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GEOSPATIAL DISTRIBUTION OF FOREST SPECIES IN THE BOTANICAL GARDEN OF RECIFE, PERNAMBUCO, BRAZIL

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Resumo

Distribuição geoespacial de espécies florestais no Jardim Botânico do Recife, Pernambuco, Brasil. A adoção de estratégias adequadas para conservação e manejo dos ecossistemas florestais associados à Mata Atlântica, depende da compreensão acerca do padrão de distribuição espacial das espécies florestais, principalmente, em áreas protegidas. Desse modo, este trabalho teve como objetivo avaliar a distribuição geoespacial de espécies florestais em um fragmento de Mata Atlântica (Floresta Ombrófila Densa das Terras Baixas) no Jardim Botânico do Recife, Pernambuco, Brasil. O estudo fitossociológico foi realizado pelo método das parcelas, sendo alocadas 40 parcelas de 10 m x 25 m, distribuídas de forma sistemática, onde foram identificados e georreferenciados todos os indivíduos vivos que apresentaram circunferência a 1,30 m acima do solo ≥ 15 cm. Para identificar a existência de similaridade florística entre as parcelas, os dados obtidos foram submetidos à análise de agrupamento hierárquico. A caracterização da variabilidade espacial das espécies florestais foi realizada utilizando análise geoestatística. Os dados foram interpolados por krigagem, seguido da elaboração de mapas temáticos de distribuição espacial. A análise de agrupamento hierárquico constatou a formação de dois grupos de parcelas. As espécies florestais *Artocarpus heterophyllus*, *Dialium guianense*, *Helicostylis tomentosa*, *Hevea brasiliensis*, *Pouteria durlandii* e *Thyrsordium spruceanum* apresentaram dependência espacial. O uso da geoestatística permitiu a visualização dos arranjos de distribuição espacial e a identificação dos locais de concentração dessas espécies. Informações sobre a distribuição geoespacial das espécies florestais podem ser utilizadas para preservação, conservação e manejo de remanescentes florestais.
Palavras-chave: Mata Atlântica, área protegida, geoestatística, krigagem

Abstract

The adoption of appropriate strategies for the conservation and management of forest ecosystems associated with the Atlantic Forest depends on understanding the pattern of spatial distribution of forest species, mainly in protected areas. Thus, this study aimed to evaluate the geospatial distribution of forest species in a fragment of Atlantic Forest (Lowland Dense Ombrophilous Forest) in the Botanical Garden of Recife, Pernambuco, Brazil. The phytosociological study was carried out by the plot method, with 40 plots of 10 m x 25 m, systematically distributed, where all living individuals that showed circumference at 1.3 m above the ground ≥ 15 cm were identified and georeferenced. To identify the existence of floristic similarity between the plots, the obtained data were subjected to hierarchical cluster analysis. The spatial variability of forest species was characterized using geostatistical analysis. The data were interpolated by kriging, followed by the construction of thematic maps of spatial distribution. Hierarchical cluster analysis revealed the formation of two groups of plots. The forest species *Artocarpus heterophyllus*, *Dialium guianense*, *Helicostylis tomentosa*, *Hevea brasiliensis*, *Pouteria durlandii* and *Thyrsordium spruceanum* showed spatial dependence. The use of geostatistics allowed visualizing the spatial distribution arrangements and identifying the concentration sites of these species. Information on the geospatial distribution of forest species can be used for the preservation, conservation and management of forest remnants.
Keywords: Atlantic Forest, protected area, geostatistics, kriging

INTRODUCTION

The continuous process of devastation of the Atlantic Forest is a consequence of the disorderly occupation and exploitation of natural resources, which occur since the beginning of the colonization period of Brazil. This resulted in drastic reduction of natural vegetation area, high concentration of small forest fragments (< 50 hectares) and inclusion of the biome on the list of priority areas for conservation (RIBEIRO *et al.*, 2009). The biome came to be considered the most threatened in Brazil and one of the 35 hotspots worldwide. Hotspots are areas that have great endemic biological diversity, with less than 30% of their original vegetation cover (MITTERMEIER *et al.*, 2011).

The adoption of appropriate strategies for the conservation and management of forest ecosystems associated with the Atlantic Forest depends on understanding the changes caused by the process of devastation and fragmentation. For this, it is necessary to understand the pattern of spatial distribution of forest species, mainly in protected areas. The natural factors that influence the spatial distribution of forest species, as well as vegetation dynamics, include: seed dispersal syndrome, soil and relief differences, and mortality (SAMBUICHI *et al*., 2002). On the other hand, among the anthropic factors that stand out are deforestation, predatory hunting, fires and the introduction of invasive alien species.

The spatial distribution pattern of forest species can be evaluated by applying techniques related to geostatistics. In the forestry area, this precision technology has gained prominence, being considered increasingly essential, significantly contributing to the adoption of appropriate strategies for the management and maintenance of biodiversity, as it makes it possible to model and describe the spatial variability of the spatial distribution of species in highly diverse ecosystems (AMARAL *et al*., 2013; ROVEDA *et al*., 2018; SILVA *et al*., 2018).

In addition, when using this tool, it is possible to estimate the number of individuals of the species in unsampled sites, based on the theoretical semivariogram, represented by mathematical models, using interpolators (DALE *et al*., 2002). Kriging interpolation is the most used in geostatistics. In this method, the spatialization of sampling is performed considering the sampling field and the points that were not measured. Estimates are generated from the information about sample position and the value of the variable at each point. Thus, the value of the variable and the coordinates (x and y) are obtained for each sampling point and used to construct the maps of distribution of forest species (BRANDÃO *et al.*, 2018).

In view of the above, this study aimed to evaluate the geospatial distribution of forest species in a fragment of Atlantic Forest (Lowland Dense Ombrophilous Forest) in the Botanical Garden of Recife, Pernambuco, Brazil.

MATERIAL AND METHODS

Study area

The study was carried out at the Botanical Garden of Recife (BGR), located on the south margin of BR-232 highway, southwest region of the municipality of Recife, Pernambuco, Brazil. The area is located under the geographical coordinates 08°04' and 08°05' S Latitude and 34°59' and 34°57' W Longitude. It has 11.23 ha, including vegetation cover, gardens, forest nursery, and built and visitation areas (Figure 1). The BGR was created in 1979, by Municipal Decree No. 11,341. Currently, it is included in the category of protected unit of the Municipal System of Protected Units - SMUP (Municipal Law No. 18.014/2014).

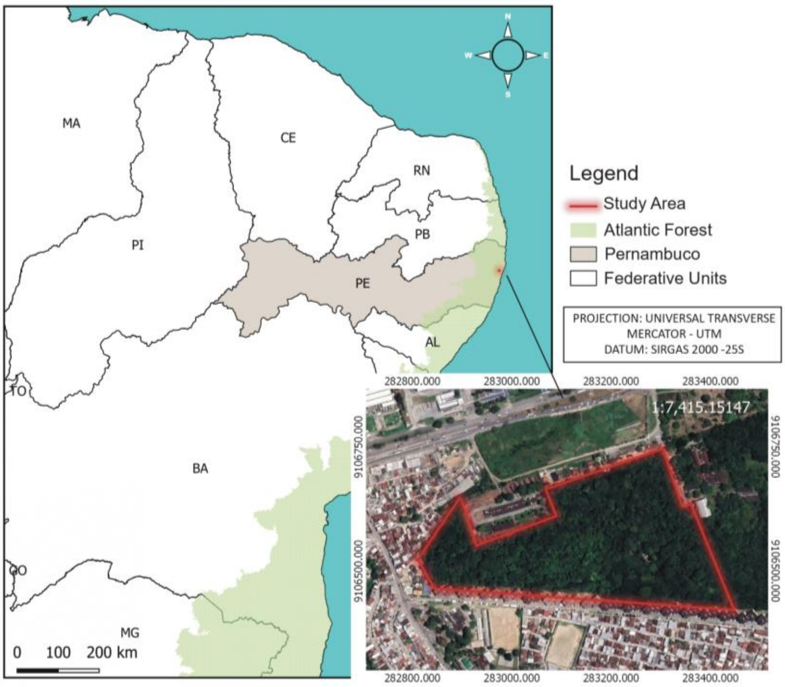

Figure 1. Geographical location of the Botanical Garden of Recife, Pernambuco, Brazil.
Figura 1. Localização geográfica do Jardim Botânico do Recife, Pernambuco, Brasil.

The area with vegetation cover in the BGR corresponds to a fragment of Atlantic Forest with 10.72 ha and predominance of the phytophysiognomy Lowland Dense Ombrophilous Forest. This forest phytophysiognomy, in general, occupies coastal plains, occurring from the Amazon and extending throughout the Northeast region to the state of Rio de Janeiro, being characterized by having phanerophytes (macro and mesophanerophytes), woody lianas and epiphytes in abundance (IBGE, 2012).

According to Köppen's climate classification, the climate of the region is Am type, with a rainy season concentrated between March and August, annual rainfall of 2,457 mm and monthly temperature ranging between 20.6 and 30.2 ºC (ALVARES *et al*., 2013; APAC, 2021).

The predominant soil in the area is *Argissolo Vermelho Amarelo distrófico* (Ultisol), according to the Brazilian Soil Classification System. This soil is characterized by a textural B horizon immediately below A or E, with base saturation below 50% in most of the first 100 cm of the B horizon (SANTOS *et al*., 2018).

Data collection

In the fragment of Atlantic Forest, 40 plots of 10 m x 25 m (250 m²), totaling 1 ha of sample, were allocated. The plots were systematically distributed, 10 m apart (Figure 2).

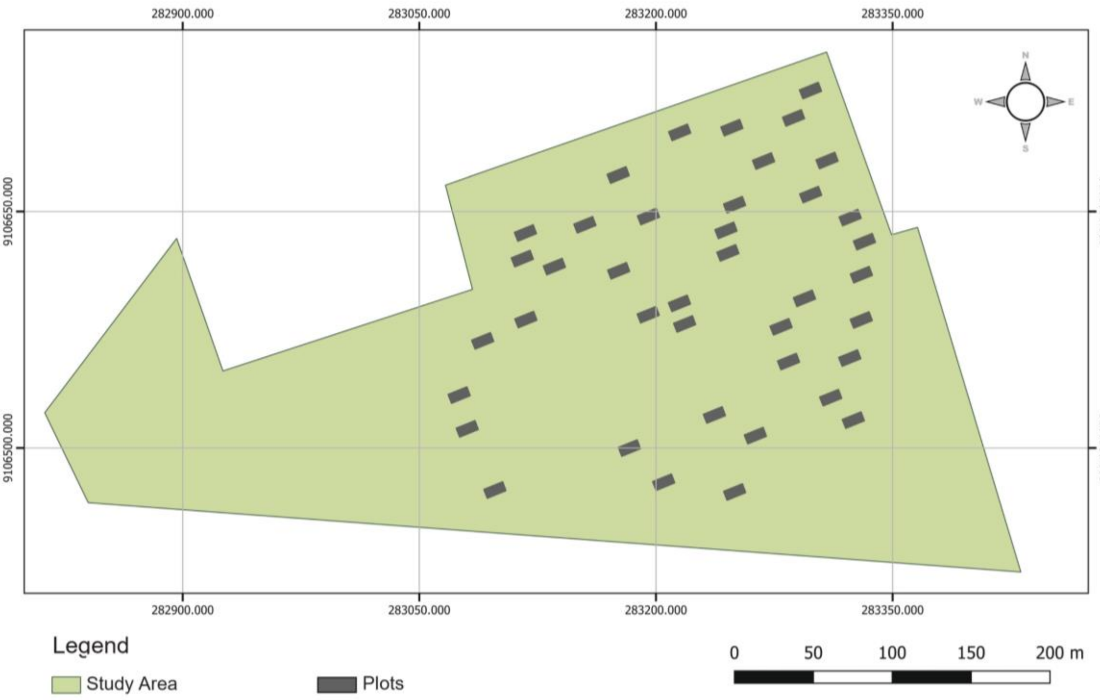

Figure 2. Schematic diagram of plot distribution in the area of the Botanical Garden of Recife, Pernambuco, Brazil.
Figura 2. Diagrama esquemático da distribuição de parcelas na área do Jardim Botânico do Recife, Pernambuco, Brasil.

In each plot, all living individuals that had circumference at 1.3 m above the ground ≥ 15 cm were measured. After measurement, the individuals were identified, aiming at recording their number and taxon, and then their locations were georeferenced.

The selected species were grouped into families according to the Angiosperm Phylogeny Group IV system, while the synonymy and the spelling of the taxa were updated according to the species index in the Flora do Brasil database (http://floradobrasil.jbrj.gov.br).

In addition, they were classified according to origin (native species, native species endemic to Brazil or alien species from other countries), ecological group (pioneer, early secondary and late secondary) and seed dispersal syndrome (autochorous, anemochorous and zoochorous).

Data analysis

To analyze the spatial distribution of forest species in the BGR, the abundance matrix of the species was formed by the number of individuals per plot of the i-th species. Only species with absolute density ≥ 10 individuals were included. This procedure is considered convenient because rare or low-density species increase the volume of calculation and interpretation errors (AMARAL *et al.*, 2019).

In order to identify the existence of floristic similarity between the plots, a vegetation matrix was created considering the density of the selected species per plot. Floristic similarity was determined by hierarchical agglomerative cluster (HAC) analysis, using the square Euclidean distance and Ward method for linkage.

The spatial variability of the forest species was characterized using geostatistical analysis. The data obtained were subjected to semivariance analysis, aiming to understand the spatial variability of the forest species studied. Under the intrinsic hypothesis theory, the experimental semivariogram was estimated by the following equation:

$$\hat{\gamma}(h)=\frac{1}{2\,N\,(h)}\sum_{i=1}^{N(h)}[Z(x_i)-Z(x_i+h)]^2$$

Where:
$\hat{\gamma}(h)$: semivariance estimated from experimental data;
N (h): number of pairs involved in the calculation of semivariance;
Z (X_i): value of the variable at the position x_i;
Z (x_i+h): value of the variable at the position $x_{(i+h)}$;
i: sample position;
h: distance between two samples.

The theoretical semivariogram was obtained by fitting a mathematical model (Spherical, Exponential or Gaussian) to the calculated values of the experimental semivariogram, based on the parameters nugget effect (C_0), structural variance (C), sill (C_0 + C) and range (a). The nugget effect corresponds to the semivariance value for a distance greater than zero and shorter than the shortest sampling distance, indicating the random variation component; structural variance is obtained through the difference between the sill and the nugget effect, representing the spatially structured semivariance; sill indicates the semivariance value at which the curve stabilizes at a constant value; and range corresponds to the distance from the origin up to which the sill reaches stable values, expressing the distance beyond which the samples are not correlated.

The theoretical models were fitted using the ordinary least squares method. The best models were selected based on the lowest residual sum of squares (RSS) and the highest coefficient of determination (R^2). Subsequently, these models were validated by cross-validation of the Jack-Knifing test, in which the mean should be close to zero and the standard deviation should be close to 1. The analysis was performed using GEO-EAS® software.

The degree of spatial dependence (DSD) of forest species was determined by the analysis of semivariograms. The values obtained were classified according to Cambardella *et al*. (1994), who consider DSD as strong when semivariograms have a nugget effect lower than or equal to 25%, moderate when it is between 25% and 75%, and weak when it is above 75%.

After verifying the DSD, the data were interpolated by kriging, using the parameters of the semivariograms (fitted model, nugget effect, structural variance and range), followed by the construction of thematic maps of spatial distribution.

Geostatistical analysis was performed using GS+ software version 7, while kriging maps were constructed using Surfer software version 9.0.

RESULTS

The vegetation matrix was composed of 18 native species, 5 native species endemic to Brazil and 1 alien species from another country, totaling 24 tree species, which represented 79.34% of the total sampled individuals. These species are distributed in 20 genera and 13 botanical families, and the most representative in number of species are: Moraceae (5) and Sapotaceae (3), Anarcadiaceae, Burseraceae, Euphorbiaceae, Fabaceae and Malvaceae, with two species each, while the other families were represented by only one species. The species with the highest abundance were: *Helicostylis tomentosa*, *Artocarpus heterophyllus*, *Protium heptaphyllum*, *Dialium guianense*, *Parkia pendula*, *Pouteria durlandii*, *Protium giganteum* and *Thyrsodium spruceanum*. Regarding dispersal syndrome, zoochorous species predominated (58.33%), followed by autochorous (20.83%), anemochorous (12.5%) and unclassified (8.33%) species (Table 1).

Table 1. List of families and forest species selected to make up the vegetation matrix, common name, absolute density (AD), place of origin (PO), ecological group (EG) and dispersal syndrome (DS).
Tabela 1. Relação das famílias e espécies florestais selecionadas para compor a matriz de vegetação, nome popular, densidade absoluta (DA), local de origem (LO), grupo ecológico (GE) e síndrome de dispersão (SD).

Family/Species	Common name	AD	PO	EG	DS
Anarcadiaceae					
Tapirira guianensis Aubl.	Cupiúba	16	N	LS	UNC
Thyrsodium spruceanum Benth.	Caboatão-de-leite	35	N	ES	ZOO
Araliaceae					
Schefflera morototoni (Aubl.) Maguire et al.	Sambaquim	20	N	ES	ZOO
Arecaceae					
Bactris ferruginea Burret	Coco-de-fuso	12	NEB	LS	ZOO
Burseraceae					
Protium giganteum Engl.	Amescla-gigante	36	N	LS	ZOO
Protium heptaphyllum (Aubl.) Marchand	Amescla-de-cheiro	78	N	ES	ZOO
Euphorbiaceae					
Hevea brasiliensis (Willd. ex A.Juss.) Müll.Arg.	Seringueira	31	N	LS	AUT
Mabea piriri Aubl.	Canudo-de-cachimbo	18	N	P	AUT
Fabaceae					
Dialium guianense (Aubl.) Sandwith	Pau-ferro-da-mata	55	N	ES	ZOO
Parkia pendula (Willd.) Benth. ex Walp.	Visgueiro	51	N	LS	AUT
Lecythidaceae					
Eschweilera ovata (Cambess.) Mart. ex Miers	Imbiriba	17	NEB	P	AUT
Malvaceae					
Eriotheca gracilipes (K.Schum.) A.Robyns	Munguba	12	N	LS	ANE
Luehea ochrophylla Mart.	Açoita-cavalo	11	N	ES	ANE
Melastomataceae					
Miconia affinis DC.	Tinteiro	17	N	ES	ZOO
Moraceae					
Artocarpus heterophyllus Lam.	Jaqueira	105	AL	UNC	AUT
Brosimum guianense (Aubl.) Huber	Quirí	23	N	LS	ZOO
Brosimum rubescens Taub.	Quirí	24	N	ES	ZOO
Helicostylis tomentosa (Poepp. & Endl.) Rusby	Amora-da-mata	177	N	ES	ZOO
Sorocea hilarii Gaudich.	Pau-tiú	10	NEB	ES	ZOO
Rubiaceae					
Alseis pickelii Pilg. & Schmale	Goiabinha	11	NEB	ES	ANE
Sapindaceae					
Cupania impressinervia Acev.-Rodr.	Caboatã-de-rego	12	NEB	ES	ZOO
Sapotaceae					
Pouteria bangii (Rusby) T.D.Penn.	Leiteiro	14	N	ES	ZOO
Pouteria durlandii (Standl.) Baehni	Abricó-da-mata	39	N	UNC	UNC
Pouteria grandiflora (A.DC.) Baehni	Guapeba	21	N	ES	ZOO

N = native; NEB = native endemic to Brazil; AL = alien; P = pioneer; ES = early secondary; LS = late secondary; UNC = unclassified; ANE = anemochorous; AUT = autochorous; ZOO = zoochorous.

The hierarchical agglomerative cluster (HAC) analysis, based on the density of the selected species, revealed the formation of two groups of plots, the first one formed by 9 plots and the second one formed by 31 plots (Figure 3). This indicates that the plots that make up both groups showed greater floristic similarity to each other.

The species found in greatest abundance in the first group were: *A. heterophyllus*, *Hevea brasiliensis*, *H. tomentosa*, *P. heptaphyllum* and *D. guianense*. In the second group, the species with the highest abundance were: *H. tomentosa*, *P. heptaphyllum*, *P. pendula*, *D. guianense*, *P. durlandii*, *T. spruceanum*, *P. giganteum* and *A. heterophyllus*. It is worth pointing out that all species occurred in greater abundance in the second group of plots, except *A. heterophyllus* and *H. brasiliensis*, which predominated in the first group. This may have influenced the formation of these two groups.

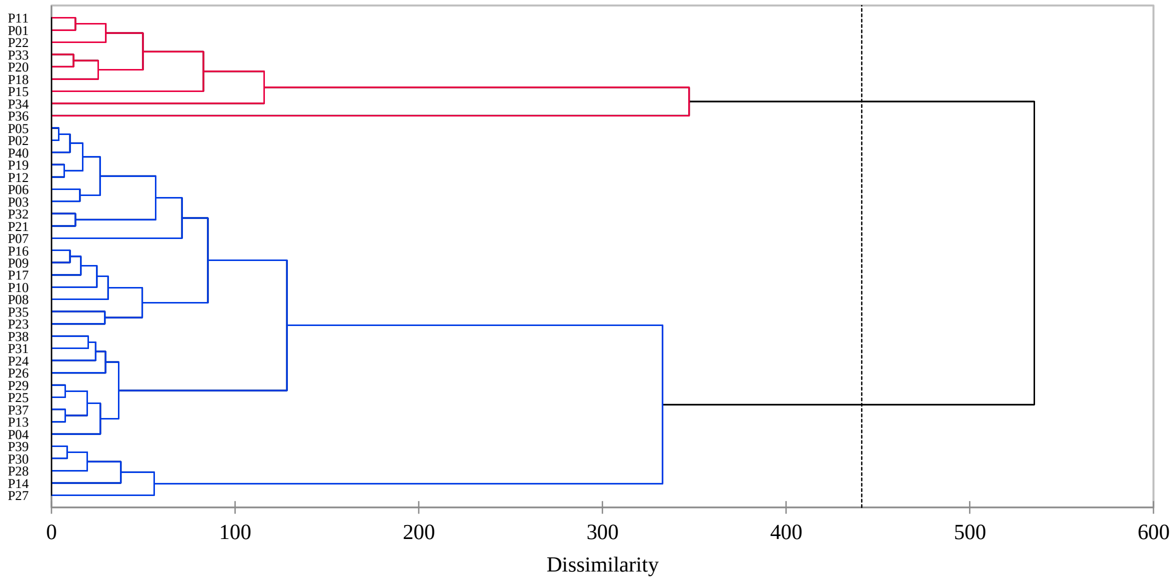

Figure 3. Dendrogram of hierarchical agglomerative cluster (HAC) analysis of plots used for vegetation sampling in the Botanical Garden of Recife, based on species density.
Figura 3. Dendrograma da análise de agrupamento hierárquico (CAH) das parcelas utilizadas para amostragem da vegetação no Jardim Botânico do Recife, com base na densidade das espécies.

Among the 24 species listed in Table 1, the forest species with spatial dependence were: *A. heterophyllus*, *D. guianense*, *H. tomentosa*, *H. brasiliensis*, *P. durlandii* and *T. spruceanum*. The Gaussian model was the one that best fitted to the semivariograms of the forest species (3 species), followed by Spherical (2 species) and Exponential (1 species) (Table 2).

Table 2. Models and parameters of semivariograms of forest species in the Botanical Garden of Recife, Pernambuco, Brazil.
Tabela 2. Modelos e parâmetros de semivariogramas de espécies florestais no Jardim Botânico do Recife, Pernambuco, Brasil.

Species	Model	C_0	$C_0 + C$	a	R^2	$C_0/(C_0 + C)$	DSD	Jack-Knifing	
								Mean	SD
A. heterophyllus	Exp	6.930	31.030	485.700	0.861	22.333	St	0.019	0.962
D. guianense	Sph	0.001	1.312	29.000	0.678	0.076	St	0.018	1.034
H. tomentosa	Gau	4.240	12.420	91.106	0.732	34.138	Md	0.000	1.021
H. brasiliensis	Gau	2.260	15.890	73.265	0.722	14.222	St	0.010	1.225
P. durlandii	Sph	0.304	2.011	37.700	0.838	15.117	St	0.060	1.016
T. spruceanum	Gau	0.001	0.772	33.255	0.592	0.130	St	-0.026	1.116

Exp = Exponential; Sph = Spherical; Gau = Gaussian; C_0 = nugget effect; $C_0 + C$ = sill; a = range; R^2 = coefficient of determination; $C_0/(C_0+C)$ = spatial dependence; DSD = degree of spatial dependence; St = strong; Md = moderate; SD = standard deviation.

The coefficient of determination (R^2) ranged from 0.59 to 0.86, with the lowest value for *T. spruceanum* and the highest value for *A. heterophyllus*. This indicates that, for these data, at least 60% of the variability in the estimated semivariance values were explained by the fitted models. The range (a) varied from 29 to 485.7 m, with the lowest values found for *D. guianense*, *T. spruceanum* and *P. durlandii* and the highest values for *A. heterophyllus*, *H. tomentosa* and *H. brasiliensis*. The relations between nugget effect and sill showed predominance of the strong DSD (*A. heterophyllus*, *D. guianense*, *H. brasiliensis*, *P. durlandii* and *T. spruceanum*), followed by moderate DSD (*H. tomentosa*).

The semivariogram models fitted for the forest species allowed estimating the number of individuals of these species in unsampled sites, using the method of data interpolation by kriging. Thus, with the estimated values, it was possible to construct isoline maps. These maps allowed visualizing the spatial distribution arrangements and identifying the concentration sites of the forest species (Figure 4).

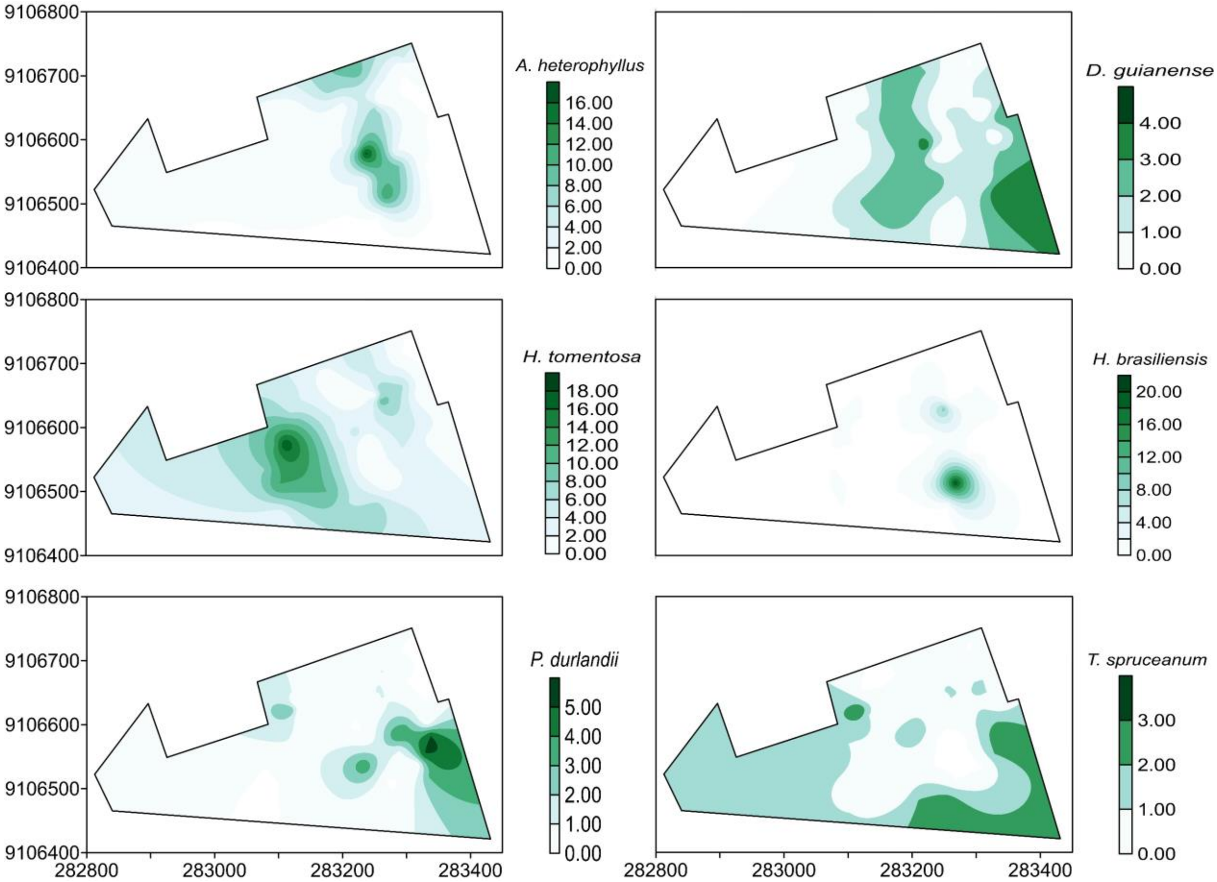

Figure 4. Kriging maps of the spatial distribution of forest species (ind.ha^{-1}) in the Botanical Garden of Recife, Pernambuco, Brazil.

Figura 4. Mapas de krigagem da distribuição espacial de espécies florestais (ind. ha^{-1}) no Jardim Botânico do Recife, Pernambuco, Brasil.

A. heterophyllus, *H. tomentosa* and *P. durlandii* occurred over the entire area of the fragment. However, it is possible to notice that *A. heterophyllus* concentrates a greater number of individuals in the central region, while the individuals of *H. tomentosa* and *P. durlandii* are concentrated on the left and right side of the fragment, respectively. In addition, it was observed that in the area of concentration of *A. heterophyllus* individuals, the other species had low abundance. *H. brasiliensis* occurred only in the central region of the fragment. *D. guianense* and *T. spruceanum* had a similar spatial distribution pattern. Although they occur throughout the fragment area, few individuals of these species were found concentrated in a single region (Figure 4).

DISCUSSION

The families found in the fragment with the highest abundance of species are commonly cited in studies evaluating the floristic composition of the tree component and natural regeneration in Atlantic Forest fragments in the state of Pernambuco (LIMA *et al*., 2019; SILVA *et al*., 2019). Likewise, species that showed higher abundance are commonly found in the tree component, as well as in the natural regeneration of these fragments, with abundance varying between fragments (OLIVEIRA *et al*., 2013; LIMA *et al*., 2019; SILVA *et al*., 2019).

It is important to highlight the presence of *A. heterophyllus*, popularly called jackfruit, among the species with the highest abundance in the fragment. This was the only alien species found in the fragment; it is native to India and is among the first alien species that were introduced into Brazil in the Atlantic Forest region. Due to its high potential for dispersal, germination and establishment, it came to be considered an invasive alien species, being among the most relevant in the Dense Ombrophilous Forest (ZENNI; ZILLER, 2011; BERGALLO *et al*., 2016).

The species *H. brasiliensis*, despite being native to Brazil, occurs naturally in the Amazon region. Therefore, just as *A. heterophyllus*, it was anthropically introduced into the forest fragment, which suggests that it is a fragment with anthropic influence.

The dispersal syndrome of forest species varies according to forest typology and successional stage. In ombrophilous forests, the proportion of species with zoochorous dispersal syndrome can exceed 80%. In addition, this proportion tends to be higher in forests that are preserved and in more advanced successional stage, as the dispersing fauna is susceptible to anthropic disturbances (CARVALHO, 2010). Thus, despite the anthropic influence identified, due to the introduction of alien species, the forest fragment studied shows signs of preservation, as well as more advanced successional stage.

The semivariogram models fitted for forest species differ from those selected by Silva *et al*. (2018) when evaluating the geospatial distribution of forest species in regeneration in an Atlantic Forest fragment in the state of Pernambuco. The authors highlighted that, for the forest species analyzed, the best fits were obtained with the Spherical model. Brandão *et al*. (2018), when studying the spatial distribution of *Euxylophora paraensis* Huber in natural forest managed in the Eastern Amazon, also reported that the best fit was obtained with the Spherical model. This occurs because the semivariogram of each forest species analyzed needs to be fitted with best model.

The range values obtained correspond to the radii of the areas considered homogeneous for each species (LIMA *et al*., 2014). Brandão *et al*. (2018) highlight that the range should be considered a parameter of extreme importance, because it represents the distance within which there is spatial dependence between the samples, allowing an analysis of the progress of the dispersal of forest species in the forest fragment studied.

A. heterophyllus and *H. tomentosa* were the species that had the longest radii of homogeneous distribution. The values were higher than those obtained by Silva *et al.* (2018) when evaluating the geospatial variability of the distribution of forest species in Atlantic Forest fragment in the state of Pernambuco, with range varying from 81.4 to 130.8 m. This difference may be related to several factors, especially the intrinsic characteristics of each forest fragment, as well as the different species analyzed.

The wide spatial distribution of *A. heterophyllus* and *H. tomentosa* may be associated with the fruit and seed dispersal syndrome of these species. The dispersal syndrome of *A. heterophyllus* is predominantly autochorous. In this type of dispersal, seeds tend to disperse and germinate near the mother plant, justifying the high concentration of individuals of this species in the central region of the fragment. However, the fruit of this species is highly appreciated by small mammals (FABRICANTE, 2014). As a result, the species has zoochorous secondary dispersal syndrome. Zoochory is the predominant dispersal syndrome of *H. tomentosa*. Species with this type of dispersal have a high capacity to disperse their seeds in the environment.

Boni *et al*. (2009), when studying the spatial distribution pattern of *A. heterophyllus* in the Paulo Fraga Rodrigues Biological Reserve in the state of Espírito Santo, observed variation in the spatial distribution pattern. The authors found individuals of this species occurring in strongly patchy, regularly spaced and sparingly placed patterns. These results are similar to those found in the present study. Thus, due to its high invasion potential, *A. heterophyllus* can prevent the establishment of native species, mainly in the area where it occurs in greater abundance.

In the areas with higher abundance of *A. heterophyllus*, there is low concentration of individuals of the other forest species analyzed, which may be related to the low sociability among these species. This indicates that native species may not tolerate the presence and effects caused by invasive alien species in the biophysical environment (FABRICANTE, 2014). In the long term, this can lead to reduced abundance of native species and increased dominance of *A. heterophyllus*. Thus, it is necessary to take mitigation actions for its control, mainly in protected areas, aiming at the conservation and maintenance of local biodiversity.

Alves Jr. *et al*. (2006), when evaluating the pattern of spatial distribution of forest species in Atlantic Forest fragment in the state of Pernambuco, observed that *H. tomentosa* showed a tendency of aggregate distribution. The authors emphasized that the spatial distribution of dominant species tends to be aggregate or clustered. This behavior was observed for *H. tomentosa* in the present study. Although the species is found throughout the fragment area, there is a concentration of a high number of individuals in a specific region.

The occurrence of *H. brasiliensis* only in the central region of the fragment may also be associated with the predominantly autochorous dispersal syndrome of the species. In addition, the seeds of this species are unattractive to wildlife. Therefore, the germination and establishment of regenerating individuals tend to occur near the mother plant, resulting in the formation of spatially grouped populations.

D. guianense and *T. spruceanum* have zoochorous dispersal syndrome. This explains the occurrence of these species throughout the fragment area, as well as the low concentration of individuals in a single region. In a study carried out by Alves Jr. *et al*. (2006), *D. guianense* showed a tendency to uniform distribution and *T. spruceanum* showed a tendency to clustering. Paula and Soares (2011) reported that *D. guianense* showed random distribution and *T. spruceanum* showed aggregate distribution. These variations are related to habitat characteristics and variation in the abundance of these species among the fragments.

Therefore, the understanding of the geospatial distribution of forest species in their natural environment can be considered extremely important for the preservation of forest resources. Geostatistical methods and spatial interpolators are indispensable support tools, as they allow understanding and visualizing how forest species are spatially distributed in large areas. From this, preservation actions, as well as actions of conservation and management of native and invasive alien species in the forest remnants, can be carried out.

CONCLUSIONS

- The presence of *A. heterophyllus* and *H. brasiliensis* suggests that the fragment of the Botanical Garden of Recife has anthropic influence. Despite that, the forest fragment shows signs of preservation and advanced successional stage.
- The forest species studied have spatial dependence and can be geostatistically modeled.
- The use of geostatistics allowed visualizing the spatial distribution arrangements and identifying concentration sites of the forest species.
- Information on the geospatial distribution of forest species can be used for the preservation, conservation and management of forest remnants.

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