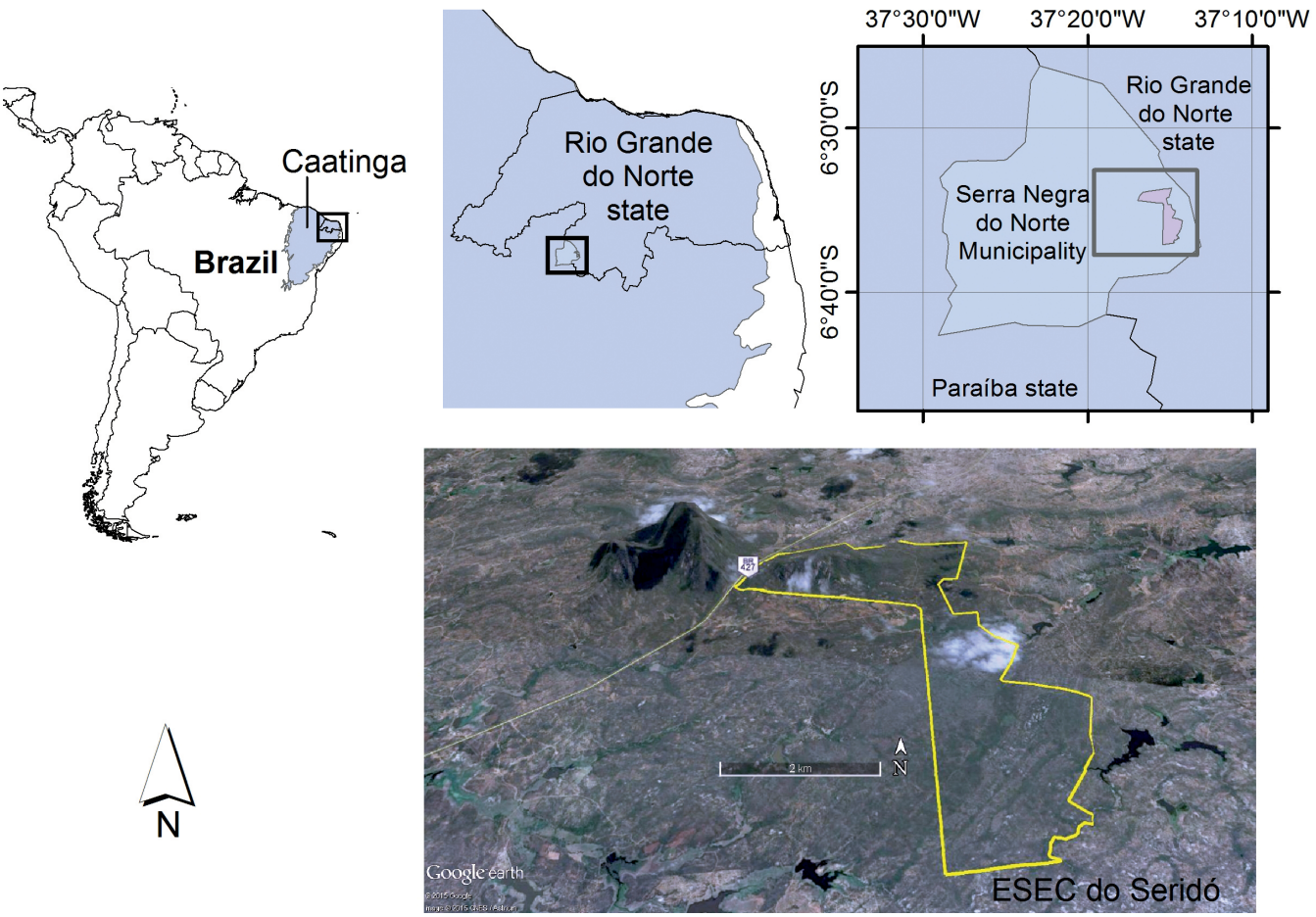

Figure 1 – Geographical location of the Seridó Ecological Station (ESEC Seridó), Serra Negra do Norte municipality, Rio Grande do Norte state, Brazil. Satellite image source: Google Earth.

Table 1 – Abundance data for each species reported in the previously published phytosociological surveys made in the Seridó Ecological Station (ESEC Seridó).
The data comes from Amorim et al. (2005) and Santana & Souto (2006). Species names were updated according the List of Species of The Brazilian Flora (Jardim Botânico do Rio de Janeiro 2014). *Santana & Souto (2006) refer to "*Cassia tetrafila* Linn." in their work, but this is a name used in error. The name *Cassia tetraphylla* Desv. (not L.) is a valid name, but refers to a herbaceous species. The authors probably misused the name and this record most likely refers to one to the many woody *Senna* species in Caatinga previously placed in *Cassia*.

Nº	Family	Species	Abundance reported in Santana & Souto 2006 (0,6 ha)	Abundance reported in Amorim et al. 2005 (1 ha)	The two surveys summed
1	Apocynaceae	*Aspidosperma pyrifolium* Mart.	375	1199	1574
2	Bignoniaceae	*Dolichandra unguis-cati* (L.) L.G.Lohmann	31	-	31
3	Bignoniaceae	*Handroanthus impetiginosus* (Mart. ex DC.) Mattos	25	12	37
4	Boraginaceae	*Varronia globosa* Jacq.	-	6	6
5	Burseraceae	*Commiphora leptophloeos* (Mart.) J.B.Gillett	85	2	87
6	Cactaceae	*Cereus jamacaru* DC.	1	-	1
7	Capparaceae	*Cynophalla flexuosa* (L.) J.Presl	1	85	86
8	Combretaceae	*Combretum leprosum* Mart.	120	120	240
9	Erythroxylaceae	*Erythroxylum pungens* O.E.Schulz	86	77	163
10	Euphorbiaceae	*Cnidoscolus quercifolius* Pohl	44	-	44
11	Euphorbiaceae	*Croton heliotropiifolius* Kunth	65	-	65
12	Euphorbiaceae	*Croton sonderianus* Müll.Arg.	641	452	1093
13	Euphorbiaceae	*Jatropha mollissima* (Pohl) Baill.	105	103	208
14	Fabaceae	*Amburana cearensis* (Allemão) A.C.Sm.	10	2	12
15	Fabaceae	*Anadenanthera colubrina* (Vell.) Brenan	90	123	213
16	Fabaceae	*Bauhinia cheilantha* (Bong.) Steud.	24	15	39
17	Fabaceae	*Cassia* sp.*	3	-	3
18	Fabaceae	*Chloroleucon foliolosum* (Benth.) G.P.Lewis	-	562	562
19	Fabaceae	*Libidibia ferrea* (Mart. ex Tul.) L.P.Queiroz	62	-	62
20	Fabaceae	*Mimosa acutistipula* (Mart.) Benth.	-	287	287
21	Fabaceae	*Mimosa tenuiflora* (Willd.) Poir.	139	-	139
22	Fabaceae	*Piptadenia stipulacea* (Benth.) Ducke	112	-	112
23	Fabaceae	*Poincianella pyramidalis* (Tul.) L.P.Queiroz	420	202	622
24	Fabaceae	*Senna macranthera* (DC. ex Collad.) H.S.Irwin & Barneby	8	-	8
25	Verbenaceae	*Lantana camara* L.	1	-	1
		TOTAL	2,448	3,247	5,695

very hot climate, "BSh" according to Köppen (Alvares et al. 2013). The rainy season generally occurs from January to May, and mean annual rainfall is 727 mm, with mean annual temperature around 26°C, according to the values provided for the site by the WorldClim model (Hijmans et al. 2005).

The ESEC Seridó is a small nature reserve intended to protect the semiarid Caatinga and is part of the official Brazilian Network of Nature Reserves. Rio Grande do Norte is a state with the majority of its area under semiarid climates, with over 90% of its area located within the Caatinga Phytogeographical Domain, one of the six large natural regions of Brazil (IBGE 2004). In the whole state we can find only 16 nature reserves, most having very small sizes. This is partly derived from the impression that dry areas are species-poor sites and thus lack importance for conservation. Among Rio Grande do Norte's nature reserves, the ESEC Seridó was chosen because it is assumed to be very poor in species, a conclusion reinforced by the previous botanical surveys published to the area, which focused only on woody plants.

Nomenclature

The nomenclature and taxonomic position adopted in this study follows the official database of the Brazilian Flora, the *Lista de Espécies da Flora do Brasil* (Jardim Botânico do Rio de Janeiro 2014), from where data about the status of each species (endemic, non-endemic native or exotic) was obtained.

Floristic sample and rarefaction procedures

Previous studies in the ESEC Seridó (Amorim et al. 2005, Santana & Souto 2006) have focused on gathering phytosociological data for the woody component. These two phytosociological studies together sampled 5,695 individuals, summing up to only 25 woody species (table 1). Such small alpha-diversity would put the Seridó among the least rich areas of the Caatinga (as mapped by Moro et al. 2015a based on the available literature). To evaluate whether the small number of woody species reported in these previous studies (Amorim et al. 2005, Andrade et al. 2006) was due to small

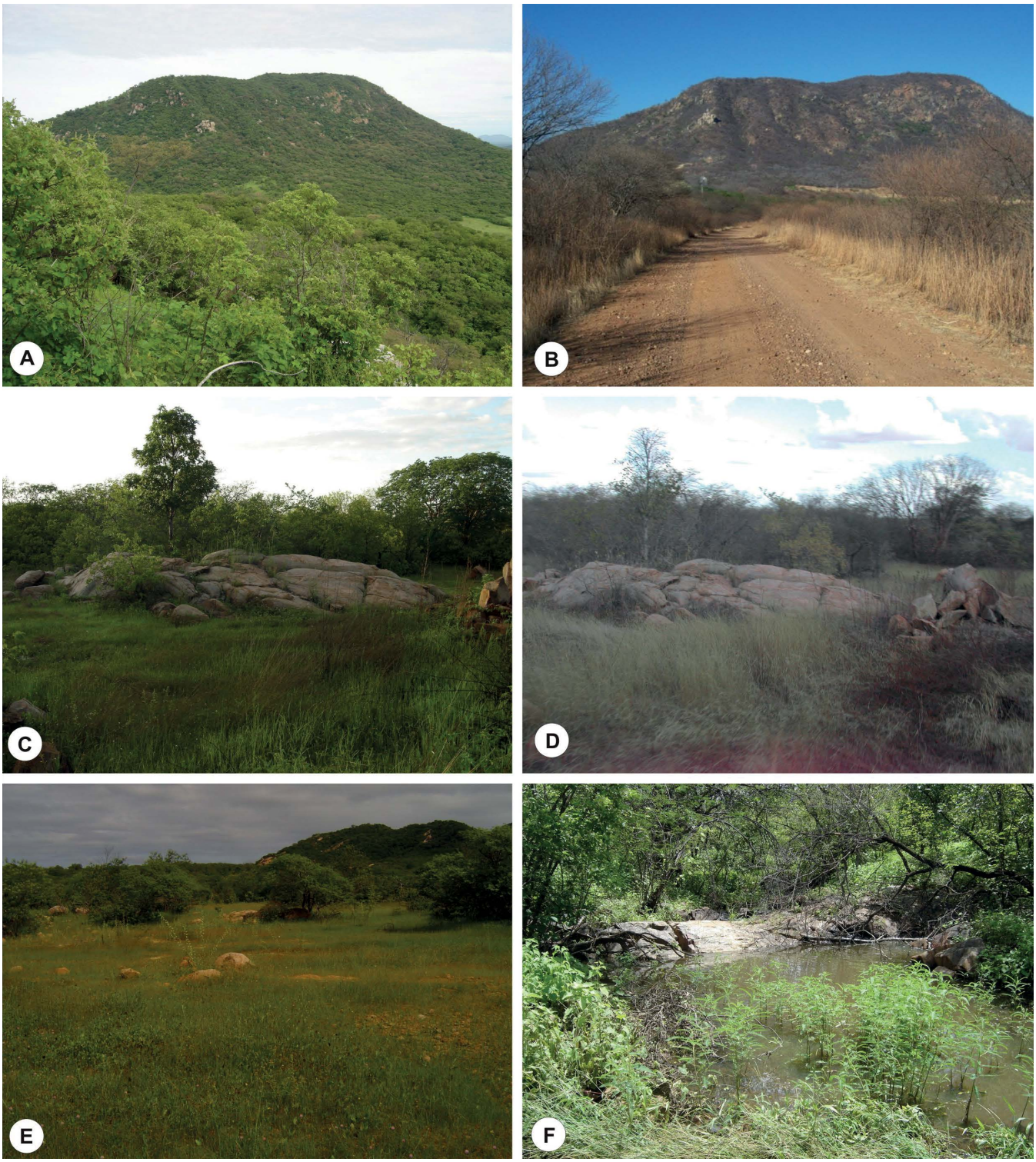

Figure 2 – A–E: The main terrestrial habitats of the Seridó Ecological Station (ESEC Seridó). A & B, closed caatinga during rainy and dry season, respectively; C & D, open caatinga during the rainy and dry season, respectively. Note in both photos a small patch of rock outcrop. In other places, rock outcrops are much more extensive; E, very open caatinga, or grassland. These areas are usually formed due to previous anthropogenic impacts and overgrazing; F, a small temporary pond formed only during the rainy season. Photographed by Rubens Teixeira Queiroz.

Figure 3 – The different habitats of the Seridó Ecological Station (ESEC Seridó). A & B, the open caatinga in the dry and in the beginning of the rainy season, respectively; C–F, aquatic and amphibious ecosystems of the ESEC Seridó; C–D, swamped grasslands (localy known as *Ipueiras*); E, artificial reservoir (*açude*); F, temporary river that appears only during the rainy season. Photographs: A, D & E by Carlos Alberto Varela Freire; B, C & F by Rubens Teixeira Queiroz.

sampling size or a real small number of woody species, we took these phytosociological sampling and made an abundance-based rarefaction (Magurran 2004, Gotelli & Colwell 2011) using iNEXT package (http://johnsonhsieh.github.io/iNEXT/) for R environment (Chao et al. 2014). We built species accumulation curves (interpolated curves) that show how the recorded richness increases following the increased sampling effort made by the authors. We also present an extrapolated sampling curve for each survey, showing how much recorded richness would increase if each study had done a sampling effort twofold the sampling actually made.

In order to contrast the expected total richness of woody species with the non-woody species richness, we performed a general floristic survey using opportunistic sampling in the main habitats of the ESEC Seridó. In the terrestrial environment, we collected in three habitats. The most widespread one is the closed caatinga vegetation (fig. 2), which is a dense scrubland or woodland with many thorny deciduous woody plants. Another important habitat in the ESEC Seridó was the open caatinga vegetation (fig. 3), with sparse deciduous woody plants and herbaceous plants densely covering the ground during the rainy season, but dying in the dry season (figs 2 & 3). The last terrestrial ecosystem surveyed was the rupicolous vegetation, including inselbergs and rocky surfaces (inselbergs and lajedos). The Caatinga Phytogeographical Domain also has a wealth of temporary aquatic ecosystems, which flourish during the rainy season, but normally disappear in the dry season (figs 2 & 3). Regarding aquatic ecosystems, we surveyed aquatic plants in (1) temporary rivers that appear in the wet season, but dry during the dry season; in (2) natural temporary ponds; and also in (3) an artificial reservoir that exists in the ESEC Seridó and usually keeps water during the dry season.

Collections were made from 2005 to 2006, weekly during the rainy season (from March to July) and every two weeks during the dry season (from August to February), totaling 38 field trips. Each trip lasted from three to five days. We recorded species from the ESEC Seridó giving special attention to the non-woody component. Invasive exotic plants found in the study site were collected and reported tagged as exotic following the suggestions of Moro et al. (2012). All collected material was deposited in the herbarium UFRN. In a further attempt to complement the local species list we evaluated material from the ESEC Seridó deposited in IPA, MOSS, HUEFS, JPB, UFP and PEUFR herbaria (acronyms according to Thiers 2014). All species collected in the ESEC Seridó represented by vouchers in these herbaria were added to our list.

Habit and life form spectra in the local plant community

We classified each species we recorded from the ESEC Seridó in one of the following plant habits: Trees: woody plants over 3 m high; shrubs: woody plants usually below 3 m high; subshrubs: small plants (less than 1 m high) with tender branches and woodiness only at the plant base; herbs: plants without woody parts or only very slightly wooded; climbers: climbing plants, separated in woody climbers (phanerophytic climbers) and non-woody climbers (chamaephytic, geophytic and therophytic climbers); parasites: plants that obtain their nutrients from other plants.

All terrestrial plants were classified in one of the Raunkiaer's (1934) life forms, namely: phanerophyte, chamaephyte, hemicryptophyte, geophytes and therophyte.

All species recorded in aquatic ecosystems were classified in one of the life forms proposed by Sculthorpe (1967), namely: plants attached to the substrate [emergent (A1); floating-leaved (A2); submerged hydrophytes (A3)]; and plants not attached to the substrate or free-floating hydrophytes (FF). If a species was encountered in terrestrial as well as in aquatic ecosystem, it received one life form for each habitat. Irrespectively to the habitat where the species was found, all plants were classified in one of the habits: tree, shrub, herb, climber or parasite.

In order to compare the relative importance of woody versus non-woody plants across sites in Caatinga, we selected, from the literature on the Brazilian semiarid vegetation, floristic lists that sampled both woody and non-woody species for a study site. The Brazilian semiarid has different ecosystems, but we considered here only studies performed in the caatinga *sensu stricto* vegetation. This is the predominant vegetation of the region, being a deciduous and spiny vegetation, growing on the crystalline peneplains that dominate most of the Brazilian semiarid. Then, we used the data reported in these studies to create a database of plant habits. We excluded from this database all records not identified to species level (i.e. records identified only to genus or family level) and exotic species. After that, we classified each species as "woody", "non-woody", "epiphytic" and "parasite/hemiparasite". Having classified each species we constructed a spectrum of plant-habits for each site.

RESULTS

We recorded in our survey 335 species (307 native, 28 invasive exotic species) belonging to 68 families (table 2). Two of these were Lycophytes, one was an aquatic fern and 332 were Angiosperms (304 native, 28 invasive). We found one species of Nymphaeaceae (Basal Angiosperm), one species of Aristolochiaceae (Magnoliids), thirteen families and eighty species of Monocotyledons, one Ceratophyllales, and 52 families and 214 species of Eudicotyledons.

The most important families in the area were Fabaceae (61 spp.), Poaceae (30 spp.), Cyperaceae (20 spp.), Convolvulaceae (20 spp.), Euphorbiaceae (18 spp.), Asteraceae (17 spp.) and Malvaceae (15 spp.). These families summed up 191 species or 63% of all recorded species and were among the most important in other studies focusing on the non-woody component of the Caatinga flora (table 3).

Regarding the invasive exotic species, Poaceae was the richest family, with fourteen invasive species in the site. We also recorded invasive species among the Convolvulaceae (3 species), Fabaceae (3), Amaranthaceae (2), Nyctaginaceae (2), Aizoaceae (1), Cucurbitaceae (1), Solanaceae (1) and Zygophyllaceae (1) (table 2).

Table 2 – List of plant species recorded in the Seridó Ecological Station (ESEC Seridó), Serra Negra do Norte Municipality, Rio Grande do Norte State.
"Habit", habit of each species (WC: woody climber, NWC: non-woody climber); "LF ter", life forms of plants in terrestrial ecosystems according to Raunkiaer (1934) (Phan: phanerophyte, Cha: chamaephyte, Geo: geophyte, Hem: hemicryptophyte, The: therophyte); "LF aqu", life forms of plants in aquatic ecosystems according to Sculthorpe (1967) (A: hydrophytes attached to the substrate, A1: emergent hydrophytes, A2: floating-leaved hydrophytes, A3: submerged hydrophytes, FF: free-floating hydrophytes); "TER", species recorded in terrestrial habitats; "AQUA", species recorded in aquatic habitats. * marks exotic invasive species and ** marks Brazilian endemic species. A more detailed version of this table with authors of species names, a detailed information of the subtypes of terrestrial and aquatic environments in which each species was recorded and specimens collected and deposited in the UFRN herbarium, as well as a KML file are available on the Figshare repository at the following address: http://dx.doi.org/10.6084/m9.figshare.1221797.

Group, family and species	Habit	LF ter	LF aqu	TER	AQUA
LYCOPHYTES					
ISOETACEAE					
Isoetes sp.	Herb	Geo	A1	x	x
SELAGINELLACEAE					
Selaginella convoluta	Herb	Hem		x	
FERNS					
SALVINACEAE					
Salvinia auriculata	Herb		FF		x
ANGIOSPERMS					
ACANTHACEAE					
Dicliptera mucronifolia	Subshrub	Cham	A1	x	x
Elytraria imbricata	Subshrub	Cham		x	
Ruellia asperula	Subshrub	Cham	A1	x	x
Ruellia paniculata	Subshrub	Cham	A1	x	x
AIZOACEAE					
Glinus radiatus	Herb	The	A1	x	x
*Trianthema portulacastrum**	Herb	The		x	
ALISMATACEAE					
Echinodorus subalatus	Herb		A1		x
Hydrocleys parviflora	Herb		A2		x
Limnocharis flava	Herb		A1		x
ALSTROMERIACEAE					
Alstroemeria inodora	Herb	Geo		x	
AMARANTHACEAE					
Alternanthera brasiliana	Herb	The		x	
Alternanthera pungens	Herb	The		x	
Alternanthera tenella	Herb	The		x	
*Amaranthus deflexus**	Herb	The		x	
*Amaranthus spinosus**	Herb	The		x	
Froelichia humboldtiana	Herb	The		x	
Gomphrena demissa	Herb	The		x	
Xerosiphon angustiflorus	Herb	The		x	
AMARYLLIDACEAE					
Habranthus sylvaticus	Herb	Geo		x	
APOCYNACEAE					
*Allamanda blanchetii***	WC	Phan		x	
Aspidosperma pyrifolium	Tree	Phan		x	
Ditassa hastata	WC	Phan		x	
Funastrum clausum	WC	Phan		x	
Matelea harleyi	WC	Phan		x	
Petalostelma martianum	WC	Phan		x	

Group, family and species	Habit	LF ter	LF aqu	TER	AQUA
ARACEAE					
Lemna aequinoctialis	Herb		FF		x
Taccarum peregrinum	Herb	Geo		x	
ARISTOLOCHIACEAE					
Aristolochia birostris	WC	Phan		x	
ASTERACEAE					
Acanthospermum hispidum	Herb	The		x	
Acmella uliginosa	Herb	The	A1	x	x
Ageratum conyzoides	Herb	The		x	
Bidens cynapiifolia	Herb	The		x	
Blainvillea acmella	Herb	The		x	
Blainvillea dichotoma	Herb	The		x	
Centratherum punctatum var. *punctatum*	Herb	The		x	
Delilia biflora	Herb	The	A1	x	x
Eupatorium sp.	Herb	The	A1	x	x
Eclipta prostrata	Herb	The	A1	x	x
Lagascea mollis	Herb	The		x	
Melanthera latifolia	Herb	The		x	
Pectis linifolia var. *linifolia*	Herb	The		x	
Pectis oligocephala var. *oligocephala*	Herb	The		x	
Stilpnopappus pratensis	Herb	The		x	
Stilpnopappus rubropappus	Herb	The		x	
Tridax procumbens	Herb	The		x	
BIGNONIACEAE					
Handroanthus impetiginosus	Tree	Phan		x	
Macfadyena unguis-cati	WC	Phan		x	
BORAGINACEAE					
Euploca lagoensis	Herb	The	A1	x	x
Euploca procumbens	Herb	The	A1	x	x
Heliotropium elongatum	Herb	The	A1	x	x
Heliotropium ternatum	Herb	The		x	
BROMELIACEAE					
Encholirium spectabile	Herb	Cham		x	
BURSERACEAE					
Commiphora leptophloeos	Tree	Phan		x	
CACTACEAE					
Cereus jamacaru	Tree	Phan		x	
Pilosocereus gounellei	Shrub	Phan		x	

Table 2 (continued) – List of plant species recorded in the Seridó Ecological Station (ESEC Seridó), Serra Negra do Norte Municipality, Rio Grande do Norte State.

Group, family and species	Habit	LF ter	LF aqu	TER	AQUA
CAPPARACEAE					
Cynophalla flexuosa	Tree	Phan		x	
CERATOPHYLLACEAE					
Ceratophyllum demersum	Herb		A3		x
CLEOMACEAE					
Hemiscola diffusa	Herb	Hem		x	
Physostemon guianense	Herb	The	A1	x	x
Physostemon lanceolatum	Herb	The	A1	x	x
Physostemon tenuifolium	Herb	The		x	
Tarenaya spinosa	Herb	Cham	A1	x	x
COMBRETACEAE					
Combretum leprosum	Tree	Phan		x	
COMMELINACEAE					
Aneilema brasiliense	Herb	The		x	
Callisia filiformis	Herb	The		x	
Commelina benghalensis	Herb	The		x	
Commelina obliqua	Herb	The		x	
Tinantia sprucei	Herb	The		x	
Tradescantia ambigua	Herb	The		x	
CONVOLVULACEAE					
Cuscuta racemosa	Parasite	The		x	
Evolvulus cordatus	Herb	The		x	
Evolvulus filipes	Herb	The		x	
Evolvulus gypsophiloides	Herb	The		x	
*Ipomoea bahiensis***	NWC	The	A1	x	x
Ipomoea hederifolia	NWC	The		x	
Ipomoea longeramosa	NWC	The		x	
*Ipomoea nil**	NWC	The		x	
Ipomoea parasitica	NWC	The		x	
Ipomoea piurensis	NWC	The		x	
Ipomoea sp.	NWC	the		x	
*Ipomoea tenera***	NWC	The		x	
*Ipomoea triloba**	NWC	The		x	
*Ipomoea wightii**	NWC	The		x	
Jacquemontia agrestis	NWC	The		x	
Jacquemontia evolvuloides	NWC	The		x	
Jacquemontia gracillima	NWC	The		x	
Jacquemontia mucronifera	NWC	The		x	
Merremia aegyptia	NWC	The	A1	x	x
Operculina macrocarpa	NWC	Geo		x	
CURCUBITACEAE					
Cayaponia tayuya	WC	Phan		x	
Cucumis anguria	NWC	The		x	
Luffa operculata	NWC	The		x	
*Momordica charantia**	NWC	The	A1	x	
CYPERACEAE					
Abildgaardia scirpoides	Herb	The		x	
Bulbostylis capillaris	Herb	The		x	
Bulbostylis conifera	Herb	The		x	
Cyperus distans	Herb	The	A1	x	x
Cyperus digitatus	Herb	The	A1	x	x
Cyperus odoratus	Herb	The	A1	x	x
Cyperus schomburgkianus	Herb	The		x	
Cyperus squarrosus	Herb	The		x	
Cyperus surinamensis	Herb	The	A1	x	x
Cyperus uncinulatus	Herb	The		x	
Eleocharis interstincta	Herb		A1		x
Eleocharis filiculmis	Herb		A1		x
Fimbristylis dichotoma	Herb	The		x	
Lipocarpha micrantha	Herb	The		x	
Lipocarpha salzmanniana	Herb	The		x	
Rhynchospora aberrans	Herb	The		x	
Rhynchospora caracasana	Herb	The		x	
Rhynchospora contracta	Herb	The		x	
Rhynchospora riparia	Herb	The		x	
Scleria melaleuca	Herb	The	A1	x	x
DIOSCORIACEAE					
Dioscorea ovata	NWC	Geo		x	
ERIOCAULACEAE					
Eriocaulon sp1	Herb	The		x	
Eriocaulon sp2	Herb	The		x	
ERYTHROXYLACEAE					
Erythroxylum pungens	Tree	Phan		x	
EUPHORBIACEAE					
Acalypha comunis	Herb	The		x	
Astraea lobata	Herb	The		x	
Bernardia sidoides	Herb	The		x	
Caperonia palustris	Herb	The		x	
Cnidosculos loefgrenii	Subshrub	Cham		x	
Cnidoscolus quercifolius	Tree	Phan		x	
Cnidosculos urens	Subshrub	The		x	
Croton hirtus	Herb	The		x	
Croton moritibensis	Shrub	Phan		x	
Croton sonderianus	Shrub	Phan		x	
Euphorbia comosa	Herb	The		x	
Euphorbia heterophylla	Herb	The		x	
Euphorbia hirta	Herb	The		x	
Euphorbia hyssopifolia	Herb	The	A1	x	x
Euphorbia prostrata	Herb	The	A1	x	x
Jatropha mollissima	Shrub	Phan		x	
Microstachys corniculata	Herb	The		x	
Tragia volubilis	NWC	The		x	
FABACEAE					
Aeschynomene americana	Subshrub	The	A1	x	x
Aeschynomene benthamii	Subshrub	The		x	
Aeschynomene filosa	Subshrub	The	A1	x	x
Aeschynomene paniculata	Subshrub	The		x	
Aeschynomene rudis	Subshrub	The		x	

Table 2 (continued) – List of plant species recorded in the Seridó Ecological Station (ESEC Seridó), Serra Negra do Norte Municipality, Rio Grande do Norte State.

Group, family and species	Habit	LF ter	LF aqu	TER	AQUA
Aeschynomene scabra	Subshrub	The	A1	x	x
Aeschynomene viscidula	Subshrub	The		x	
Amburana cearensis	Tree	Phan		x	
Anadenanthera colubrina var. *cebil*	Tree	Phan		x	
Ancistrotropis peduncularis	NWC	The		x	
*Arachis dardanii***	Herb	The		x	
*Arachis seridoensis***	Herb	The		x	
Bauhinia cheilantha	Tree	Phan		x	
Centrosema brasilianum	NWC	The	A1	x	x
Centrosema macranthum	NWC	The		x	
Centrosema pascuorum	NWC	The		x	
Chamaecrista absus	Herb	The		x	
Chamaecrista calycioides	Herb	The		x	
Chamaecrista diphylla	Herb	The		x	
*Chamaecrista duckeana***	Herb	The		x	
Chamaecrista hispidula	Herb	The		x	
Chamaecrista pilosa var. *luxurians*	Herb	The		x	
Chamaecrista rotundifolia var. *rotundifolia*	Herb	The		x	
Chamaecrista serpens var. *serpens*	Herb	The		x	
Crotalaria incana L.	Herb	The		x	
*Crotalaria retusa**	Herb	The		x	
Desmodium glabrum	Herb	The		x	
Galactia jussiaeana	WC	Phan		x	
Galactia striata	NWC	The		x	
*Indigofera blanchetiana***	Subshrub	The		x	
*Indigofera hirsuta**	Subshrub	The		x	
*Indigofera microcarpa***	Herb	The	A1	x	x
*Indigofera suffruticosa**	Subshrub	Cham		x	
Libidibia ferrea	Tree	Phan		x	
Macroptilium atropurpureum	NWC	The		x	
Macroptilium bracteatum	NWC	The		x	
Macroptilium lathyroides	Herb	The	A1	x	x
Macroptilium martii	NWC	The		x	
Mimosa camporum	Herb	The		x	
Mimosa hostilis	Shrub	Phan		x	
Mimosa misera	Herb	Hem		x	
Mimosa ursina	Herb	The		x	
Mimosa quadrivalvis var. *leptocarpa*	Herb	The		x	
Mimosa tenuiflora	Tree	Phan		x	
Neptunia plena	Herb	Cham	A1	x	x
Piptadenia stipulacea	Tree	Phan		x	
Pithecellobium diversifolium	Tree	Phan		x	
Poincianella pyramidalis	Tree	Phan		x	
Rhynchosia minima	WC	Phan		x	
Senna macranthera	Shrub	Phan		x	
Senna obtusifolia	Subshrub	The	A1	x	x
Senna uniflora	Subshrub	The		x	
Sesbania sp.	Shrub	Phan	A1	x	x
Stylosanthes angustifolia	Herb	The		x	
Stylosanthes guianensis	Subshrub	The		x	
Stylosanthes humilis	Herb	The		x	
Stylosanthes viscosa	Subshrub	The		x	
Tephrosia cinerea	Subshrub	The		x	
Zornia brasiliensis	Subshrub	The		x	
Zornia leptophylla	Herb	The		x	
Zornia reticulata	Herb	The		x	
GENTIANACEAE					
Schultesia guianensis	Herb	The		x	
HIDROLEACEAE					
Hidrolea spinosa	Subshrub		A1		x
IRIDACEAE					
Alophia linearis	Herb	Geo		x	
Cypella gracilis	Herb	Geo		x	
KRAMERIACEAE					
Krameria sp.	Subshrub	Hem		x	
LAMIACEAE					
Hyptis suaveolens	Subshrub	The		x	
Marsypianthes chamaedrys	Herb	The		x	
Rhaphiodon echinus	Herb	The		x	
LENTIBULARIACEAE					
Utricularia foliosa	Herb		A1		x
Utricularia subulata	Herb	The		x	
LOASACEAE					
Aosa rupestris	Herb	The		x	
Mentzelia asperula	Herb	The		x	
LOGANIACEAE					
Spigelia antelmia	Herb	The		x	
LYTHRACEAE					
Cuphea campestris	Herb	The		x	
Pleurophora anomala	Subshrub	The	A1	x	x
MALPIGHIACEAE					
Heteropterys trichanthera	WC	Phan		x	
MALVACEAE					
*Ayenia erecta***	Herb	The		x	
Corchorus argutus	Herb	The		x	
*Herissantia tiubae***	Subshrub	The		x	
Malachra fasciata	Herb	The	A1	x	x
Melochia piramidata	Herb	The		x	
Pavonia canceolata	NWC	The		x	
Sida cordifolia	Herb	The		x	
Sida galheirensis	Subshrub	Cham		x	

Table 2 (continued) – List of plant species recorded in the Seridó Ecological Station (ESEC Seridó), Serra Negra do Norte Municipality, Rio Grande do Norte State.

Group, family and species	Habit	LF ter	LF aqu	TER	AQUA
Sida procumbens	Herb	The		x	
Sida rhombifolia	Subshrub	The		x	
Sida sp.	Herb	The		x	
Sida spinosa	Subshrub	The		x	
Waltheria bracteosa	Subshrub	The		x	
Waltheria rotundifolia	Subshrub	Cham		x	
Wissadula hernandioides	Subshrub	The		x	
MOLLUGINACEAE					
Mollugo verticilata	Herb	The	A1	x	x
NYCTAGINACEAE					
*Boerhavia coccinea**	Herb	The		x	
*Boerhavia diffusa**	Herb	The		x	
NYMPHAEACEAE					
Nymphaea ampla	Herb		A2		x
ONAGRACEAE					
Ludwigia longifolia	Herb	The	A1	x	x
Ludwigia octovalvis	Herb	The	A1	x	x
OROBANCHACEAE					
Agalinis hispidula	Herb	The	A1	x	x
OXALIDACEAE					
Oxalis divaricata	Herb	The		x	
Oxalis glaucescens	Herb	The		x	
PASSIFLORACEAE					
Passiflora cincinnata	WC	Phan		x	
Passiflora foetida	NWC	The		x	
Piriqueta racemosa	Herb	The		x	
Piriqueta duarteana	Herb	The		x	
Turnera cearensis	Herb	The		x	
Turnera subulata	Herb	The		x	
PHYLLANTHACEAE					
Phyllanthus amarus	Herb	The	A1	x	x
Phyllanthus carolinensis	Herb	The	A1	x	x
Phyllanthus heteradenius	Herb	The		x	
PHYTOLACACEAE					
Microtea paniculata	Herb	The		x	
Microtea glochidiata	Herb	The		x	
PLUMBAGINACEAE					
Plumbago scandens	Herb	The		x	
PLANTAGINACEAE					
*Angelonia biflora***	Herb	The	A1	x	x
*Angelonia campestris***	Herb	The		x	
*Bacopa angulata***	Herb	The	A1	x	x
Bacopa sp.	Herb	The	A1	x	x
Scoparia dulce	Herb	The		x	
Stemodia sp.	Herb	The		x	
POACEAE					
Anthephora hermaphrodita	Herb	The	A1	x	x
Aristida adscensionis	Herb	The		x	
Aristida elliptica	Herb	The		x	
Aristida setifolia	Herb	The		x	
Bouteloua americana	Herb	The		x	
Bouteloua aristoides	Herb	The		x	
*Cenchrus ciliaris**	Herb	The	A1	x	x
Chloris virgata	Herb	The		x	
Cynodon dactylon	Herb	The	A1	x	x
*Dactyloctenium aegyptium**	Herb	The		x	
*Digitaria bicornis**	Herb	The		x	
*Digitaria sanguinalis**	Herb	The		x	
*Echinochloa colona**	Herb	The	A1	x	x
*Eleusine indica**	Herb	The		x	
Enteropogon mollis	Herb	The		x	
*Eragrostis cilianensis**	Herb	The		x	
*Eragrostis ciliares**	Herb	The		x	
Eragrostis hypnoides	Herb	The		x	
Eragrostis maypurensis	Herb	The		x	
*Eragrostis pilosa**	Herb	The		x	
Eragrostis tenella	Herb	The		x	
Hymenachne amplexicaulis	Herb	The	A1	x	x
*Hyparrhenia rufa**	Herb	The		x	
Leptochloa panicea subsp. *Brachiata*	Herb	The		x	
*Melins repens**	Herb	The		x	
Mesosetum pappophorum	Herb	The		x	
*Neesiochloa barbata***	Herb	The		x	
Panicum peladoense	Herb	The		x	
Panicum trichoides	Herb	The		x	
Paspalum fimbriatum	Herb	The		x	
Paspalum maritimum	Herb	The		x	
*Paspalum scutatum***	Herb	The		x	
Paspalum pleostachyum	Herb	The		x	
Setaria parviflora	Herb	The		x	
Sorghum arundinaceum	Herb	The		x	
Sporobolus pyramydatus	Herb	The		x	
Tragus berteronianus	Herb	The		x	
*Urochloa fusca**	Herb	The		x	
*Urochloa mollis**	Herb	The		x	
*Urochloa plantaginea**	Herb	The		x	
POLYGALACEAE					
Asemeia violacea	Herb	The		x	
Monnina insignis	Herb	The		x	
Polygala bryoides	Herb	The		x	
Polygala longicaulis	Herb	The		x	
Polygala paniculata	Herb	The		x	
PONTEDERIACEAE					
Heteranthera oblongifolia	Herb		A1		x
PORTULACACEAE					
Portulaca halimoides	Herb	The		x	

Table 2 (continued) – List of plant species recorded in the Seridó Ecological Station (ESEC Seridó), Serra Negra do Norte Municipality, Rio Grande do Norte State.

Group, family and species	Habit	LF ter	LF aqu	TER	AQUA
Portulaca elatior	Herb	The		x	
Portulaca oleracea	Herb	The		x	
TALINACEAE					
Talinum triangulare	Herb	The		x	
RHAMNACEAE					
Crumenaria decumbens	Herb	The		x	
RUBIACEAE					
Borreria scabiosoides	Herb	The	A1	x	x
Diodella teres	Herb	The		x	
Mitracarpus baturitensis	Herb	The		x	
Mitracarpus salzmannianus	Herb	The		x	
Oldenlandia corimbosa	Herb	The		x	
Oldenlandia filicaulis	Herb	The		x	
Richardia grandiflora	Herb	The		x	
Staelia virgata	Herb	The		x	
Spermacoce tenuior	Herb	The	A1	x	x
SAPINDACEAE					
Cardiospermum corindum	WC	Phan		x	
SOLANACEAE					
Melananthus ulei	Herb	The		x	
*Physalis angulata**	Herb	The		x	
Physalis pubescens	Herb	The		x	
Schwenckia americana	Herb	The		x	
Solanum agrarium	Herb	The	A1	x	x
Solanum americanum	Herb	The		x	
Solanum sisymbriifolium	Herb	The	A1	x	x
TYPHACEAE					
Typha angustifolia	Herb		A1		x
URTICACEAE					
Laportea aestuans	Herb	The		x	
VERBENACEAE					
Lantana camara	Shrub	Phan		x	
Stachytarpheta angustifolia	Herb	The		x	
Stachytarpheta sanguinea	Herb	The		x	
VIOLACEAE					
Hybanthus calceolaria	Herb	The		x	
VITACEAE					
Cissus verticillata	WC	Phan		x	
Cissus simsiana	WC	Phan		x	
ZYGOPHYLLACEAE					
Kallstroemia tribuloides	Herb	The		x	
*Tribulus terrestris**	Herb	The		x	

Table 3 – Most representative plant families in floristic studies that focused on the non-woody component of Caatinga.
Ast = Asteraceae, Cac = Cactaceae, Con = Convolvulaceae, Cyp = Cyperaceae, Eup = Euphorbiaceae, Fab = Fabaceae, Mal = Malvaceae, Poa = Poaceae, Rub = Rubiaceae.

Reference	N° of reported families	N° of reported genera	N° of reported species	Most representative families
This study	68	189	307	Fab, Poa, Cyp, Con, Ast
Araújo et al. (2002)	58	190	354	Poa, Ast, Fab, Eup, Con
Feitoza (2004)	28	47	53	Eup, Poa, Con, Cac
Pessoa et al. (2004)	24	45	54	Poa, Ast, Eup
Reis et al. (2006)	36	62	73	Mal, Poa, Eup, Con, Fab
Silva et al. (2009)	39	75	95	Poa, Eup, Ast, Con, Cyp

Proportion of woody and non-woody species in the community

Our sampling resulted in 209 native herbaceous plants, 31 subshrubs, 27 herbaceous climbers (25 therophytic and 2 geophytic), totaling 267 non-woody plants, plus one parasitc species. The woody component consisted of 16 native trees, 8 shrubs and 15 woody (phanerophytic) climbers, totaling 39 woody species (fig. 4A). In the terrestrial habitat, the therophytic life form is by far the most common, representing 233 species (79% of the local plant community). Phanerophytic woody plants represented only 39 species, or 13% of the sampled richness (fig. 4B). In the aquatic ecosystem, the most common life forms were those attached to the substrate, with emergent hydrophytes as the most common. The free floating life form was found in only two species (table 2, fig. 4C).

The two previously available phytosociological studies (Amorim et al. 2005, Santana & Souto 2006) sampled together 5,695 individuals summing up only 25 species. We clearly see from this sampling that the cumulative richness of woody plants almost reached an asymptote for the alpha diversity of each site (fig. 5).

Evaluating the relative importance of woody versus non-woody species across caatinga *sensu stricto* sites (table 4, fig. 6), we found that non-woody plants are a very important component of this vegetation (Alcoforado-Filho et al. 2003, Lourenço & Barbosa 2003, Costa et al. 2007, 2009, Santos et al. 2009, Araújo et al. 2011). The proportion of non-woody plants ranged from 30 to over 80% of the local richness, and non-woody plants represented over 50% of the richness in most sites (table 4, fig. 6), showing that the predominance of non-woody plants is a common feature in this semiarid ecosystem.

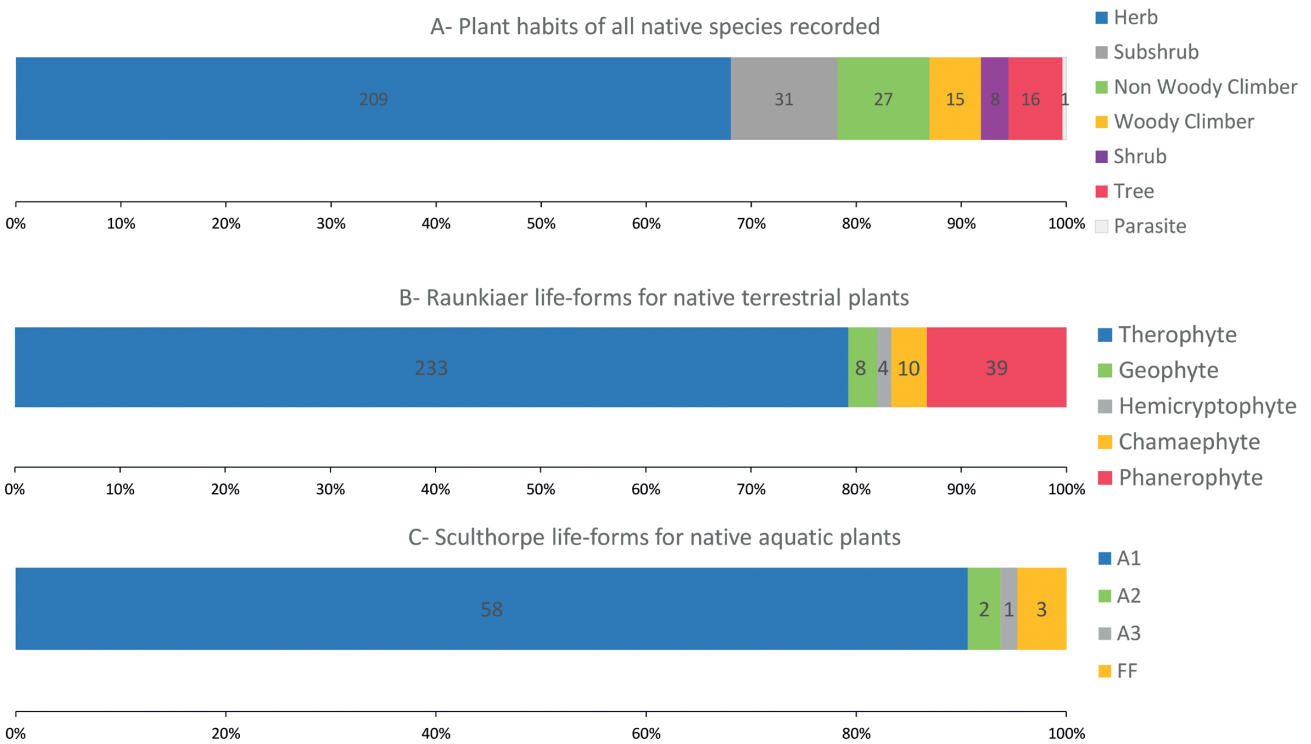

Figure 4 – A, plant habit spectrum for all 307 native species recorded; B, Raukiaer life form spectrum for the Seridó Ecological Station (ESEC Seridó) considering the 294 native terrestrial plants recorded; C, Sculthorpe life form spectrum for the Seridó Ecological Station (ESEC Seridó) considering the 64 native aquatic plants recorded.

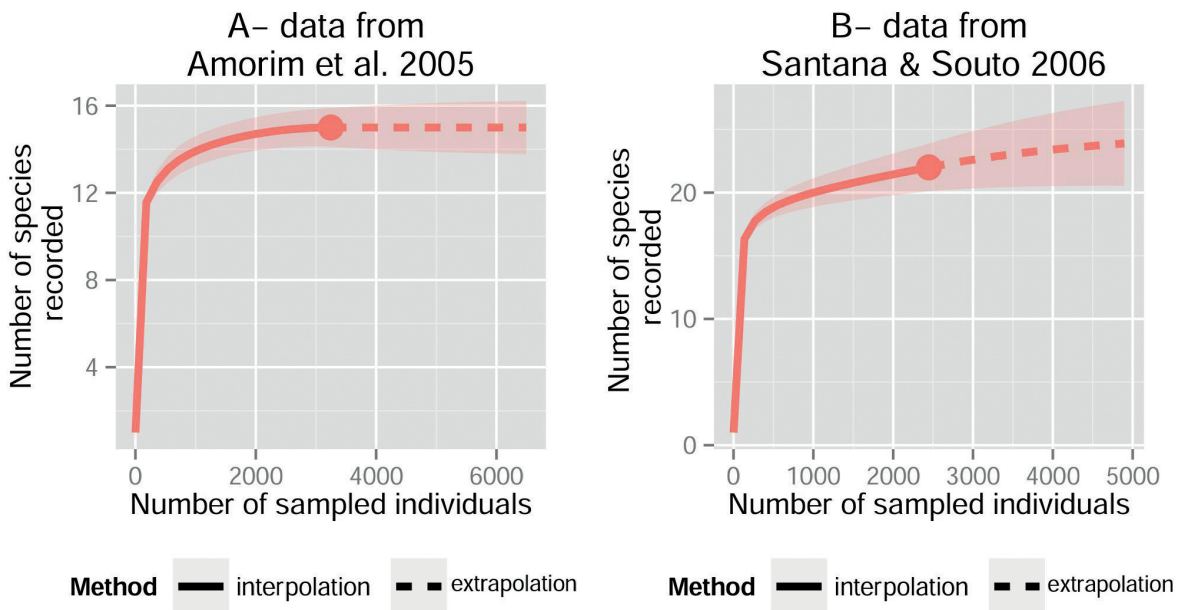

Figure 5 – Abundance-based interpolation curve (also known as rarefied species accumulation curve - solid red line) showing the cumulative number of species recorded by each previously published phytosociological study at the Seridó Ecological Station (ESEC Seridó). We also present here an extrapolated sampling curve (dashed red line) showing that even if the authors had made a sampling effort two times greater the actual sampling, the expected extra number of reported woody species to be collected would be very small. The transparent red area around each line is the 95% confidence interval for the sampling.

Table 4 – Number of woody versus non-woody species in caatinga *sensu stricto* vegetation calculated from floristic surveys made across the Brazilian semiarid region.
To calculate these numbers we excluded from each list records not identified to species level and exotic species.

Area code	Site	Non Woody	Epiphyte	Parasite / Hemiparasite	Woody	Total number of native species	Reference
Caat-Seridó	ESEC Seridó, Serra Negra do Norte, Rio Grande do Norte state	267	-	1	39	307	This study
Caat01	Serra das Almas Reserve, Crateus, Ceará state	80	-	-	43	123	Araújo et al. (2011)
Caat02	Quixadá, Ceará state	68	-	-	36	104	Costa et al. (2007)
Caat03	Betânia/Floresta, Pernambuco state	52	3	-	33	88	Costa et al. (2009)
Caat04	Floresta, Pernambuco state	32	-	-	14	46	Santos et al. (2009)
Caat05	Caruaru, Pernambuco state	29	-	-	48	77	Alcoforado-Filho et al. (2003)
Caat06	Lagoa Seca, Paraíba state	28	1	1	61	91	Lourenço & Barbosa (2003)

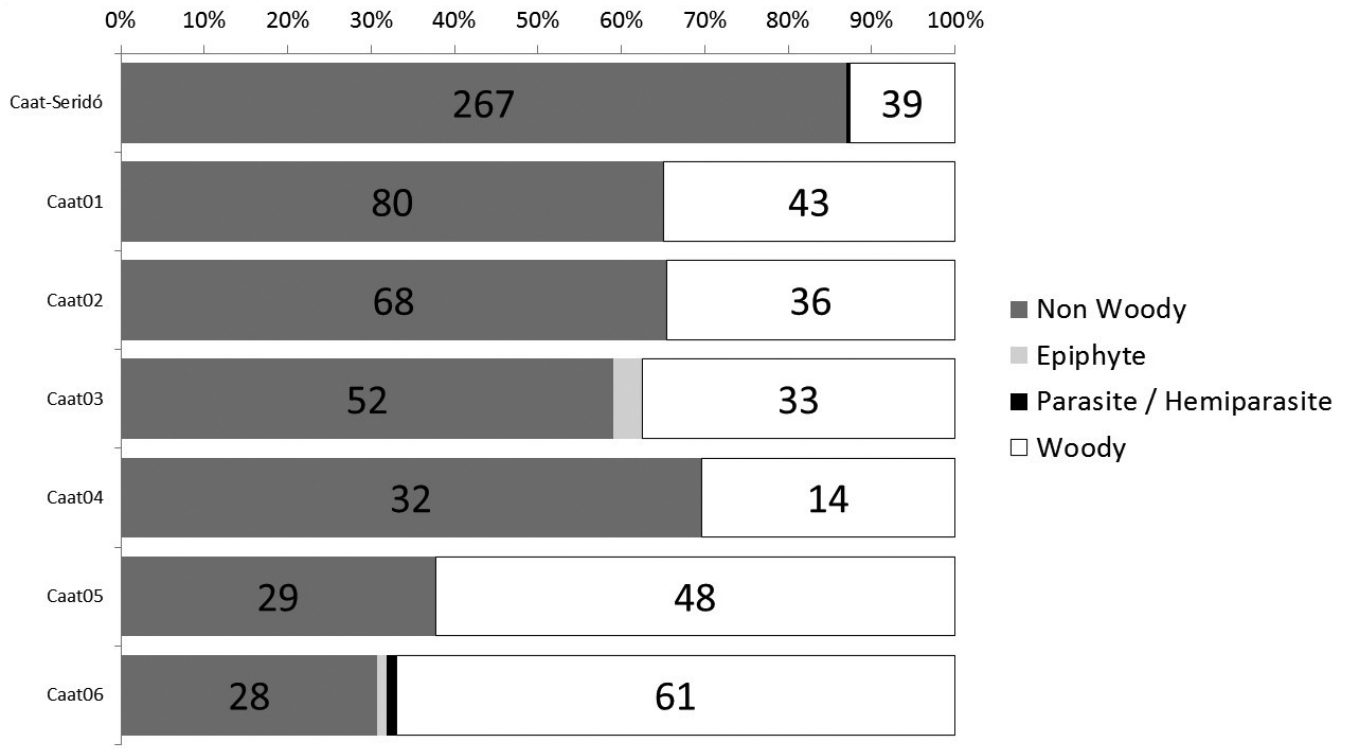

Figure 6 – Proportion of woody versus non-woody species reported in different floristic surveys made across the caatinga *sensu stricto* vegetation.

DISCUSSION

Non-woody plants are a major component of open vegetation such as the savannas and the semiarid caatinga *sensu stricto* vegetation (Batalha & Martins 2002, Sano et al. 2008, Moro et al. 2014a). Nevertheless, much more data is available for woody plants in the Caatinga than for non-woody plants (Moro et al. 2014a). This is problematic because in this vegetation the non-woody plants were predominant in most sites analyzed (table 4, fig 6). Moreover, floristic studies are used as foundational data for integrative macroecological and biogeographical studies. Up to date the vast majority of these studies have focused only on the patterns revealed by the most widely available data for woody species (Oliveira-Filho & Fontes 2000, Ratter et al. 2003, Santos et al. 2012). But in the Brazilian semiarid, the patterns inferred for woody plants can be different from those expressed by the non-woody assemblages (Moro et al. 2015b). This means that conclusions drawn from macroecological studies focusing on woody plants in semiarid ecosystems will not necessarily hold for non-woody species.

The historical focus on woody species in botanical surveys in the Caatinga can even lead to conservational problems, as conservation policies traditionally focused on creating nature reserves in areas with high species richness. The Caatinga Phytogeographical Domain is strongly threatened by deforestation, anthropogenic fire, desertification, overgrazing and logging (Sampaio 1995, 2010, Castelletti et al. 2003, Miles et al. 2006). Yet, it is one of the least protected ecosystems of Brazil (Castelletti et al. 2003, Menezes et al. 2010). This may be a consequence of the notion that dry ecosystems are less valuable for conservation, reflecting the idea that semiarid ecosystems are species-poor environments. This vision is aggravated in the Seridó region because this area has a very small number of recorded woody species in the floristic-phytosociological literature (Amorim et al. 2005, Santana & Souto 2006).

Indeed, our estimation of asymptotic alpha-diversity for woody plants in Seridó suggests the richness of woody plants to be low (fig. 5), but in this area the non-woody component is clearly predominant (figs 4 & 6). The previous phytosociological studies recorded only 25 woody species (table 1), and our floristic study recorded only 39 woody species. In a general synthesis for the Caatinga Domain (Moro et al. 2015a), the Seridó also appeared as one of the least species-rich regions of Caatinga. Here we show that the alpha-diversity of the Seridó is quite high, but the plant diversity is strongly concentrated in the usually overlooked non-woody component (table 2, fig. 4). While we compiled 267 non-woody species, we could find only 39 woody species for the site, totaling 307 native species in the ESEC Seridó (15 endemic to Brazil). A high proportion of non-woody species is a feature also found in other Caatinga sites, where non-woody plants commonly represent over 50% of the local plant communities (table 4, fig. 6).

We also call attention to the diversity of aquatic plants in the Caatinga Domain. In a similar fashion to what happens with non-woody terrestrial plants, aquatic plants have been largely ignored by botanists in the region, and only in the last decade a growing number of floristic studies have focused on this habitat (Moro et al. 2014b, 2015a).

It is noteworthy that therophytes are by far the most important life form in the local flora in the ESEC Seridó, reflecting the high importance of non-woody plants for the biodiversity of semiarid ecosystems (Costa et al. 2007, 2009, Araújo et al. 2011). In semiarid ecosystems, both therophytes and phanerophytes are relevant floristic elements in terms of species number (Costa et al. 2007, 2009, Araújo et al. 2008, 2011, Porto et al. 2008, Gomes & Alves 2010, Mendes & Castro 2010). But the caatinga *sensu stricto*, located on the shallow soils of the crystalline basement, were richer in therophytes (Costa et al. 2007, 2009, Araújo et al. 2011), while sites over the deep soils of sedimentary basins have more phanerophytes (Mendes & Castro 2010, Araújo et al. 2011). We also expect that rainfall gradients influence the local spectra, with drier sites having more therophytes than wetter ones. In fact, the Seridó is one of the driest areas of Caatinga and 79% of its flora was composed by therophytes, the largest proportion of therophytes ever reported to a site in the Caatinga Domain (Costa et al. 2007, 2009, Araújo et al. 2008, 2011, Porto et al. 2008, Gomes & Alves 2010, Mendes & Castro 2010). On the other hand, one of the sites included in our comparison had a proportion of non-woody plants of only 30% (fig. 6), and this was precisely the wettest site, with an annual rainfall of 901 mm (Lourenço & Barbosa 2003). We suggest that botanists working in seasonally dry tropical vegetation should also spend time in collecting and recording herbaceous species. In these dry ecosystems, therophytes can be the richest component of plant communities. Nevertheless, such component has received little attention.

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