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SCIENTIFIC ARTICLE

Biodiverse neighborhoods: an *ex-situ* conservation tool

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Abstract

Urban forests are responsible for a lot of benefits, and can be used as a tool to *ex-situ* conservation of native species. Our study investigated a public urban forest aiming to provide subside to management projects in order to allow the accurate fulfillment of social, aesthetic and ecological functions displayed by trees. Our survey was conducted in 6 public squares and 5 gardens in the *Jardins* neighborhood. We classified the trees according to their phytogeographic origins and seed dispersal habit. The Shannon-Weaver (H') index, Simpson's dominance (D') and Pielou's equability (J) were determined. A total of 507 individuals were sampled, located in 12 botanical families and 29 species, and 13 of them were classified as native and 16 as exotic. The family with higher species richness and number of species was Fabaceae (36%). Regarding the seed dispersal syndrome, the most representative was zoochory (52%). The ecological index showed medium species diversity (H'=2.2284), high dominance (D'=0.7899) and medium number of individuals (J) 0.6552. Although the *Jardins* neighborhood was planned, the urban forest in this area still needs improvement; such as incentive measures that can promote biodiversity and the application of ex-situ conservation.
Keywords: phytosociology, planned neighborhood, urban conservation, urban forests.

Resumo

Bairros biodiversos: uma ferramenta para conservação *ex-situ*

As florestas urbanas apresentam infinidades de benefícios, podendo atuar como uma ferramenta para conservação *ex-situ*. O estudo teve como objetivo realizar o diagnóstico de uma floresta urbana pública, com o intuito de oferecer subsídios para o manejo e garantir que a arborização possa cumprir com funções sociais, estéticas e ecológicas. O levantamento foi desenvolvido em 6 praças e 5 canteiros centrais do Bairro Jardins. As espécies foram classificadas quanto a sua origem fitogeográfica e forma de dispersão de sementes. Foram determinados os índices de diversidade de Shannon-Weaver (H'), dominância de Simpson (D') e equabilidade de Pielou (J). Ao todo foram identificados 507 indivíduos, pertencentes a 12 famílias e distribuídos em 29 espécies, sendo 13 nativas e 16 exóticas. A família que apresentou maior riqueza em número de espécies foi a Fabaceae (36%). Quanto à classificação da síndrome de dispersão, a mais ocorrente foi por zoocoria (52%). Os índices ecológicos calculados do bairro mostraram ocorrência de média diversidade de espécies (H' = 2.2284), dominância elevada (D' = 0.7899) e médio equilíbrio do número de indivíduos (J) de 0.6552. Embora o bairro Jardins tenha sido planejado, a floresta urbana nessa área ainda precisa de melhorias; tais como medidas de incentivo que podem promover a biodiversidade e a aplicação de conservação *ex-situ*.
Palavras-chave: fitossociologia, bairros projetados, florestas urbanas, conservação urbana.

Introduction

Urban forests can be defined as a group of vegetation situated in the urban perimeter, which includes public and private areas such as forests, public squares, residential gardens, street trees and green areas in general and usually are composed by isolated or grouped trees. The presence of urban forests promotes an infinity number of aesthetic, social and ecological benefits, and contributes to a better air quality and hydric balance, increasing the thermal comfort, decreasing the noise pollution and wind speed, as well as visually harmonizing the environment, being used as passive bio-monitors of environmental pollution (Cardoso et al., 2017).

The urbanization process contributes to a decrease in the richness of native species, and can reduce the ecological

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aspect of trees, especially in the Caatinga and Atlantic Forest biomes, which are highly anthropized. Streets that holds the presence of native trees are a key element in providing food for the local fauna and contributes to the genetic fluxes by forming ecological corridors in the landscape (Kolbe et al., 2016; Lynch, 2019). In addition, urban forests are capable of cushioning the impact of urban areas in adjacent natural areas, particularly flagrant when taking in consideration the diversity and richness of its composition (Sartori et al., 2019).

Brazil is internationally recognized as a mega diverse country (Moro and Castro, 2014), but there is still a high utilization of exotic species in urban forest projects, with many of them being considered as invasive species (Brun et al., 2017). According to Coelho Jr. et al. (2019), replacing native for exotic species is a recurrent practice utilized in public areas, which leads to alterations in the remaining natural environments in urban zones. This practice also contributes to the homogenization of the landscape in public areas and decreases the diversity of flora and fauna. In this sense, it is necessary to invest continually in the maintenance of the urban forests (Kowarik et al., 2019) by promoting landscape analysis and floristic composition studies in order to accomplish the desirable ecological benefits.

It is possible to use adequate urban forestry techniques as an *ex-situ* tool to preserve the native trees by utilizing them as ornamental elements, representing the local biodiversity and increasing opportunities to create awareness about the native flora to conserve and preserve those species (Moro and Castro, 2014). In this sense, our study aims to evaluate a public urban forest in a residential neighborhood in order to provide subsidy to management and conservation projects, ensuring that those urban forests fulfill their social and aesthetic functions, as well as guaranteeing its ecological functioning. We tested the following questions: i) the native tree species are being prioritized in urban forest projects? ii) Is there species diversity in the composition of this forest? and iii) This urban forest can be considered a food resource for the local fauna?

Material and methods

Our study was conducted in the *Jardins*, a planned neighborhood located in São Gonçalo do Amarante municipality, in the metropolitan area of Natal, the capital of Rio Grande do Norte State. The area is situated in the mesoregion of the East Potiguar (Figure 1). According to IBGE (2019), the municipality range is 249.800 km², with 14 neighborhoods, and a total population of 102 thousand of inhabitants and a total of 12.8% of forested area in public spaces.

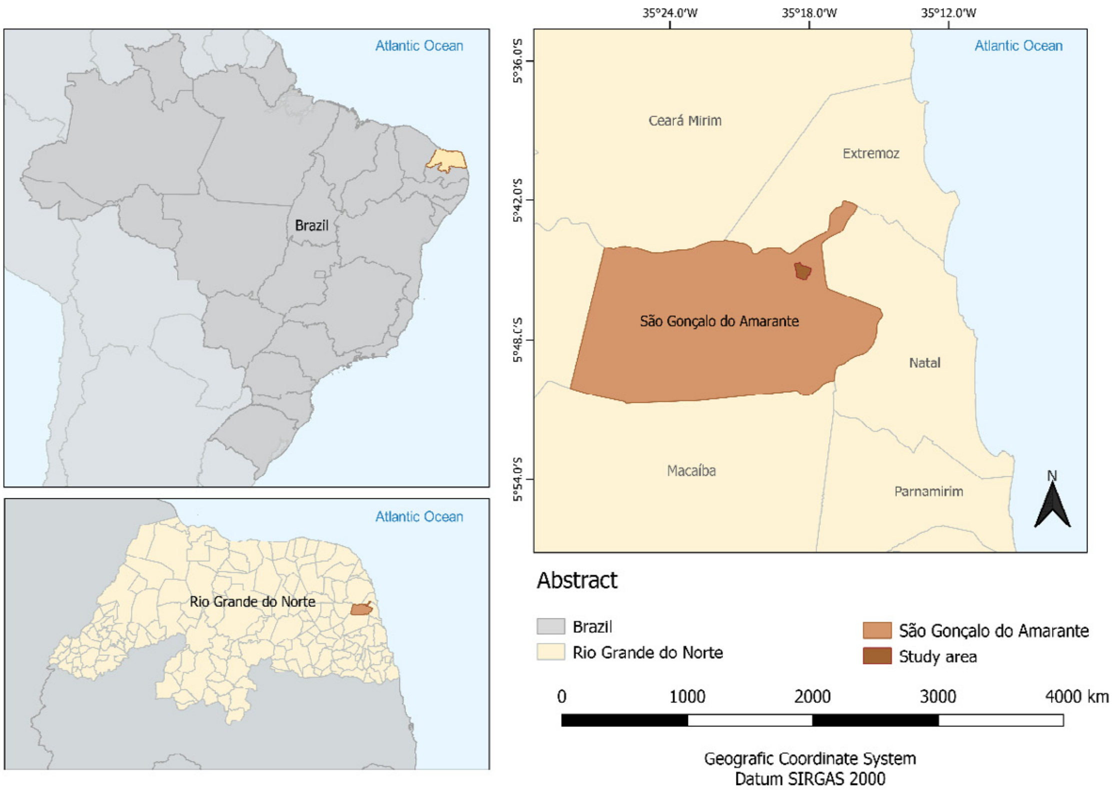

Figure 1. Location of the study area (*Jardins* neighborhood).

The climate in the region is characterized as type A of Köppen, i.e. warm and humid tropical, with two distinct seasons: dry winters and rainy summers. The mean annual temperature is 26 ºC, the relative air humidity is 76%, with a mean annual precipitation of 1140 mm. The main phytophysiognomies in the area are Caatinga and Atlantic Forest (Alvares et al., 2014; IBGE, 2019).

The floristic survey of the trees was carried in public spaces, totalizing 6 squares and 5 green traffic islands in the main avenues of the *Jardins* neighborhood, in May 2018 (Figure 2). The total area and the geographic coordinates of each environment were determined utilizing the software Google Earth.

Figure 2. Squares and green traffic islands located in the *Jardins* neighborhood.

The trees were visually identified according to the species level and their scientific or common etymology name were registered. Samples of flowers, fruits, and leaves from the unknown species were collected, pictures were taken and their individual morphological characteristics (such as bark color, vegetative and reproductive characteristics) were registered for posterior identification by a specialist. All the species sampled were placed in the Herbarium of Universidade Federal do Rio Grande do Norte (APG, 2016).

The species in our survey were classified according to their phytogeographical origins (native from Brazil or exotic) and dispersal syndrome in three categories: anemochoric (wind dispersion), zoochoric (animal dispersion) and autochoric (self-dispersion). We determined the district's phytosociological parameters and its subdivisions (squares and public gardens) by calculating the absolute density, absolute frequency and relative frequency. The Shannon-Weaver diversity index, Simpson's dominance and Pielou's equability index were also calculated (Table 1).

Table 1. Formulas used to determine the phytosociological parameters of the floristic composition of the *Jardins* neighborhood. N = total number of individuals; ni = number of individuals per species; S = number of species; A = area.

Parameters	Formulas
Absolute frequencies (AF)	$AF=N$
Relative frequency (RF)	$RF=\left(\frac{ni}{N}\right)*100$
Absolute Density (AD)	$AD=ni/A$
Shannon–Wiener index(H')	$H'=\frac{[N*\ln(N)-\sum_{i=1}^{S} ni*\ln(ni)]}{N}$
Pielou's evenness index(J)	$J=\frac{H'}{\ln(S)}$
Simpson's Index (D')	$D'=\frac{\sum_{i=1}^{S} ni(ni-1)}{N(n-1)}$

All the data sampled was tabulated and submitted to descriptive statistical analysis to determine: i) families and species that are usually utilized; ii) proportion of exotic and native species and iii) the predominant dispersion syndrome in the region. All the tables and graphics were developed utilizing the statistical program Microsoft Excel® 2016 version.

Results and discussion

The floristic composition and urban afforestation of the public squares and gardens at *Jardins* neighborhood presented 507 individuals, from 12 botanical families and distributed in 29 species: 13 of them were classified as native species and 16 were classified as exotic (Table 2).

Table 2. List of families (in alphabetical order) and species sampled in the floristic survey of urban forestry in the *Jardins* neighborhood, São Gonçalo do Amarante-RN, Brazil. CN= Common etymology name; N= native; E= exotic; O= origin; AF= absolute frequency; RF= relative frequency (% of total individuals sampled); SD= ways of seed dispersal; ZOO= Zoochoric; ANE= Anemochoric; AUT= Autochoric; NI = Not identified.

Family	Scientific name	CN	O	AF	RF	SD
Anacardiaceae	*Anacardium occidentale* L.	Cajueiro	N	51	10.00	ZOO
	Mangifera indica L.	Mangueira	E	27	5.33	ZOO
	Spondias purpurea L.	Seriguela	E	5	0.99	ZOO
	Spondias sp.	NI	NI	6	1.18	ZOO
	Myracrodruon urundeuva All.	Aroeira	N	3	0.59	ANE
Arecaceae	*Cocos nucifera* L.	Coqueiro	E	11	2.17	ZOO
	Roystonea oleracea (Jacq.) O.F. Cook	Palmeira imperial	E	8	1.58	ZOO
Bignoniaceae	*Handroanthus impetiginosus* (Mart. *ex* DC.) Mattos	Ipê-roxo	N	63	12.40	ANE
	Tabebuia alba (Cham.) Sandwith	Ipê-rosa	N	8	1.58	ANE
	Handroanthus heptaphyllus (Vell.) Mattos	Ipê-amarelo	N	4	0.79	ANE
Combretaceae	*Terminalia catappa L.*	Castanhola	E	3	0.59	ZOO
Chrysobalanaceae	*Licania tomentosa* (Benth.) Fritsch	Oiti	N	1	0.20	ZOO
Fabaceae	*Pithecellobium dulce* Benth.	Espinheiro	E	8	1.58	ANE
	Zygia sanguínea (Benth.) L. Rico	Ingá velho	N	4	0.79	AUT
	Paubrasilia echinata (Lam.) E.Gagnon, H.C. Lima & G.P. Lewis	Pau Brasil	N	19	3.75	AUT
	Adenanther apavonina Linnaeus	Olho de dragão	E	5	0.99	ANE
	Bauhinia cheilantha (Bong.) Steud.	Pata de vaca	N	2	0.39	AUT
	Prosopis juliflora (Sw.) DC.	Algaroba	E	1	0.20	ZOO
	Delonix regia (Hook.) Raf	Flamboyant	E	1	0.20	AUT
	Pityrocarpa moniliformis (Benth.) Luckow & R. W. Jobson	Catanduva	N	1	0.20	AUT
	Clitoria ternatea L.	Cunhã	E	12	2.37	AUT
	Poincianella pyramidalis Tul.	Catingueira	N	2	0.39	AUT
Malvaceae	*Hibiscus tiliaceus* L.	Algodão da Praia	E	27	5.33	ANE
Meliaceae	*Azadirachta indica* A. Juss.	Nim	E	204	40.20	ZOO
Moraceae	*Ficus benjamina* L.	Figueira-Benjamina	E	13	2.56	ZOO
Myrtaceae	*Psidium guajava* L.	Goiabeira	E	2	0.39	ZOO
	Syzygium cumini (L.) Skeels	Azeitona roxa	E	2	0.39	ZOO
Rubiaceae	*Tocoyena sellowiana* (Cham. &Schltdl.) K.Schum.	Jenipapo	N	1	0.20	ZOO
Sapindaceae	*Sapindus saponaria* L.	Saboneteira	N	2	0.39	ZOO
NI	-	-	-	11	2.17	-
TOTAL				507	100	

According to Milano and Dalcin (2000), the ideal composition for an urban forest should include more than 20 species, while the minimum acceptable is 10 species. In this sense, the *Jardins* neighborhood fits the authors recommendations authors. Urban forests with a high number of species are becoming a useful tool for *ex-situ* conservation, since they provide an increased number of food resources to the animals in those areas (Pinheiro et al., 2018). It is important to highlight that an increased number of trees in these regions affect positively the human well-being (Carrus et al., 2015).

The families Fabaceae (36%), Anacardiaceae (14%) and Bignoniaceae (11%) were the ones with higher species richness and species number, totalizing 67% of the trees sampled (Figure 3). The predominance of the use of species from these families is commonly found in other regions, as observed in studies carried out by Moussa et al. (2020) when analyzing the urban forests from the cities Niamey and Maradi in Nigeria, with higher species number from the Fabaceae family. Silva et al. (2019a), when analyzing the public squares from the Gurupi municipality in Tocantins State, Brazil, found a predominance of individuals from Fabaceae and Anacardiaceae families, while Fernandes et al. (2018) found a predominance of Fabaceae and Bignoniaceae families when analyzing the most popular square in São José do Rio Preto municipality, São Paulo State, also in Brazil.

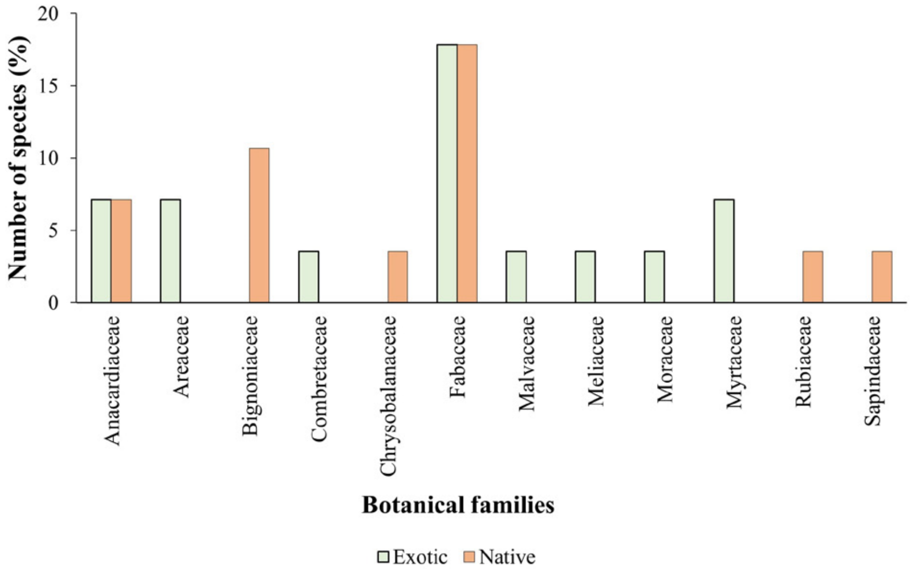

Figure 3. Percentage of the number of species as to their origin within the families sampled in the floristic assessment of urban forestry in *Jardins* neighborhood, São Gonçalo do Amarante-RN, Brazil.

Fabaceae is one of the most representative families of Angiosperms, with approximately 19 thousand species and 727 genera (APG, 2016). In our study it was possible to evidence that there was an equilibrium regarding the presence of individuals from the Fabaceae family, with 5 of them being classified as native and 5 as exotic species. Trees from the Fabaceae family are commonly utilized in urban forests in Brazilian cities (Fernandes et al., 2018; Silva et al., 2019; Toledo et al., 2021). Among the reasons for the wide use of species from the Fabaceae family are: the canopy architecture (shade from the tree), the presence of colorful inflorescences, aesthetic beauty, and easy seed dispersal, which increase the spontaneous emergence of new individuals, as well as the use of those trees by local inhabitants of a given area, which also increases the seedling of new individuals (Cabreira and Canto-Dorow, 2016).

The Anacardiaceae family is mainly utilized due to the fact that they provide edible fruits, which is widely known by the local inhabitants. However, species such as *Mangifera indica* L. and *Anacardium occidentale* L., from the aforementioned family, are not considered as adequate for urban areas like public squares and avenues, as the trees are too big, with long roots, present canopies with heterogeneous shape and might promote accidents with their fruits, which can cause damage to urban areas such as sidewalks, electric wiring and the obstruction of manholes, as well as the unpleasant smell of decomposing fruits (Oliveira et al., 2018; Silva et al., 2019).

The total of exotic trees was also superior to the total of native trees, with 54% and 46%, respectively. The use of exotic species in urban forests in Brazilian municipalities is a common practice (Freitas et al., 2020), and can be justified by the lack of information about native species, as well as lack of planning and due to the need for rapid construction of green areas that are capable to provide thermal comfort and wellbeing for the human population. This also occurs in cities from the Amazon Domain, one of the most biodiverse areas of the world, where there is a wide usage of exotic species in urban areas due to the fact that the population acts as an enhancer of the urban forest, without the proper monitoring from the public sector (Vieira and Panagopoulos, 2020).

The inadequate utilization of exotic invasive species in urban forest projects like public squares, woods, parks and avenues, can lead to a series of problems, like the alteration of the vegetation structure of the community, nutrient cycling and, as a more drastic consequence, can lead to losses in the biodiversity.

In a recent review conducted by Isernhagen et al. (2009) regarding the advantages of using regional native species in public spaces, we can highlight that the utilization of those trees can be a great tool to maintain the *ex-situ* genetic pool of native tree populations, as well as providing food and shelter for the local fauna, which contributes to the continuity of the genetic fluxes. Besides, it can also contribute to the ecological re-education of the local population by providing direct contact with the original vegetation of the area. In general, utilizing those species might promote the *ex-situ* conservation, leading to the conservation of non-natural populations, which is mainly important for species that are at risk of extinction such as *Paubrasilia echinata* (Pau Brasil), present our study area, which is categorized as endangered according to the red book of the flora of Brazil (Martinelli and Moraes, 2013).

Nevertheless, it is important to highlight that the utilization of exotic species in urban forests shouldn't be considered as only harmful, as they can help to improve quality of life for the inhabitants of a certain areas, as well as providing ecological and economic benefits for the human population (Davis et al., 2011; Riley et al., 2017). However, the utilization of exotic species in urban areas must be planned aiming to reduce the risks of them becoming invasive. Milano and Dalcin (2000) also emphasize that in urban forest projects it is important that each of the species utilized don't outreach 15% of the total of individuals in a population, avoiding risks of losing the local biodiversity.

The Meliaceae family, represented in our study mainly by *Azadirachta indica* A. Juss, also known as Nim, was one of the most representative trees, accounting for 40.2% of the species sampled and being present in 4 public squares and 5 public gardens. According to Moro et al., (2013) *A. indica* is a popular species generally utilized in urban forest projects in public streets in the northeast region in Brazil. The species is well distributed in warm, dry areas with soils that are well drained, which makes the northeast region a potential area for its occurrence (Neves, 2004).

Due to the favorable conditions and rapid growth, *A. indica* plants were introduced by many city councils in order to increase the shaded areas in public avenues. However, in the past few years the frequency of utilization of *A. indica* in urban forests is increasing, mainly due to the fact that this species is becoming more popular with the local inhabitants. *A. indica* is a natural bug repellent, and is also considered as an ornamental plant, and those characteristics made this species the favorite one to be planted by the local population.

However, the use of *A. indica* can cause many problems such as pipe obstructions, damage to the electric wiring, and there's a need of constantly trimming the branches. Recently, there were a few studies that indicated that *A. indica* has a potential to be an invasive species (Ansong et al., 2019; Santos and Kiwango, 2010), which leads to the need of taking preventive measures when utilizing this species in the urban afforestation, like monitoring the seedlings, removing and/or substituting the trees from *A. indica* growing near protected natural areas (Moro et al., 2013).

The ecological indexes calculated to *Jardins* neighborhood (Table 3) indicate that there is a medium species diversity (H' = 2.2284), with high dominance (D' = 0.7899). We noticed the presence of 29 tree species being utilized in the afforestation of this neighborhood, but there is also a homogeneous distribution of those trees, where we could notice a high number of individuals from a few species. This can be highlighted when we observe the diversity between different localities (public squares and gardens) where the Shannon-Weaver index is lower. The avenue 3 and the public squares 3, 4 and 6 showed a high equability (J), with values close to 1 (Brower and Zar, 1984), indicating that only in these localities the species are in equilibrium regarding the number of individuals.

Table 3. Phytosociological parameters of afforestation in the squares and green traffic islands (GTI) of *Jardins* neighborhood, São Gonçalo do Amarante-RN, Brazil. E (%) = Exotic; N (%) = Native; NI = Not identified; AD = Absolute Density; H '= Shannon-Weaver index; D ‹= Simpson›s index; J = Pielou›s equability index.

Location	E (%)	N (%)	NI (%)	AD (ind m^{-2})	H'	D'	J
Square 1	92	8	0	0.0063	0.9943	0.5069	0.6094
Square 2	86	0	14	0.0035	0.4101	0.2449	0.5916
Square 3	68	32	0	0.0038	1.2805	0.6980	0.9237
Square 4	57	29	14	0.0089	1.7478	0.8163	0.9755
Square 5	82	18	0	0.0043	0.9976	0.4775	0.6198
Square 6	64	36	0	0.0052	1.2882	0.6942	0.9292
GTI Av. 1	60	35	5	0.0234	2.1945	0.8202	0.7745
GTI Av. 2	86	10	4	0.0279	1.5153	0.0279	0.5742
GTI Av. 3	100	0	0	0.0027	1.3421	0.7272	0.9681
GTI Av. 4	56	44	0	0.0140	1.6631	0.7153	0.6483
GTI Av. 5	95	5	0	0.0043	0.6631	0.3181	0.4783
GERAL	-	-	-	-	**2.2284**	**0.7899**	**0.6552**

The low species diversity can be changed by replacing the exotic species with high frequency, or even planting new seedlings of native species, since the locations analyzed in our study had a low absolute density (AD), which indicates the existence of spaces for new individuals to be planted in those areas. The existence of urban forests in public avenues and squares could act as ecological trampolines or steppingstones, promoting dynamism for the animal species, which are the major responsible for pollination and seed dispersion (Lynch, 2019).

Piratelli et al. (2017) highlights that the creation of greener cities with higher species biodiversity will benefit the wildlife, as well as positively impacting the human life, making the cities healthier and more pleasant to inhabit. It is also important to incorporate a diversified pool of native species in urban forests, because they can promote an increase in the *ex-situ* conservation of species, since those species are also capable of releasing different resources in different phenological periods of the year.

In the *Jardins* neighborhood, 52% of the species in a total of 331 individuals were classified as zoochory dispersed; 27% of the species with 41 individuals were wind dispersed and 21% of the 118 individuals were autochory dispersed (Figure 4). The dispersion syndrome is an important determinant to increase the population of a certain individual, increasing the survival and perpetuation of the species. By planning and managing the urban forests, the city of Belo Horizonte, in Brazil, could retain 20% of the birds inside the urban matrix (Pena et al., 2017).

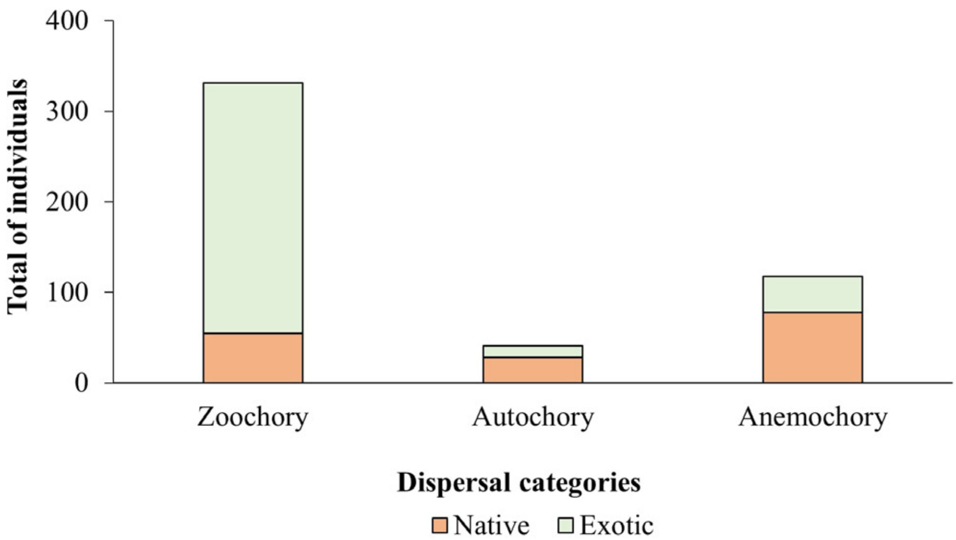

Figure 4. Number of individuals in its exotic or native origin by the form of dispersion of the urban forestry in the *Jardins* neighborhood, São Gonçalo do Amarante-RN, Brazil.

Zoochory can be characterized as the dispersion promoted by animals, and is one of the most common dispersion syndromes among trees in tropical environments (Gomes, 2018). In urban forests the amount of vegetation cover positively influences the presence of native birds with different eating habits, mainly the granivores (Villasenor et al., 2021), as well as the existence of complex/specific interactions between plants and pollinators, which makes this fact an important reason to utilize a higher diversity of native trees and increase the conservation of native species.

It is important to utilize native tree species aiming to increase the genetic fluxes of those individuals, taking in consideration their dispersion syndromes, as well as increasing the number of individuals in the urban forests and decreasing the predominance of exotic species (Siqueira, 2017). The existence of urban forests provides a myriad of ecosystem services, and it is important that the decision makers take in consideration planning ahead the urban forests by including landscape covers and local characteristics of the flora, reducing the habitat loss of native species and preventing the existence of risky areas in urban spaces (Smith et al., 2018; Vieira and Panagopoulos, 2020).

It is essential that the decision makers include competent staff from the forest industry in their management teams to implement urban forests in a sustainable way, increasing the social perception of the biodiversity as well as promoting the *ex-situ* conservation of native species. The decision makers should include environmental education, reforestation planning, and partnerships between the universities and the public sector in order to promote the urban conservation of native species (Vieira and Panagopoulos, 2020). Carrying floristic surveys like our study is important to ensure the planning and subsidize management activities in urban forests.

Conclusions

Despite being a planned environment, the correct project and the implementation of the urban forest in public areas of this district (public squares and avenue gardens) were neglected, which could be proved by the usage of tree species that were inadequate for urban areas and the high number of exotic species. The study area presented a moderate diversity and can be considered a food source for the local fauna, once most of the individuals' dispersal syndrome is the zoochory.

In addition, it is important to implement native trees that are adapted to the region when planning urban forests aiming the conservation of the ecosystem, such as increasing the number of *Paubrasilia echinate* individuals, as it is in danger of extinction, and inserting other species characteristic of the Caatinga and Atlantic Forest, the predominant biomes of the region. Native species indicated for urban afforestation represent a lower risk of accidents, less infrastructure problems, lower maintenance costs and increased genetic flows. By doing so, it is possible to perpetuate the life of those species and to promote ecological equilibrium in the environment, as the urban forest can accomplish certain social, aesthetic and environmental functions.

Author contribution

JGMUF: research project design, project methodology, data collection, data analysis and interpretation and writing; **FMFL**: analysis and interpretation of data and writing; **DMA**: data collection and writing; **BRFS**: data collection and writing; **DMA**: Illustrations; **DYOB**: critical review; **TKBA**: project methodology and critical review.

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