

A check list of plant species in the urban forestry of Fortaleza, Brazil: where are the native species in the country of megadiversity?

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Abstract Although Brazil is recognized as a country of megadiversity many Brazilian cities have an overwhelming number of exotic street trees in their urban environments. Here we investigate this situation in the city of Fortaleza, Brazil's fifth largest city. Through an extensive qualitative survey, complemented by published quantitative surveys, we developed the most complete inventory done to date in Fortaleza. We registered the largest possible number of plant species which we could record in the public treescape of the city. We recorded 219 tree species, of which 158 were exotic to Fortaleza's ecosystems. Of the 61 native species, some were represented only by relictual individuals spared during urban growth and only 39 native species were cultivated plants. Most of these 39 cultivated natives are represented by a small number of individuals in the city, while most of common trees are exotic species. We show that many native plants that are potentially suitable for ornamental use in urban settings are being ignored and argue that exotics are overvalued, including some plants that are invasive. We also discuss the consequences of the predominance of alien species for the public perception of native biodiversity. We advocate that increasing the number of native plants in cities has many advantages from an ecological perspective.

Keywords Treescaping · Street trees · Ornamental plants · Exotic species · Urban biodiversity

Introduction

Urban trees bring many benefits to a city. They reduce the heat island effect, provide shade, contribute to psychological well-being and play an important role in maintaining biodiversity within urban environments (Lombardo 1985; Kweon et al. 1998; Sukopp 2004; Wong and Yu

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2005; Dearborn and Kark 2010). A further, rarely recognized role that urban trees and garden plants can play is to introduce native biodiversity to the people living in cities. In a heavily urbanized world, people live mainly in urban ecosystems and usually do not have contact with, or knowledge about, plants that occur outside cities. If the majority of plants in a city are aliens, the urban people's knowledge of native biodiversity may be reduced, as well as support for the conservation of biodiversity (McKinney 2006; Dearborn and Kark 2010).

Another aspect to be considered is that garden plants and urban trees may provide a pathway for disseminating invasive plants (Richardson 1998; Harrington et al. 2003; Pemberton and Liu 2009). Although most of the exotic species introduced to an area may not cause problems, given the astonishing number of alien ornamental plants available in the market (Lorenzi and de Souza 2008; Cullen et al. 2011), it is not surprising that the horticultural industry is responsible for many cases of plant invasions (Harrington et al. 2003; Richardson and Rejmánek 2011; Zenni 2013). If a higher proportion of plants cultivated as garden and street trees were native, we would expect a reduction in exotic plants escaping cultivation, combined with an increase in appreciation for native plants and a higher public awareness about conservation concerns (Harrington et al. 2003; McKinney 2006; Pemberton and Liu 2009; Dearborn and Kark 2010).

Brazil is known as a country of megadiversity and is home to more plant species than any other country in the world (Lewinsohn and Prado 2002; Forzza et al. 2010). Given Brazil's proactive role in the conservation of biodiversity, and the widely acknowledged advantages of using native species in urban treescapes, one might expect to find native species as common ornamental species in many Brazilian cities. However, this is not the case, and many Brazilian cities have treescapes composed mostly of exotic plants, surpassing by far the native trees in both numbers of species and abundance of individuals (Rocha et al. 2004; Santos et al. 2009; Barros et al. 2010; Moro and Westerkamp 2011; Moro et al. 2014).

In order to promote discussion on the role of native biodiversity in urban forestry we produced the most comprehensive species list to date for the trees and large shrubs occurring in public spaces in the city of Fortaleza, one of the largest cities in Brazil. Our objectives were to:

- (1) Provide a comprehensive species list of woody plants in the urban public areas of Fortaleza, in Northeastern Brazil;
- (2) Document the proportion of exotic versus native species used in Fortaleza's treescape;
- (3) Assess how many of the exotic species present in Fortaleza's treescape have been recorded as invasive in Brazil as a whole, and in Fortaleza in particular;
- (4) Estimate how many native species occurring in natural ecosystems of coastal Ceará are not represented in the urban treescape of Fortaleza. This aims to illustrate the untapped potential for use of this native biodiversity in an urban setting.

Methods

The study site

Fortaleza is the capital of Ceará state, in northeastern Brazil (Fig. 1). It is the fifth largest city in the country, with a population of 2,452,185 (IBGE 2010). It is a coastal city (3°43'02"S 38°32'35"W), 16 m above sea level with a tropical sub-humid climate. It has an annual rainfall of 1338 mm and a mean temperature of 26–28°. The original vegetation of the city included coastal semi-deciduous forests ("mata de tabuleiro"), coastal savannas ("cerrados costeiros"),

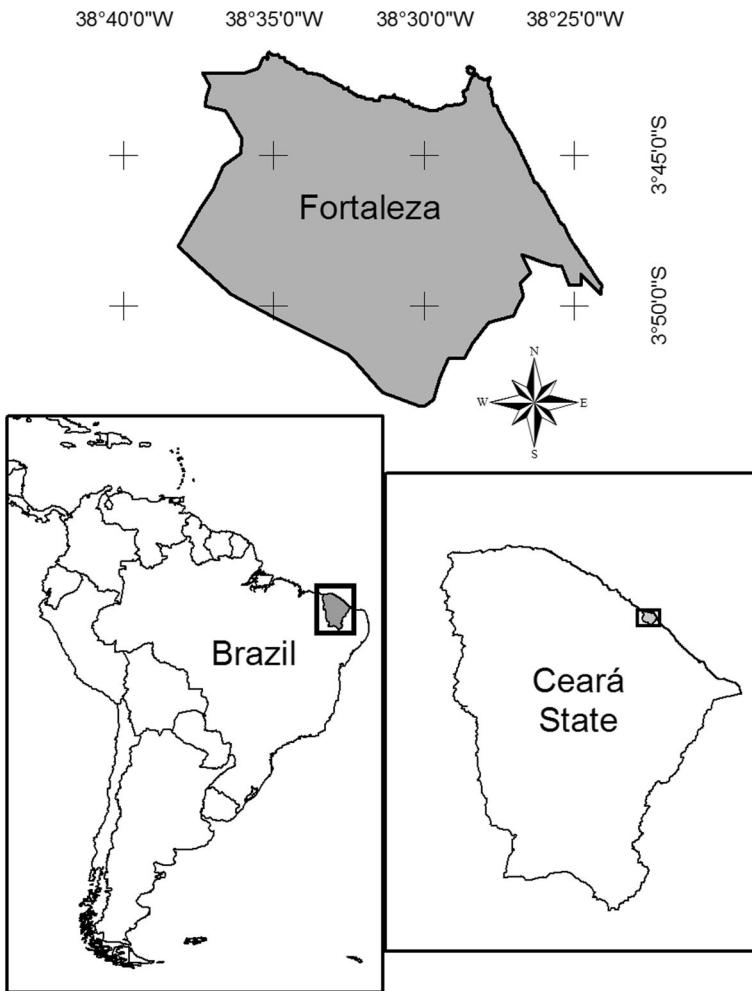


Fig. 1 Geographical position of the municipality of Fortaleza within Brazil and Ceará state

mangroves, dunes, “restinga” vegetation and, in the southern part of the municipality, dry woodlands known as Caatinga (Figueiredo 1997; Fortaleza 2003; Moro et al. 2011). Fortaleza grew from less than 50,000 people at the beginning of the twentieth century to more than two million at the end of the same century. This rapid and extensive urban growth resulted in a significant reduction of the original vegetation, which is now restricted to less than 10 % of its original extent and mostly reduced to vegetation fragments (Fortaleza 2003; Moro et al. 2011).

The list of species in public treescape of Fortaleza

This check list is based on more than 10 years of qualitative observations of urban trees in the city. During this time the authors visited most of Fortaleza’s regions, from low-income, peripheral districts, to rich districts located in the beach front. We visited long established districts, such as the downtown and surrounding areas (Centro, Jacarecanga, Benfica, Montese districts, some of these districts being over one hundred years old), as well as newly urbanized

areas or areas currently under urban development (Cocó and Sapiranga regions). In each of these districts we recorded the species present in public spaces (streets and squares) of the city in the last decade. In our list, we considered only trees and large shrubs present in streets, squares and parks, but not those present in native vegetation fragments or private spaces. We included in our survey all plants which could attain at least 3 m in height, excluding lianas. We classified species as native if they were known to occur naturally in the coastal region of Ceará or in the adjacent Caatinga dry forest vegetation (Figueiredo 1997). Species that do not occur naturally in the native ecosystems surrounding the city were classified as exotics. Exotic species were further subdivided to distinguish plants which are not native to Fortaleza but are considered native somewhere in Brazil, here termed ‘Exotic to Fortaleza’, from those species which are exotic to Brazil as a whole, termed ‘Exotic to Brazil’. Based on this list we calculated how many native and exotic species were present in the treescape of the city.

We further classified the species in our list according to whether they are considered invasive somewhere in Brazil, following Zenni and Ziller’s (2011) preliminary list of invasive plants of Brazil. Since Brazil has many ecosystems and a species may be invasive in one ecosystem but not in another, we also provide data for each exotic plant stating whether it is naturalized or invasive in the urban vegetation fragments of Fortaleza. We applied the terms naturalized and invasive exotic species according to the concepts of Richardson et al. (2000), i.e. the species must be able to reproduce and maintain a self replacing population in an urban vegetation fragment or in semi-natural areas inside Fortaleza limits to be considered naturalized, and it should spread autonomously to be considered invasive (Richardson et al. 2000).

A tree or shrub may be present in a city because it was cultivated by humans, but also because it was present in natural vegetation and was spared when urbanization took place, or even because it grew spontaneously within the city after urbanization had occurred. A further classification was then necessary to distinguish the reasons for why trees are present in the city. We classified as *cultivated plants* those deliberately grown by people in the city due aesthetic or functional purposes (e.g. shade or fruit trees). Some plant species (both native and invasive) manage to survive in heavily urbanized areas, despite being never or rarely planted in Fortaleza. Such plants maintain viable populations inside the city through wind or animal dispersal and germinate in streets, squares, gardens, backyards, parks or in wastelands. We classified those as *self established plants*. Some bat dispersed plants (as the alien *Ficus microcarpa* and the native *Ficus elliotiana* and *Piper tuberculatum*), for example, fall in this category. Additionally, some trees are spared when land clearing occurs for urban growth and eventually these plants, although not cultivated, may be incorporated into the treescape of the city. These plants were classified as *remaining plants*.

To determine whether a species was *cultivated*, *remaining* or *self-established* we made informal observations on which species are available for purchase from nurseries and also observed which species are planted by citizens in front of their houses. Species we know to be available in nurseries or species we could see planted by citizens were considered *cultivated*. A few species (e.g. the native *Ficus elliotiana* and *Piper tuberculatum* and the exotic *Calotropis procera*) we could never find as cultivated individuals, but we could locate self-established seedlings of these species and monitored these to reproductive age as fully grown individuals. These were considered self-established species. Other species such as *Himatanthus drasticus* and *Andira surinamensis* were never observed as cultivate or as self-established plants, but these species are known to remain in natural vegetation fragments in Fortaleza (Moro et al. 2011). We were able to observe fully grown individuals of a few native and exotic species spared and incorporated in the forestry of the city in recently urbanized

districts, and thus, considered these species to be *remaining* species within the city, as these were neither cultivated nor self-established individuals.

These three categories are not mutually exclusive and a species may be represented in the city by a combination of planted, remaining and self established individuals (e.g. the native *Copernicia prunifera* and *Guazuma ulmifolia* and the naturalized *Mangifera indica*, see Table 1).

We also classified each species on a subjective abundance scheme, from rare species to very common ones. This is a subjective classification based primarily on our observations of the city's trees over many years, but a few quantitative surveys of forestry in some Fortaleza's districts are available, which we also took into account (Borges 2002; Moro and Westerkamp 2011; Moro et al. 2014). The five most abundant species in the quantitative surveys available in the literature (Moro and Westerkamp 2011; Moro et al. 2014) were classified as "very common"; species commonly found within the city in many different districts and usually with a moderate abundance were classified as "common"; species easily found around the city, but not in most of the districts, and usually represented by a small number of individuals, were classified as "moderate"; species recorded only in a few districts, usually in small number, and not frequently found around the city were classified as "rare". Although a subjective classification, this scheme conveys a general impression of the relative frequency and abundance of native and exotic species to facilitate discussion.

Comparing the number of exotic versus native species and estimating the number of excluded native species in the city

We aimed not only to document the proportions of native and exotic species in the urban treescape of Fortaleza, but also to explore the untapped potential for urban horticulture of the many native tree species of the coastal region of Ceará. To address the former point we calculated from our urban species list the ratio of native to exotic species. To address the latter question we compared our species list of Fortaleza's treescape with the lists of native trees and large shrubs in published surveys of the natural ecosystems of coastal Ceará (Matias and Nunes 2001; Moro et al. 2011; Castro et al. 2012).

Results

We recorded 219 species of trees and large shrubs in the public treescape of Fortaleza (Table 1). The families best represented as urban trees were Fabaceae (41 species), Arecaceae (36 species), Malvaceae (13), Bignoniaceae (12) and Anacardiaceae (10), together accounting for 51 % of the species in our list (Fig. 2). Exotic plants comprise the great majority of our list, contributing 158 species. Of these, 124 species were exotic to all ecosystems of Brazil and 34 were native elsewhere in Brazil, but exotic to Fortaleza (Fig. 3). Plants native to Fortaleza's ecosystems accounted for only 61 species or 28 % of the total (Fig. 3). All "very common" species in our survey (defined as the five most abundant species in Moro et al. 2014 and Moro and Westerkamp 2011 studies) were exotic (Fig. 4). In contrast, 44 (72 %) of the 61 natives were classified in the category "rare" (Table 2; Fig. 4).

Of the 219 species in our list, 195 are cultivated by humans in Fortaleza's public horticulture or landscaping, 44 species have remaining individuals that were spared when clearance occurred for urban expansion, and 29 species have self established individuals that grew by themselves in the city (a particular species may fall into more than one of these categories—Table 1). The majority of the 61 native plants in Fortaleza's treescape are represented as remaining

Table 1 List of trees and large shrubs in the urban treescape of Fortaleza, Brazil, with their vernacular names (where available), origin and information if the species is invasive in Brazil or within Fortaleza. “F” means that the species is naturalized or invasive (sensu Richardson et al. 2000) in vegetation fragments of Fortaleza, following our own field observations; “B” means that the species is reported as invasive somewhere in Brazil according to the list published by Zenni and Ziller (2011). Cultivated species are those voluntarily cultivated by humans; Self Established species are those that set fruit, disperse and autonomously establish new individuals in urban spaces; Remaining species are native or exotic species occurring in natural or semi-natural areas which are spared when land clearing occur, thereafter being incorporated into the urban treescape. The subjective abundance classification is based in quantitative surveys of the city’s street trees (Moro and Westerkamp 2011; Moro et al. 2014) and our field experience, and reflect the degree of abundance and frequency of each species in public spaces, varying from “rare” to “very common” plants. Native—species native to the original ecosystems of Fortaleza or the adjacent Caatinga dry forests; Exotic-Fortaleza—species exotic to Fortaleza, but native somewhere in Brazil; Exotic-Brazil—species exotic to Brazil

N°	Family	Species	Popular name	Origin	Invasive or naturalized	Cultivated	Self established	Remaining	Subjective abundance classification
Gymnosperms									
1	ARAUCARIACEAE	<i>Araucaria heterophylla</i> (Salisb.) Franco	Pinheiro-de-natal	Exotic-Brazil		X			Rare
2	CUPRESSACEAE	<i>Chamaecyparis obtusa</i> (Siebold & Zucc.) Endl.		Exotic-Brazil		X			Rare
3	CUPRESSACEAE	<i>Cupressus</i> sp.		Exotic-Brazil		X			Rare
4	CUPRESSACEAE	<i>Juniperus chinensis</i> L.		Exotic-Brazil		X			Rare
5	CUPRESSACEAE	<i>Platycladus orientalis</i> (L.) Franco	Tuia	Exotic-Brazil		X			Rare
6	CYCADACEAE	<i>Cycas thouratii</i> R.Br.	Cicas	Exotic-Brazil		X			Moderate
7	PINACEAE	<i>Pinus</i> sp.	Pinheiro	Exotic-Brazil		X			Rare
8	PODOCARPACEAE	<i>Podocarpus macrophyllus</i> (Thunb.) Sweet	Podocarpus	Exotic-Brazil		X			Rare
Angiosperms									
9	ANACARDIACEAE	<i>Anacardium occidentale</i> L.	Cajuzeiro	Native		X	X	X	Moderate
10	ANACARDIACEAE	<i>Astronium fraxinifolium</i> Schott ex Spreng.	Gonçalo-alves	Native				X	Rare
11	ANACARDIACEAE	<i>Mangifera indica</i> L.	Mangueira	Exotic-Brazil	F and B	X	X	X	Common
12	ANACARDIACEAE	<i>Myracrodruon urundeuva</i> Allemão	Aroeira	Native		X			Rare
13	ANACARDIACEAE	<i>Schinus molle</i> L.	Aroeira-salsa	Exotic-Fortaleza		X			Rare
14	ANACARDIACEAE		Aroeira-da-praia	Exotic-Fortaleza		X			Rare

Table 1 (continued)

N°	Family	Species	Popular name	Origin	Invasive or naturalized	Cultivated	Self established	Remaining	Subjective abundance classification
<i>Schinus terebinthifolius</i>									
Raddi									
15	ANACARDIACEAE	<i>Spondias dulcis</i> Parkinson	Cajarana	Exotic-Brazil		X			Rare
16	ANACARDIACEAE	<i>Spondias mombin</i> L.	Cajazeira	Native		X	X		Rare
17	ANACARDIACEAE	<i>Spondias purpurea</i> L.	Siriguela	Exotic-Brazil		X			Rare
18	ANACARDIACEAE	<i>Tapirira guianensis</i> Aubl.	Pau-pombo	Native			X		Rare
19	ANNONACEAE	<i>Annona glabra</i> L.	Araucum-do-brejo	Native			X		Rare
20	ANNONACEAE	<i>Annona squamosa</i> L.	Ata	Exotic-Brazil		X			Moderate
21	ANNONACEAE	<i>Annona muricata</i> L.	Graviola	Exotic-Brazil		X			Rare
22	APOCYNACEAE	<i>Calotropis procera</i> (Aiton) Dryand.	Ciúme; hortênsia	Exotic-Brazil	F and B		X		Moderate
23	APOCYNACEAE	<i>Himatanthus drasticus</i> (Mart.) Plumel	Janaguba	Native				X	Rare
24	APOCYNACEAE	<i>Nerium oleander</i> L.	Espiradeira	Exotic-Brazil		X			Moderate
25	APOCYNACEAE	<i>Plumeria caracasana</i> J.R.Johnst.	Jasmim	Exotic-Brazil		X			Moderate
26	APOCYNACEAE	<i>Plumeria rubra</i> L.	Jasmim-manga	Exotic-Brazil		X			Moderate
27	APOCYNACEAE	<i>Tabernaemontana laeta</i> Mart.		Exotic-Fortaleza		X			Rare
28	APOCYNACEAE	<i>Thevetia peruviana</i> (Pers.) K.Schum.	Chapéu-de-Napoleão	Exotic-Fortaleza		X			Moderate
29	ARALIACEAE	<i>Polyscias guilfoylei</i> (W.Bull) L.H.Bailey	Árvore-da-felicidade	Exotic-Brazil		X			Moderate
30	ARALIACEAE	<i>Polyscias scutellaria</i> (Burm.f.) Fosberg		Exotic-Brazil		X			Rare
31	ARALIACEAE	<i>Schefflera actinophylla</i> (Endl.) Harms	Guarda-chuva	Exotic-Brazil		X			Moderate
32	ARECACEAE	<i>Acrocomia intumescens</i> Drude	Macatuba	Native		X	X		Rare
33	ARECACEAE	<i>Adonidia merrillii</i> (Becc.) Becc.	Palmeira-Havai	Exotic-Brazil		X			Moderate
34	ARECACEAE	<i>Alphans aculeata</i> Willd.	Corozo	Exotic-Fortaleza		X			Rare

Table 1 (continued)

N°	Family	Species	Popular name	Origin	Invasive or naturalized	Cultivated	Self established	Remaining	Subjective abundance classification
35	ARECACEAE	<i>Archontophoenix cunninghamiana</i> (H.Wendl.) H.Wendl. & Drude	Seafórtia	Exotic-Brazil	B	X			Rare
36	ARECACEAE	<i>Areca catechu</i> L.	Cateca	Exotic-Brazil		X			Rare
37	ARECACEAE	<i>Attalea speciosa</i> Mart. ex Spreng.	Babaçu	Native		X			Rare
38	ARECACEAE	<i>Bismarckia nobilis</i> Hildebr. & H.Wendl.	Bismarquia	Exotic-Brazil		X			Rare
39	ARECACEAE	<i>Carpentaria acuminata</i> (H. Wendl. & Drude) Becc.	Carpentária	Exotic-Brazil		X			Rare
40	ARECACEAE	<i>Caryota mitis</i> Lour.	Palmeira-mulambo	Exotic-Brazil		X			Moderate
41	ARECACEAE	<i>Caryota urens</i> L.	Palmeira-mulambo	Exotic-Brazil		X			Moderate
42	ARECACEAE	<i>Coccothrinax argentea</i> (Lodd.) Sarg. ex Becc.	Palmeira-leque	Exotic-Brazil		X			Rare
43	ARECACEAE	<i>Coccothrinax barbadensis</i> (Lodd. ex Mart.) Becc.	Palmeira-leque	Exotic-Brazil		X			Rare
44	ARECACEAE	<i>Cocos nucifera</i> L.	Coqueiro	Exotic-Brazil		X			Moderate
45	ARECACEAE	<i>Copernicia macroglossa</i> H.Wendl. ex Becc.	Camatuba-de-saia	Exotic-Brazil		X			Rare
46	ARECACEAE	<i>Copernicia prunifera</i> (Mill.) H.E. Moore	Camatuba	Native		X	X	X	Moderate
47	ARECACEAE	<i>Dypsis decaryi</i> (Jum.) Beenjje & J. Dransf.	Palmeira-triângulo	Exotic-Brazil		X			Moderate
48	ARECACEAE	<i>Dypsis lutescens</i> (H. Wendl.) Beenjje & J. Dransf.	Areca-bambu	Exotic-Brazil		X			Moderate
49	ARECACEAE	<i>Elaeis guineensis</i> Jacq.	Dendê	Exotic-Brazil	F and B	X			Rare
50	ARECACEAE	<i>Euterpe edulis</i> Mart.	Palmito	Exotic-Fortaleza		X			Rare
51	ARECACEAE	<i>Euterpe oleracea</i> Mart.	Açaí	Exotic-Fortaleza		X			Rare
52	ARECACEAE	<i>Hyophorbe lagenicaulis</i> (L.H.Bailey) H.E.Moore	Palmeira-garrafa	Exotic-Brazil		X			Rare

Table 1 (continued)

N°	Family	Species	Popular name	Origin	Invasive or naturalized	Cultivated	Self established	Remaining	Subjective abundance classification
53	ARECACEAE	<i>Phoenix dactylofera</i> L. ^a	Tamareira	Exotic-Brazil		X			Rare
54	ARECACEAE	<i>Pritchardia pacifica</i> Seem. & H. Wendl.	Palmeira-leque-de-Fiji	Exotic-Brazil		X			Moderate
55	ARECACEAE	<i>Psychosperma miacarthurii</i> (H.Wendl. ex H.J.Veitch) H. Wendl. ex Hook.f.		Exotic-Brazil		X			Moderate
56	ARECACEAE	<i>Roystonea borinquena</i> O. F. Cook	Palmeira-coca-cola	Exotic-Brazil		X			Moderate
57	ARECACEAE	<i>Roystonea oleracea</i> (Jacq.) O.F. Cook	Palmeira-imperial	Exotic-Brazil		X			Moderate
58	ARECACEAE	<i>Roystonea regia</i> (Kunth) O.F. Cook	Palmeira-real	Exotic-Brazil		X			Moderate
59	ARECACEAE	<i>Sabal maritima</i> (Kunth) Burret	Sabal	Exotic-Brazil		X			Moderate
60	ARECACEAE	<i>Sabal minor</i> (Jacq.) Pers.	Sabal-anão	Exotic-Brazil		X			Rare
61	ARECACEAE	<i>Saribus rotundifolius</i> (Lam.) Blume	Palmeira-leque	Exotic-Brazil		X			Rare
62	ARECACEAE	<i>Syagrus cearensis</i> Noblick	Côco-babão	Native		X			Moderate
63	ARECACEAE	<i>Syagrus oleracea</i> (Mart.) Becc.	Catolé	Exotic-Fortaleza		X			Rare
64	ARECACEAE	<i>Syagrus romanzoffiana</i> (Cham.) Glassman	Jerivá	Exotic-Fortaleza		X			Moderate
65	ARECACEAE	<i>Syagrus schizophylla</i> (Mart.) Glassman	Arcturiroba	Exotic-Fortaleza		X			Rare
66	ARECACEAE	<i>Veitchia arecina</i> Becc.	Veitia	Exotic-Brazil		X			Rare
67	ARECACEAE	<i>Wodyetia bifurcata</i> A.K.Irvine	Rabo-de-raposa	Exotic-Brazil		X			Moderate
68	ASPARAGACEAE	<i>Dracaena fragrans</i> (L.) Ker Gawl.	Pau-d'água	Exotic-Brazil	B	X			Moderate
69	ASPARAGACEAE	<i>Dracaena marginata</i> Lam.	Dracena	Exotic-Brazil		X			Moderate
70	ASPARAGACEAE	<i>Dracaena reflexa</i> Lam.	Pleomele	Exotic-Brazil		X			Moderate

Table 1 (continued)

N°	Family	Species	Popular name	Origin	Invasive or naturalized	Cultivated	Self established	Remaining	Subjective abundance classification
71	ASPARAGACEAE	<i>Yucca aloifolia</i> L.	Luca	Exotic-Brazil		X			Moderate
72	ASPARAGACEAE	<i>Yucca gigantea</i> Lem.	Luca	Exotic-Brazil		X			Moderate
73	ASPARAGACEAE	<i>Yucca gloriosa</i> L.	Luca	Exotic-Brazil		X			Rare
74	BIGNONIACEAE	<i>Crescentia cujete</i> L.	Coié	Exotic-Brazil		X			Rare
75	BIGNONIACEAE	<i>Handroanthus chrysotrichus</i> (Mart. ex DC.) Mattos	Ipê-amarelo	Exotic-Fortaleza		X			Moderate
76	BIGNONIACEAE	<i>Handroanthus impetiginosus</i> (Mart. ex DC.) Mattos	Ipê-roxo	Native		X			Moderate
77	BIGNONIACEAE	<i>Handroanthus serratifolius</i> (Vahl) S. O. Grose	Ipê-amarelo	Native		X			Moderate
78	BIGNONIACEAE	<i>Jacaranda brasiliana</i> (Lam.) Pers.	Caroba	Native		X			Moderate
79	BIGNONIACEAE	<i>Sparatospertia leucanthum</i> (Vell.) K.Schum.		Exotic-Fortaleza		X			Rare
80	BIGNONIACEAE	<i>Spathodea campanulata</i> P.Beauv.	Espatódia	Exotic-Brazil	B	X			Moderate
81	BIGNONIACEAE	<i>Tabebuia aurea</i> (Silva Manso) Benth. & Hook. f. ex S. Moore	Caraiúba	Native		X		X	Moderate
82	BIGNONIACEAE	<i>Tabebuia pallida</i> (Lindl.) Miers	Ipê-zinho	Exotic-Brazil		X			Moderate
83	BIGNONIACEAE	<i>Tabebuia rosea</i> (Bertol.) A. DC.	Ipê-rosa	Exotic-Brazil		X			Moderate
84	BIGNONIACEAE	<i>Tabebuia roseodoba</i> (Ridl.) Sandwith	Peroba	Native		X			Moderate
85	BIGNONIACEAE	<i>Tecoma stans</i> (L.) Juss. ex Kunth	Ipê-zinho-de-jardim	Exotic-Brazil	B	X			Moderate
86	BIXACEAE	<i>Bixa orellana</i> L.	Urucum	Exotic-Fortaleza		X			Rare
87	BIXACEAE	<i>Cochlospermum vitifolium</i> (Willd.) Spreng.	Pacotê	Native		X		X	Rare
88	BORAGINACEAE	<i>Cordia alliodora</i> (Ruiz & Pav.) Cham.	Louro-freijó	Exotic-Fortaleza		X			Rare
89	BORAGINACEAE	<i>Cordia oncocalyx</i> Allemão	Pau-branco	Native		X			Moderate
90	BORAGINACEAE	<i>Cordia toqueve</i> Aubl.	Jangada	Native				X	Rare

Table 1 (continued)

N°	Family	Species	Popular name	Origin	Invasive or naturalized	Cultivated	Self established	Remaining	Subjective abundance classification
91	CACTACEAE	<i>Cereus jamaicaru</i> DC.	Mandacaru	Native		X		X	Rare
92	CANNABACEAE	<i>Trema micrantha</i> (L.) Blume	Periquiteira	Native			X	X	Rare
93	CAPPARACEAE	<i>Cratava tapia</i> L.	Trapiá	Native		X	X	X	Rare
94	CARICACEAE	<i>Carica papaya</i> L.	Mamão	Exotic-Brazil		X	X		Rare
95	CASUARINACEAE	<i>Casuarina equisetifolia</i> L.	Casuarina; cipreste	Exotic-Brazil	B	X		X	Moderate
96	CHRYSOBALANACEAE	<i>Licania rigida</i> Benth.	Oititeca	Native		X			Moderate
97	CHRYSOBALANACEAE	<i>Licania tomentosa</i> (Benth.) Fritsch	Oiti	Native		X			Common
98	CLUSIACEAE	<i>Calophyllum inophyllum</i> L.	Landim	Exotic-Brazil		X			Moderate
99	CLUSIACEAE	<i>Platonia insignis</i> Mart.	Bacuri	Exotic-Fortaleza		X			Rare
100	COMBRETACEAE	<i>Combretum glaucocarpum</i> Mart.	Sipauba	Native				X	Rare
101	COMBRETACEAE	<i>Terminalia catappa</i> L.	Castanhola	Exotic-Brazil	F and B	X	X	X	Very common
102	COMBRETACEAE	<i>Terminalia mantaly</i> H.Perrier	Sete-copas	Exotic-Brazil		X			Rare
103	DILLENIACEAE	<i>Dillenia indica</i> L.	Flor-de-abril; Dilênia	Exotic-Brazil		X			Rare
104	EBENACEAE	<i>Diospyros inconsistans</i> Jacq.	Fruta-de-cabra	Native				X	Rare
105	EUPHORBIACEAE	<i>Codiaeum variegatum</i> (L.) Rumph. ex A.Juss.	Croto	Exotic-Brazil		X			Moderate
106	EUPHORBIACEAE	<i>Joannesia princeps</i> Vell.	Andaçu	Exotic-Fortaleza		X			Rare
107	EUPHORBIACEAE	<i>Manihot carthagenensis</i> subsp. <i>glaziovii</i> (Müll. Arg.) Allem	Maniçoba	Native		X			Rare
108	EUPHORBIACEAE	<i>Ricinus communis</i> L.	Mamona	Exotic-Brazil	F and B		X		Moderate
109	FABACEAE	<i>Acacia mangium</i> Willd.		Exotic-Brazil	B	X			Rare
110	FABACEAE	<i>Adenanthera pavonina</i> L.	Carolina	Exotic-Brazil		X			Moderate
111	FABACEAE	<i>Albizia lebeck</i> (L.) Benth.	Espõnjinha	Exotic-Brazil	F	X	X		Common
112	FABACEAE	<i>Albizia niopoides</i> (Spruce ex Benth.) Burkart	Angico-branco	Exotic-Fortaleza		X			Rare
113	FABACEAE		Angico	Native		X			Rare

Table 1 (continued)

N°	Family	Species	Popular name	Origin	Invasive or naturalized	Cultivated	Self established	Remaining	Subjective abundance classification
<i>Anadenanthera colubrina</i> (Vell.) Brenan									
114	FABACEAE	<i>Andira surinamensis</i> (Bondt) Splittg. ex Pulle	Angelim	Native				X	Rare
115	FABACEAE	<i>Bauhinia monandra</i> Kurz	Pata-de-vaca	Exotic-Brazil		X			Rare
116	FABACEAE	<i>Bauhinia variegata</i> L.	Pata-de-vaca	Exotic-Brazil		X			Rare
117	FABACEAE	<i>Bauhinia unguilata</i> L.	Mororó	Native			X	X	Rare
118	FABACEAE	<i>Caesalpinia echinata</i> Lam.	Pau-brasil	Exotic-Fortaleza		X			Moderate
119	FABACEAE	<i>Libidibia ferrea</i> (Mart. ex Tul.) L.P. Queiroz ^b	Jucá, pau-ferro	Native		X		X	Moderate
120	FABACEAE	<i>Caesalpinia pulcherrima</i> (L.) Sw.	Flamboiózinho	Exotic-Brazil		X			Rare
121	FABACEAE	<i>Cassia fistula</i> L.	Chuva-de-ouro	Exotic-Brazil		X			Moderate
122	FABACEAE	<i>Cassia grandis</i> L.f.	Canafistula	Exotic-Fortaleza		X			Rare
123	FABACEAE	<i>Cassia javanica</i> L.	Cássia-rosa	Exotic-Brazil		X			Rare
124	FABACEAE	<i>Chloroleucon acacioides</i> (Ducke) Barneby & J.W. Grimes	Arapiraca	Native				X	Rare
125	FABACEAE	<i>Clitoria fairchildiana</i> Howard	Acácia-azul; sombreiro	Exotic-Fortaleza	B	X			Moderate
126	FABACEAE	<i>Delonix regia</i> (Bojer ex Hook.) Raf.	Flamboyant	Exotic-Brazil		X			Moderate
127	FABACEAE	<i>Enterolobium timbouva</i> Mart.	Timbaúba	Native		X		X	Moderate
128	FABACEAE	<i>Erythrina indica</i> var. <i>picta</i> Hort.	Brasileirinho	Exotic-Brazil		X			Common
129	FABACEAE	<i>Erythrina velutina</i> Willd.	Mulungu	Native		X		X	Rare
130	FABACEAE	<i>Gliricidia sepium</i> (Jacq.) Kunth	Alvorada	Exotic-Brazil		X			Rare
131	FABACEAE	<i>Hymenaea courbaril</i> L.	Jatobá	Native		X		X	Rare
132	FABACEAE	<i>Inga edulis</i> Mart.	Ingá	Exotic-Fortaleza		X			Rare
133	FABACEAE	<i>Inga laurina</i> (Sw.) Willd.	Ingá	Native		X			Rare

Table 1 (continued)

N°	Family	Species	Popular name	Origin	Invasive or naturalized	Cultivated	Self established	Remaining	Subjective abundance classification
134	FABACEAE	<i>Inga vera</i> subsp. <i>affinis</i> (DC.) T. D. Penn.	Ingá	Native		X			Moderate
135	FABACEAE	<i>Leucaena leucocephala</i> (Lam.) DeWit	Leucena	Exotic-Brazil	F and B	X	X		Moderate
136	FABACEAE	<i>Dalstedtia araripensis</i> (Benth.) M.J. Silva & s.A.M.G. Azevedo	Angelim	Native			X	X	Rare
137	FABACEAE	<i>Mimosa caesalpinifolia</i> Benth.	Sabiá	Native		X			Rare
138	FABACEAE	<i>Parkia platycephala</i> Benth.	Visgueiro	Native		X			Rare
139	FABACEAE	<i>Peltophoron dubium</i> (Spreng.) Taub.	Munseu	Exotic-Fortaleza		X			Moderate
140	FABACEAE	<i>Pithecellobium dulce</i> (Roxb.) Benth.	Acácia-nimosa; Mata-fome	Exotic-Brazil	F	X	X		Common
141	FABACEAE	<i>Platymiscium floribundum</i> Vogel	Rabugeira	Native		X			Rare
142	FABACEAE	<i>Poincianella plaviosa</i> var. <i>peltophoroides</i> (Benth.) L. P. Queiroz	Sibiruna	Exotic-Fortaleza		X			Rare
143	FABACEAE	<i>Prosopis juliflora</i> (Sw.) DC.	Algaroba	Exotic-Brazil	B	X			Rare
144	FABACEAE	<i>Pterogyne nitens</i> Tul.	Madeira-nova	Exotic-Fortaleza		X			Rare
145	FABACEAE	<i>Samanea tubulosa</i> (Benth.) Barneby & J.W. Grimes	Bordão-de-velho	Native			X	X	Rare
146	FABACEAE	<i>Schizolobium parahybae</i> (Vell.) Blake	Guapuruvu	Exotic-Fortaleza		X			Rare
147	FABACEAE	<i>Senna stamea</i> (Lam.) Irwin & Barneby	Acácia	Exotic-Brazil		X			Very common
148	FABACEAE	<i>Tamarindus indica</i> L.	Tamarindo	Exotic-Brazil		X			Moderate
149	FABACEAE	<i>Vachellia seyal</i> (Delile) P.J.H. Hurter	Acácia-scial	Exotic-Brazil		X			Rare
150	LAMIACEAE	<i>Gmelina arborea</i> Roxb. ex Sm.	Guimelina	Exotic-Brazil		X			Moderate

Table 1 (continued)

N°	Family	Species	Popular name	Origin	Invasive or naturalized	Cultivated	Self established	Remaining	Subjective abundance classification
151	LAMIACEAE	<i>Vitex agnus-castus</i> L.	Pau-de-Angola	Exotic-Brazil		X			Rare
152	LAURACEAE	<i>Persea americana</i> Mill.	Abacate	Exotic-Brazil	B	X			Rare
153	LECYTHIDACEAE	<i>Couroupita guianensis</i> Aubl.	Abriçó-de-macaco	Exotic-Fortaleza		X			Moderate
154	LYTHRACEAE	<i>Lagerstroemia indica</i> L.	Resedá	Exotic-Brazil		X			Rare
155	LYTHRACEAE	<i>Punica granatum</i> L.	Romã	Exotic-Brazil		X			Rare
156	MALPIGHIACEAE	<i>Bunchosia armeniaca</i> (Cav.) DC.		Exotic-Brazil		X			Rare
157	MALPIGHIACEAE	<i>Byrsonima sericea</i> DC.	Murici	Native		X	X		Rare
158	MALPIGHIACEAE	<i>Lophanthera lactescens</i> Ducke	Lofantera	Exotic-Fortaleza		X			Rare
159	MALPIGHIACEAE	<i>Malpighia glabra</i> L.	Acerola	Exotic-Brazil		X			Rare
160	MALVACEAE	<i>Adansonia digitata</i> L.	Baobá	Exotic-Brazil		X			Rare
161	MALVACEAE	<i>Basiloxylon brasiliensis</i> (Allemão) K. Schum.	Piroá	Exotic-Fortaleza		X			Rare
162	MALVACEAE	<i>Ceiba pentandra</i> (L.) Gaertn.	Paineira	Exotic-Fortaleza		X			Moderate
163	MALVACEAE	<i>Ceiba speciosa</i> (A. St.-Hil.) Ravenna	Paineira-rosa	Exotic-Fortaleza		X			Rare
164	MALVACEAE	<i>Guazuma ulmifolia</i> Lam.	Mutamba	Native		X	X		Rare
165	MALVACEAE	<i>Hibiscus rosa-sinensis</i> L.	Papoula	Exotic-Brazil		X			Rare
166	MALVACEAE	<i>Hibiscus schizopetalus</i> (Dyer) Hook.f.	Papoula	Exotic-Brazil		X			Rare
167	MALVACEAE	<i>Pachira aquatica</i> Aubl.	Munguba	Exotic-Fortaleza		X			Common
168	MALVACEAE	<i>Sterculia foetida</i> L.	Xixá-do-Pará	Exotic-Brazil	B	X			Moderate
169	MALVACEAE	<i>Sterculia striata</i> A.St.-Hil.& Naud.	Xixá	Native		X		X	Rare
170	MALVACEAE	<i>Theobroma cacao</i> L.	Cacau	Exotic-Brazil		X			Rare
171	MALVACEAE	<i>Talipariti filiaceum</i> (L.) Fryxell	Algodão-da-praia	Exotic-Brazil		X			Common

Table 1 (continued)

N°	Family	Species	Popular name	Origin	Invasive or naturalized	Cultivated	Self established	Remaining	Subjective abundance classification
172	MALVACEAE	<i>Thespesia populnea</i> (L.) Sol. ex Corrêa	Algodão-da-praia	Exotic-Brazil	B	X			Moderate
173	MELIACEAE	<i>Azadirachta indica</i> A. Juss.	Nim; Ninho	Exotic-Brazil	F and B	X	X		Very common
174	MELIACEAE	<i>Cedrela odorata</i> L.	Cedro	Native		X		X	Rare
175	MELIACEAE	<i>Melia azedarach</i> L.	Cinamomo	Exotic-Brazil	B	X			Rare
176	MELIACEAE	<i>Swietenia macrophylla</i> King	Mogno	Exotic-Fortaleza		X			Rare
177	MORACEAE	<i>Artocarpus altilis</i> (Parkinson ex F.A. Zorn) Fosberg ^c	Fruta-pão	Exotic-Brazil		X			Rare
178	MORACEAE	<i>Brosimum gaudichaudii</i> Trécul	Inharê	Native			X		Rare
179	MORACEAE	<i>Ficus benjamina</i> L.	Ficus; Sempre-verde; Benjamim	Exotic-Brazil		X		X	Very common
180	MORACEAE	<i>Ficus elastica</i> Roxb.	Figueira	Exotic-Brazil		X			Moderate
181	MORACEAE	<i>Ficus elliptica</i> S. Moore	Gameleira	Native			X	X	Rare
182	MORACEAE	<i>Ficus enornis</i> Mart. ex Miq.	Gameleira	Native			X		Rare
183	MORACEAE	<i>Ficus microcarpa</i> L. f.	Benjamim	Exotic-Brazil		X			Common
184	MORACEAE	<i>MacLura tinctoria</i> (L.) D.Don ex Steud.	Tatajuba	Native				X	Rare
185	MORINGACEAE	<i>Moringa oleifera</i> Lam.	Moringa	Exotic-Brazil		X			Moderate
186	MYRSINACEAE	<i>Ardisia humilis</i> Vahl	Ardisia	Exotic-Brazil		X			Rare
187	MYRTACEAE	<i>Corymbia citriodora</i> (Hook.) K.D.Hill & L.A.S.Johnson	Eucalpto	Exotic-Brazil		X			Rare
188	MYRTACEAE	<i>Eucalyptus camaldulensis</i> Dehnh.	Eucalpto	Exotic-Brazil		X			Moderate
189	MYRTACEAE	<i>Eugenia uniflora</i> L.	Pitanga	Exotic-Fortaleza		X			Rare
190	MYRTACEAE	<i>Psidium guajava</i> L.	Goabeira	Exotic-Brazil	B	X	X		Moderate
191	MYRTACEAE	<i>Syzygium cumini</i> (L.) Skeels	Azeitona	Exotic-Brazil	F and B	X	X	X	Common
192	MYRTACEAE	<i>Syzygium jambos</i> (L.) Alston	Jambo-amarelo	Exotic-Brazil		X			Rare
193	MYRTACEAE		Jambo	Exotic-Brazil		X			Very common

Table 1 (continued)

N°	Family	Species	Popular name	Origin	Invasive or naturalized	Cultivated	Self established	Remaining	Subjective abundance classification
		<i>Syzygium malaccense</i> (L.) Merr. & L.M. Perry							
194	NYCTAGINACEAE	<i>Pisonia laxa</i> Netto	João-mole	Native			X	X	Rare
195	OXALIDACEAE	<i>Averrhoa bilimbi</i> L.	Azedinho; bilimbi	Exotic-Brazil		X			Rare
196	OXALIDACEAE	<i>Averrhoa carambola</i> L.	Carambola	Exotic-Brazil		X			Rare
197	PANDANACEAE	<i>Pandanus tectorius</i> Parkinson ex Du Roi	Pândanus	Exotic-Brazil		X			Rare
198	PIPERACEAE	<i>Piper tuberculatum</i> Jacq.	Pimenta-de-macaco	Native			X		Moderate
199	POLYGONACEAE	<i>Coccoloba uvifera</i> (L.) L.	Uva-do-mar	Exotic-Brazil		X			Moderate
200	POLYGONACEAE	<i>Triplaris americana</i> L.	Pau-formiga	Exotic-Fortaleza		X			Rare
201	POLYGONACEAE	<i>Triplaris gaudieriana</i> Wedd.	Pajéú	Native		X			Rare
202	RHAMNACEAE	<i>Ziziphus joazeiro</i> Mart.	Juazeiro	Native		X	X		Rare
203	RHAMNACEAE	<i>Ziziphus undulata</i> Reissek	Juazeiro	Native		X	X		Rare
204	RHAMNACEAE	<i>Ziziphus mauritiana</i> Lam.	Dão	Exotic-Brazil		X			Rare
205	RUBIACEAE	<i>Genipa americana</i> L.	Jenipapo	Native		X			Rare
206	RUBIACEAE	<i>Morinda citrifolia</i> L.	Noni	Exotic-Brazil		X			Rare
207	RUBIACEAE	<i>Ixora phillysoniana</i> Wall. ex G.Don		Exotic-Brazil		X			Rare
208	RUTACEAE	<i>Citrus aurantifolia</i> (Christm.) Swingle	Limão	Exotic-Brazil		X			Rare
209	RUTACEAE	<i>Citrus sinensis</i> (L.) Osbeck	Laranja	Exotic-Brazil		X			Rare
210	RUTACEAE	<i>Murraya paniculata</i> (L.) Jack	Jasmim	Exotic-Brazil		X			Moderate
211	SAPINDACEAE	<i>Talisia esculenta</i> (A. St.-Hil.) Radlk.	Pitomba	Native		X	X		Moderate
212	SAPOTACEAE	<i>Mamillaria triflora</i> (Allemañ) Monach.	Massaranduba	Native		X			Rare
213	SAPOTACEAE	<i>Manilkara zapota</i> (L.) P. Royen	Sapoti	Exotic-Brazil		X			Moderate
214	SAPOTACEAE	<i>Mimusops coriacea</i> (A. DC.) Miq.	Abricó-da-praia	Exotic-Brazil		X			Rare
215	SAPOTACEAE	<i>Pouteria reticulata</i> (Engl.) Eyma	Pitomba-de-leite	Native			X		Rare
216	SOLANACEAE	<i>Brunfelsia uniflora</i> (Pohl) D. Don	Manacá	Native		X			Rare

Table 1 (continued)

N°	Family	Species	Popular name	Origin	Invasive or naturalized	Cultivated	Self established	Remaining	Subjective abundance classification
217	STRELTZIACEAE	<i>Ravenala madagascariensis</i> Sonn.	Árvore-do-viajante	Exotic-Brazil		X		X	Rare
218	URTIACEAE	<i>Cecropia palmata</i> Willd.	Torém	Native			X	X	Moderate
219	VERBENACEAE	<i>Duranta erecta</i> L.	Pingo-de-ouro	Exotic-Brazil		X			Moderate

^aWe also found the palm *Phoenix canariensis* Chabaud cultivated as a rare species in private gardens in Fortaleza, but as we could not find any individual in public spaces we didn't add the species in our list

^b*Libidibia ferrea* has two varieties in Fortaleza, previously considered separate species but now under synonym. One of the varieties, *Libidibia ferrea* var. *leioptachya* (Benth.) L.P. Queiroz (= *Caesalpinia leioptachya* (Benth.) Ducke) is exotic to Fortaleza and the other, *Libidibia ferrea* var. *glabrescens* (Benth.) L.P. Queiroz, is native to Fortaleza. As they are now considered a single species, we considered *Libidibia ferrea* as native, but one must bear in mind that if these are considered two separate species, one of them would be considered exotic to Fortaleza

^cWe also found *Artocarpus heterophyllus* Lam. cultivated as a rare species in private gardens in Fortaleza, but as we could not find any individual in public spaces we didn't add the species in our list

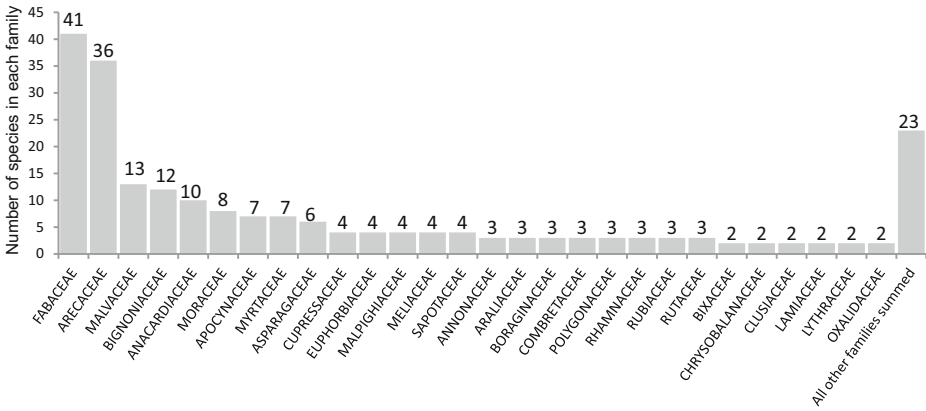


Fig. 2 Number of species in each family in the urban treescape of Fortaleza, Brazil

individuals, with 17 species as self established (Fig. 4c). In total, 39 native plants are cultivated in Fortaleza’s public treescaping, but 24 of these species are rare, 14 moderately abundant and only one native species (*Licania tomentosa*) is common. Not one of the native species was found to be very common in the city (Fig. 4). Of the 61 native species, 36 % (22) were never observed as cultivated plants, but only as remaining individuals, spared when land clearance occurred, and/or as spontaneous plants that grew naturally in urban sites (Table 1). The large majority of species are exotic, and all “very common” species in the city are exotic. Also, most of the “common”, and the majority of “moderate” species are exotic to the coastal ecosystems of Ceará (Fig. 4; Table 1).

Reproductive populations were found across the spectrum of native and non-native species. Relictual populations of the native *Annona glabra*, for example, persisted in wetland areas urbanized relatively recently. A small population of this species survived on the unpaved edge of a lake that was completely surrounded by urban development in a young district of the city (Moro et al. 2014). A few native species, dispersed by bats or birds have spread in urban environments and established a population within the city. For example, *Ficus elliotiana*, *Piper tuberculatum* and *Cecropia palmata* are dispersed by flying animals and were found to have established individuals in the public treescape, but we never observed them as cultivated plants. Some exotic species (ranging from naturalized to invasive plants) also managed to autonomously establish individuals in the urban forestry. Of these, *Ficus microcarpa* is an

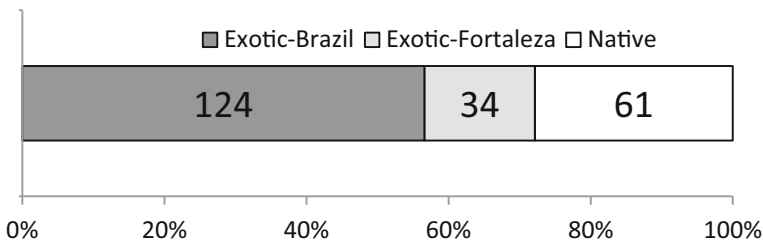
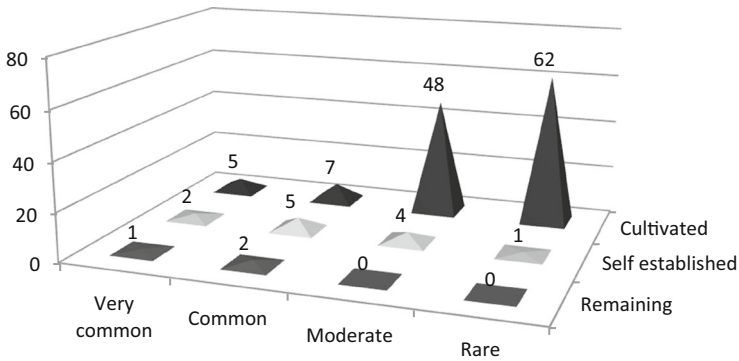
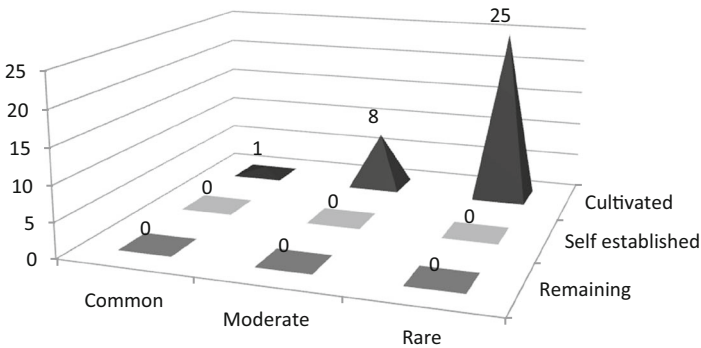


Fig. 3 Number of species represented in the urban treescape of Fortaleza, Brazil, according to their origin. We considered native species only those naturally occurring in the coastal vegetation of Ceará, or in the adjacent Caatinga dry forests (the original ecosystems of Fortaleza municipality). Species exotic to Fortaleza’s ecosystems, but native elsewhere in Brazil, are tagged as “Exotic-Fortaleza”. Species exotic to Brazil are tagged as “Exotic-Brazil”

A- Plants exotic to Brazil



B- Plants exotic to Fortaleza, but native elsewhere in Brazil



C- Plants native to Fortaleza

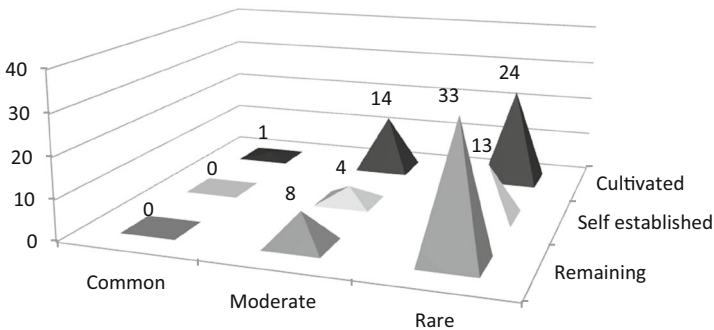


Fig. 4 Bar graph showing the number of species recorded in each “abundance class” as cultivated, self established and remaining plants in Fortaleza. The graph displays data for species exotic to Brazil, native to Brazil, but exotic to Fortaleza, and native to Fortaleza. A particular species may be present in the city due to more than one reason (species may be cultivated and also present some self established and remaining individuals), and thus, the sums in this graph is higher than the total species sums. See Table 2 to obtain the actual species numbers in each abundance class and Table 1 to see the raw data

interesting example because the plant was brought from Asia as a shade tree and was not reproductive until the introduction of its pollinator wasps from Asia. Nowadays, its fruits are

Table 2 Number of species registered in the urban forestry of Fortaleza in each subjective class of abundance according their origin

	Very common	Common	Moderate	Rare	Total
Exotic to Brazil	5	7	50	62	124
Exotic to Fortaleza, but native elsewhere in Brazil	0	1	8	25	34
Native to Fortaleza	0	1	16	44	61
Total	5	9	74	131	219

dispersed by bats and seedlings are easily found in the city. Two weedy invasive species (*Ricinus communis* and *Calotropis procera*) are present in the treescape exclusively as spontaneous species. Both are widespread invasive plants in Northeastern Brazil and are usually cut down rather than cultivated, but eventually re-grow and incorporate themselves into the forestry of the city.

Of the 158 exotic species we recorded, 21 are reported by Zenni and Ziller (2011) to be invasive in one or more Brazilian ecosystems and we recorded ten species as being naturalized or invasive in semi-urban or natural areas in Fortaleza.

From published botanical surveys in the coastal vegetation of Ceará (Matias and Nunes 2001; Moro et al. 2011; Castro et al. 2012), we compiled a list of 149 native tree and large shrub species. Although some of these species (e.g. mangrove trees) may not be technically appropriate for use as urban trees, we considered this number of species as indicative of the scale of the potential pool of native options and compared the number of potential with the actual number of native species in Fortaleza. Of the 149 native species registered in these three vegetation surveys of coastal Ceará, 37 (25 %) were present in the urban treescape (many of them as rare remaining individuals, rather than cultivated ones—Table 1). A further 23 native species were present in the urban treescape, but not captured in these vegetation surveys. Some of these are species from the surrounding Caatinga dry forests that are sometimes cultivated in the city, but others (e.g. *Annona glabra*) are native species from the coastal region not recorded in the available vegetation surveys.

Discussion

The native species in Fortaleza are strikingly underrepresented in the urban forestry. Not only is the number of exotic species much larger than that of natives, but the exotic species also represented the vast majority in terms of number of individuals. In their quantitative surveys of some districts of Fortaleza, Moro and Westerkamp (2011), Moro et al. (2014) and Borges (2002) showed that the most abundant species in the city are exotic and that native specimens comprise a small proportion of the total number of trees. They found that in some districts exotics comprise more than 90 % of individuals and only a few native species (e.g. *Licania tomentosa*) made up at least 1 % of relative abundance (Moro and Westerkamp 2011), while all of the most abundant species were exotic.

These findings can be related to the fact that people are not aware of the natural biodiversity of their own region and are not aware of which native species could be grown there (McKinney 2006; Dearborn and Kark 2010; Castro et al. 2011). Living in an urban environment where the treescape is dominated by exotics renders people more familiar with alien

species than with natives, which in turn will make aliens the species of choice when people are choosing a species to grow as an ornamental plant, creating a vicious circle. It is noteworthy that all species classified as “very common” and most of the species classified as “common” in our list are exotics (see quantitative surveys in some districts in Borges 2002; Moro and Westerkamp 2011; Moro et al. 2014) while, in contrast, 72 % of the native species (44 of 61) are in the rare category (Table 2).

The dearth of native plants in the urban treescape of Fortaleza is more striking when we take into account the fact that not only are the native species relatively poorly represented (in terms of both species and number of individuals), but also that a significant portion of the existing native individuals are not cultivated plants, but relictual individuals or self established ones (Fig. 4c). The number of native species that we recorded as being cultivated by humans is only 39 species while 156 exotic species are cultivated (Table 1). Native species that were recorded in Fortaleza and could potentially be appropriate for use on a broader scale in urban treescapes include *Astronium fraxinifolium*, *Tapirira guianensis*, *Himatanthus drasticus* and *Andira surinamensis*, but currently, each of these species is represented in the city by only relictual individuals. Thus, as these species are neither cultivated nor spontaneously occurring in the city they are likely to disappear from the urban treescape in the coming decades, unless there is a change in practice with regard to the proactive cultivation of native plants.

A noteworthy result of our study is that a number of native species on our list were never recorded as cultivated plants in the Fortaleza’s treescape but only as self established, spontaneous individuals. Gaston et al. (2005), Thompson et al. (2004) and Thompson et al. (2005) showed that in lawns and urban gardens of England spontaneous species (both native and exotic) play a role in the local biodiversity. Instead of being passive environments, in which humans alone choose which species will be present, both gardens and lawns were a mix of cultivated and spontaneous species, resulting in higher levels of biodiversity than one might otherwise expect. We found similar results in Fortaleza regarding trees and large shrubs. Of the 61 native species in our study, 17 were found to be reproducing and self-establishing in the city. Some of them such as *Crateva tapia* and *Anacardium occidentale* only rarely complete their life cycles and establish new adult individuals, but bat or bird dispersed species such as *Ficus elliotiana*, *Piper tuberculatum* and *Cecropia palmata* appear to owe their presence in the city’s treescape entirely to their own capacity for dispersal, establishment and recovery after cutting.

Another aspect to be considered is that urban plants are not only accomplishing aesthetic functions, but also make up part of the intrinsic ecology of the city. Birds, insects, mammals and many other groups depend on ornamental plants, parks and gardens to survive (Ruszczuk and Nascimento 1999; Menezes 2004; Smith et al. 2006a; Smith et al. 2006b). Both native and exotic plants perform ecological roles in the city, which is a positive aspect. But some of the cultivated exotic plants turn into invasive species and are thus environmental pests. This aspect should be considered when selecting species for urban cultivation. On the other hand, native plants are safe regarding bioinvasive risks, could improve the ecological quality of urban environments, support the native fauna and at the same time provide aesthetical benefits and act as an ex-situ conservation pool of native species.

Cultivated plants could be managed within cities to provide seeds for nurseries and could also be used as a tool to educate the citizens about the native biodiversity from their regions. The Brazilian population is becoming increasingly concentrated in urban settlements and currently, over 160 million Brazilians (84.4 % of the population) live in urban areas (IBGE 2010). This mainly urban population has more contact with ornamental plants cultivated in cities than with plants in natural ecosystems. A native treescape could be a means of improving

the knowledge of and appreciation for biodiversity, potentially increasing public support for the protection of native plants (McKinney 2006).

When we consider biological invasive risks, 21 out of the 158 exotic species of Fortaleza are reported as invasive somewhere in Brazil according Zenni and Ziller (2011), and we recorded ten of the alien plants from our list as being naturalized or invasive in ecosystems within Fortaleza (in vegetation fragments or semi-natural sites). The act of cultivating exotic species is not necessarily a hazard in itself, but when potentially invasive species are grown, urban tree planting and horticulture can become a vehicle for spreading plants that could damage the native biodiversity (Harrington et al. 2003; Zenni 2013). This has occurred both in Brazil and elsewhere, when cultivated plants have invaded native vegetation fragments (e.g. Dislich et al. 2002; Zipperer 2002).

Another aspect to be considered is that the probability of naturalization of an exotic plant depends on the number of cultivated individuals (the more individuals, the greater the chance of an exotic population becoming naturalized) and the time of introduction (Richardson et al. 2000; Pemberton and Liu 2009; Richardson and Pyšek 2012). Pemberton and Liu (2009) showed that ornamental exotic plants commercialized over a longer period in California had a greater probability of becoming invasive. Although only ten species were considered naturalized/invasive within Fortaleza, given more time it is possible that other species could naturalize and eventually spread in natural areas within the city. This was the case with *Azadirachta indica*. Intensively used as an ornamental plant in the last decade, this species is now naturalized (Moro et al. 2013) and recently we have begun to record seedlings spreading into vegetation fragments of the city. The same occurs with *Acacia mangium*, which was recently introduced as a shade tree in Fortaleza, even though is an aggressive invasive species in many parts of the world and is globally recognized as a problematic species (Richardson et al. 2011; Aguiar et al. 2014). Although this plant has not had time to naturalize here, given time, it would not be surprising if this eventually occurred in the future (e.g. Aguiar et al. 2014).

Our point is not that exotic plants should never be used as ornamentals (although invasive plants certainly should not), but that preferential use of native species offers more advantages for urban ecosystems from a biodiversity perspective. *Buchenavia tetraphylla* (Aubl.) R.A.Howard, *Byrsonima sericea* DC., *Byrsonima gardneriana* A.Juss., *Manilkara triflora* (Allemão) Monach., *Ziziphus platyphylla* Reissek and *Himatanthus drasticus* (Mart.) Plumel are all native species with great ornamental potential to coastal cities in Ceará. We recognize that currently in Brazil, there is more technical knowledge about cultivation of exotics than natives, but this is due to the lack of focus on the use of native biodiversity for treescaping. This leads to a situation where more value is given to species that come from abroad than to local ones. Many nurseries spend time and effort learning how to cultivate newly introduced exotics, while little or no effort is put into cultivating native species. This creates an ambiguous situation where researchers spend time and resources investigating the growth rate of exotic species such as *Azadirachta indica* (Silva et al. 2007), while data about native species is lacking.

This lack of environmental perception has led to a contradictory situation, where Brazil, one of the megadiverse countries in the world, does not know or value its own biodiversity. Native species are being expelled from our cities, while dozens of exotic plants, from far flung ecosystems are cultivated and nursed (Ignatieva 2012). Now, trees from India are easily recognized in our streets while very characteristic species from native ecosystems are complete strangers to most people.

Conclusions

It is time to change the focus from a merely utilitarian view of street trees to a view which prioritizes biodiversity. Brazil is signatory to the Convention on Biological Diversity and has the commitment to stop the spread of invasive species. It is contradictory that potentially invasive exotics such as *Azadirachta indica* and *Acacia mangium* are nursed and planted for ornamental purposes in Brazil. Even when “safe” exotics are available, the use of natives is preferable. Urban forestry may serve as a tool for ex-situ conservation, potentially allowing the presence of a large number of native species to be cultivated as shade and ornamental trees. Moreover, technical knowledge and nursery market developed around native plants could both provide plants for ornamental use and ecosystem restoration, creating a virtuous circle of valued and easy to obtain native seedlings. The reality we observed is the opposite, with exotic plants being readily available for purchase, while native species are extremely hard to find in the market.

Another much-ignored aspect is that stressed by McKinney (2006): people in urban areas have few chances to become familiar with the native species of their own region. Bringing native plants to the cities can be an opportunity to present native biodiversity to the people, with a goal of increasing awareness regarding native plants and the need to conserve them. Building effective bonds between people and native biodiversity is an important conservation challenge, to which wise urban tree planting can contribute, and which is all too often ignored when urban treescapes are considered.

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