Spatial distribution and diametric structure of tree species in a Dense Ombrophilous Forest in Rio Grande do Norte, Brazil

ABSTRACT

The Atlantic Forest is considered to be one of the world's most biodiverse wetlands. However, the misuse of natural resources exposes it to physical and biogeographical changes caused by both natural and anthropic disturbances. Consequently, changes in the composition and structure of the remnants forests are expected. Although many studies are performed in this biome, few address the population structure and spatial distribution. The objective was to analyze the spatial distribution pattern and the diametric structure of most representative tree species in a fragment of Dense Ombrophilous Forest in the State of Rio Grande do Norte, Brazil. Floristic and parametric vegetation surveys were performed based on quadrants sampling, with 175 sampling points distributed systematically over five transects. At each point, four quadrants were defined, and the living arboreal individual closer to the center of the point, presenting diameter at breast height (DBH) ≥ 3.18 cm, was measured and identified. The Payandeh index was employed to detect the spatial pattern of the species. The diametric structure was analyzed by the frequency distribution of six size classes, and the De Liocourt coefficients were also calculated for each species. Excluding Coccoloba alnifolia, the other species with high IVI (Importance Value Index) in the fragment shown an aggregate spatial distribution pattern or with a tendency to group. It was observed a diametric distribution pattern, tending to an inverted-J pattern, although with some peculiarities. The De Liocourt coefficient showed an unbalanced distribution for the studied species, but with a tendency to remain in the structural arrangement of the forest, once the human intervention is curbed. Except for C. alnifolia, the other species of higher IVI presented a pattern of aggregate distribution or tendency to aggregate. It was possible understanding the behavior of these species of the environment, subsidizing actions that aim at the conservation of the studied fragment.

Keywords: diameter classes; competition between species; population dynamics; aggregation pattern.

1. INTRODUCTION

The Atlantic Forest is considered one of the richest biodiversity rainforests in the world, composed of a high degree of endemism [1], but the misuse of natural resources has intensified its deforestation process [2]. Nowadays, the remnants of native forest (around 11-16%) [3], are exposed to physical and biogeographic changes caused by natural and anthropogenic disturbances that result in the disappearance of tree species [4].

In northeastern Brazil, the situation is critical when compared to southeastern [3]. There are few forest remnant, and most are limited to small patches. This scenario occurs because of the intensification of activities that cause degradation of native vegetation such as the expansion of urban centers, sugar cane farm and cattle breeding [5]. Human intervention in a forest, such as deforestation or extensive stockbreeding, can cause a significant reduction in the number of species and change the dynamics of populations, harming natural regeneration process and sustainability of the system [6; 7].

Although many works are carried out in this biome, few studies addressed on the population structure and spatial distribution of plant species in the Atlantic forest [4; 8; 9; 10; 11; 12]. The population structure and spatial distribution of species in the community are related to the competition between individuals and considering the auto-ecological features; some have a significant risk of not surviving.
In a forest in normal conditions, many young individuals do not complete their life cycle due to species competition, which reflects the natural succession process [06].

The diametric structure evaluation assumes importance in understanding over the recruitment and mortality of local species in their development record and allows evaluating the intensity of disturbances that occurred in local forestry community, besides helps to determine the growth of species and Community [13].

The spatial distribution of individuals in the area is related to the production and dispersal of seeds and the ability of germination and survival of the seedlings [06]. It is important for conservation studies to recognize the distribution pattern of individuals in an area, to understand the dynamics of populations [14], and consequently generate subsidies for the maintenance of biological diversity.

Marangon et al. [15] quote about conservancy maintenance factors of an area, that leads to comprehend the default aggregation of individuals, as morphological factors involving dispersal mechanisms, environmental factors, related, for example, with the type of soil, and phytosociological factors that relates interspecific and intraspecific competition. For this, the floristic indexes and spatial aggregation estimation [06] are important to understanding the diversity of the environment and can be utilized as parameters in the evaluation of the data [16].

According to Ribeiro et al. [3], more than 80% of the remnants of the Atlantic Forest are limited to small fragments with areas smaller than 50 ha. Often, it is possible to find small remnants of Atlantic Forest isolated in anthropic landscapes and unprotected - as the target fragment of the present study located in Brazilian Northeast. The anthropogenic impacts can lead to ecological changes in the forest structure and, consequently, threaten the biological diversity of the environment.

In this sense, this work aimed to analyze the spatial distribution pattern and diameter structure of the most representative tree species in a fragment of Atlantic forest in the state of Rio Grande do Norte (RN), Brazil, providing information for future management actions and conservation of the area.

2. MATERIAL AND METHODS / EXPERIMENTAL DETAILS / METHODOLOGY

2.1 Study area

The study was carried out in an Atlantic forest fragment of 6.5ha, located in the municipality of Macaíba/RN. Denoted “Mata do Bebo”, the fragment has the center coordinates 5° 53’30”S and 35° 21’ 30” W and average altitude of 40 m above sea level. Currently is over constant human activity due to the presence of monocultures, and other signs of environmental degradation, such as openings trails and thinning trees.

According to Koppen classification, the climate is ‘As’ type (rainy tropical), with high temperatures throughout the year and the rainy season from March to July. The average annual precipitation is 1070.7mm, and the average annual temperature is around 27.1 °C with 21 °C minimum and 32 °C maximum [17].

2.2 Sampling

The floristic and parametric vegetation survey was carried out based on the quadrant sampling method proposed by Cottan and Curtis [18], being among the most used sampling methods in native forests to obtain floristic, phytosociological and quantitative parameters [19]. To this end, 175 sampling points were systematically distributed every eight meters, over five transects, outlined in parallel at a distance of 15 meters from each other. In each transect, the allocation of the first point started at least, 10 m from the fragment edge (Figure 1).
Fig. 1. Transects layout for the floristic survey in the Fragment of Ombrophilous Dense Forest, Macaíba, RN

At each sampling point, four quadrants were defined, then in each quadrant, the individual live tree closest to the center point with diameter at breast height (DBH) $\geq 3.18$ cm and total height (Ht) $\geq 1.30$m, was measured and identified. For individuals with branches below 1.30 m, the average diameter was determined by the mean square of the respective DBHs measured.

When it was not possible to identify in the field, photographic records and collection of botanical material were carried out, aiming the preparation of exsiccates for later identification based on the specialized bibliography.

2.3 Statistical analysis

From the phytosociological analysis performed in the fragment by Araújo et al. [20], a diameter distribution graphic was constructed for the four species with the highest importance value index (IVI) in the fragment, when added they represent 41.49% of this ratio (Table 1).

Table 1. List of species with the highest IVI in the Atlantic forest fragment, Macaíba, RN

<table>
<thead>
<tr>
<th>Species</th>
<th>Family</th>
<th>IVI (%)</th>
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<tbody>
<tr>
<td>Coccoloba alnifolia Casar.</td>
<td>Polygonaceae</td>
<td>9.57</td>
</tr>
<tr>
<td>Copaifera cearenses Huber ex Ducke var.</td>
<td>Fabaceae</td>
<td>12.37</td>
</tr>
<tr>
<td>Eugenia rostrifolia D.Legrand</td>
<td>Myrtaeeae</td>
<td>9.83</td>
</tr>
<tr>
<td>Protium heptaphyllum (Aubl.) March.</td>
<td>Burseraceae</td>
<td>9.72</td>
</tr>
</tbody>
</table>

These species were selected for analysis because they presented relatively high values of density, frequency and dominance in the phytosociological analysis of the studied fragment, being able to be indicators to express changes in the structure and dynamics of the forest.

The distribution analysis of the individuals in diameter classes was performed using histograms. The width of the bands in the construction of the diameter distribution graphs varied according to each species and was estimated using mean and standard deviation of the diameters of individuals measured as shown in Table 2 below and described by [21].

Table 2. Calculation criteria used for the amplitude of the size classes for tree species of higher importance value in the Ombrophilous Dense Forest fragment, Macaíba, RN

<table>
<thead>
<tr>
<th>Diametric classes</th>
<th>Amplitude</th>
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According to Bongers et al. [22], to compare size structures between different species, it is not advisable to use uniform classes in the construction of the diagrams. Different species have specific genetic characteristics, regarding size and, in this case, using regular classes would result in a pseudo differentiation between species with different sizes, instead of differentiating species that have different size structures.

The De Liocourt “q” coefficients [23] were also individually calculated for each species, to understand the relationship of species mortality/growth in the community. The above coefficient was calculated by dividing the number of individuals of a diametric class by the number of individuals of the preceding class. According to the same author, a plant community with relatively constant “q” values among diametric classes indicates the presence of a balanced community where recruitment compensates for mortality over time.

The spatial distribution pattern analysis of the species with higher IVI in the fragment was held as Payandeh [24]. This method determines the degree of aggregation of the species through the relationship between the variance of the number of trees per sample and the average of the number of trees, where: Pi ≤ 1.0 indicates random pattern; 1.0 < Pi ≤ 1.5 indicates a tendency to group, and Pi > 1.5 indicates the group of species individuals.

For the graphical representation of the histograms of individuals and data processing the software Microsoft Excel 2007 and BioEstat 5.3 [25], were employed.

### 3. RESULTS AND DISCUSSION

It was catalogued 700 individuals distributed by 57 species, belonging to 30 botanical families. Of these, 93 individuals are represented by *Eugenia rostrifolia*, 61 by *Coccoloba alnifolia* and 74 by *Copaifera cearenses* and *Protium heptaphyllum* species that have the same number of individuals.

Among the 175 quadrants installed, the mean plant-point distance was 2.31 m, which corresponds to a total density of 1,873 individuals ha⁻¹ and a basal area of 22.13 m² ha⁻¹.

The diametric structure showed differences in the amplitude of the size classes, where *Copaifera cearenses* presented individuals with a larger diameter in the fragment, followed by *Protium heptaphyllum, Coccoloba alnifolia* e *Eugenia rostrifolia*. The same pattern was also observed for the amplitude of the size classes (Table 3).

| Table 3. Amplitude of the six diameter classes for the four species of tree with the higher importance value in the Ombrophilious Dense Forest, Macaíba, RN |
|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| Diametric classes           | *C. alnifolia*              | *C. cearenses*              | *E. rostrifolia*            | *P. heptaphyllum*           |
|                            | interval (cm)               | DA                          | interval (cm)               | DA                          |
| Class 1                    | ≤ 5.65                      | 59                          | ≤ 6.58                      | 64                          |
| Class 2                    | 5.66 to 7.52                | 40                          | 6.59 to 10.58               | 80                          |
| Class 3                    | 7.53 to 9.39                | 29                          | 10.59 to 15.48              | 27                          |
| Class 4                    | 9.40 to 11.26               | 11                          | 15.49 to 20.38              | 8                           |
| Class 5                    | 11.27 to 13.13              | 11                          | 20.39 to 25.28              | 3                           |
|                            |                            | 6.14 to 6.78                | 14.99 to 17.99              | 16                          |
The four species with highest IVI in the fragment showed a pattern of diameter distribution tending to inverted-J, behaving as expected for the uneven-aged forests. However, the values calculated for the De Liocourt "q" coefficients were highly variable, showing an irregular pattern of distribution of individual diameters for the species studied (figure 2).

The mean values of De Liocourt "q" quotient was 2.06, to Copaifera cearenses, 1.81 to Protium heptaphyllum, 1.55 to Eugenia rostrifolia, and 1.49 to Coccoloba alnifolia, with the coefficient calculated for each class varying from 0.17 to 3.33; 0.67 to 3.50; 0.63 to 2.60; and 0.80 to 2.75, respectively. According to Felfili [23], relatively constant values of "q" indicates that the diametric distribution rates are balanced, where recruitment compensates mortality over time.

The distribution pattern of individuals over the diameter classes showed irregular for the species Copaifera cearenses and Protium heptaphyllum. Variations were observed in the J-inverted structure,
with the number of individuals of the first class lower than the second class, or subsequent classes having a higher proportion of individuals compared to earlier, suggesting an imbalance between mortality and recruitment (figure 2). Such an imbalance may have been caused by anthropogenic interventions such as selective culling of individuals in the intermediate diameter classes, causing an interruption in the flow of individuals. On the other hand, the high proportion of individuals in the first classes indicates a high of self-regeneration of the species, once smaller individuals substitute the most advanced in the ecological succession process.

The *Eugenia rostrifolia* and *Coccoloba alnifolia* species, although have also presented an irregular distribution pattern, with a high concentration of individuals in the smaller diameter classes, had an uniform decrease in the number of individuals among the different size classes when compared to other to other species of higher IVI in the fragment (Figure 2).

A large amount of individuals in lower diametric classes has an important function to ensure the resilience of secondary forests [26], but can also indicate the occurrence of disturbances in vegetation. This scenario is due to possible burnings, constant attacks of pests or insects and wood extraction purposes in the recent past [27]. These disturbances, caused by possible anthropogenic interventions can provoke changes in the structure of forest [10].

Bernasol and Lima-Ribeiro [21] analyzing the diametric structure of tree species in a fragment of Cerrado observed unbalanced diametric distributions for *Piptocarpha rotundifolia* and *Butia purpurascens*, indicating the susceptibility of these species to environmental variations and disturbances when compared to other analyzed in the fragment.

Carvalho et al. [10] analyzing the diametric structure of the community, and the main tree populations in the remnant of Submontane Atlantic forest report that species that presents the low amount of individuals, in smaller diameter classes, can have problems regarding the permanence in the remnant.

Additionally, the concentration of individuals in smaller diameter classes is important to ensure the survival and perpetuation of the plant in the forest succession process [28]. In this case, it is a sign that the recruitment of individuals is higher than mortality, which characterizes the community as self-regenerating [29].

In summary, the results observed in this study indicate that despite the species with higher IVI in the fragment presented an unbalanced diametric distribution, their respective diametric distribution patterns tended to J-inverted. The species have a higher concentration of juvenile individuals, indicating that in the long run, the species tend to remain in the structural arrangement of the forest since human intervention is curbed.

Regarding the spatial distribution pattern of the species with the highest IVI in the forest, it was observed through Payandeh index that the individuals of *Protium heptaphyllum* occur aggregated, while *Copalea cearenses* and *Eugenia rostrifolia* presented a tendency to group, and *Coccoloba alnifolia* is randomly distributed in the fragment (table 4).

### Table 4. Spatial distribution pattern of the species with the highest IVI in the fragment of Atlantic forest, Macaíba/RN

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Pi index</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Coccoloba alnifolia</em></td>
<td>0.98</td>
<td>Random Distribution</td>
</tr>
<tr>
<td><em>Copalea cearenses</em></td>
<td>1.45</td>
<td>Tendency to group</td>
</tr>
<tr>
<td><em>Eugenia rostrifolia</em></td>
<td>1.03</td>
<td>Tendency to group</td>
</tr>
<tr>
<td><em>Protium heptaphyllum</em></td>
<td>1.69</td>
<td>Aggregated distribution</td>
</tr>
</tbody>
</table>

Pi: Payandeh Index

Kanieski et al. [16] analyzing the floristic composition and diversity in a fragment of Mixed Ombrophilous Forest in Rio Grande do Sul, observed that most of the species that occur in vegetation are classified as aggregated or with a tendency to group. [30] studying the spatial distribution of
*Pseudopiptadenia contorta* in a Seasonal Deciduous Forest in Vitória da Conquista, BA, reported that the specimen is distributed in the environment, mainly influenced by the chemical soil quality.

The plants are typically distributed in aggregate form because they are structured mainly by abiotic factors such as texture, fertility, soil water availability, luminosity, temperature, among others; that are directly influenced by the variations in the production and provision of energy [31].

Alves Júnior et al. [32] analyzing the edge effect in the structure of tree species in a fragment of Ombrophilous Dense Forest in Recife, found that the most representative species in the vegetation usually occur in the aggregate form or with a tendency to cluster. According to Martins et al. [33], this pattern is commonly observed in abundant species in Tropical Forests.

In fact, the spatial distribution exposes how individuals are arranged horizontally in the environment and this organization is the result of a combination of biotic and abiotic factors, such as environmental requirement, seed dispersal, predation and herbivory, and inter and intraspecific competition, among others.

Excluding Coccoloba alnifolia, the other species with highest IVI in the fragment shown an aggregate spatial distribution pattern or with a tendency to group. It is possible that this result is related to a low rate of intraspecific competition on the population or restricted dispersal of seeds near the mother-plant, as reported in other studies [34; 35]. However, studies that address the spatial genetic structure in a microscale become necessary to confirm these hypotheses.

The standard knowledge of the spatial distribution of trees individuals in a population is crucial because it allows inferences about the ecology of the species and identifies possible dysfunctions in the propagation of individuals of a given species, thus subsidizing, forest management practices.

### 4. CONCLUSION

The species with highest IVI in the fragment showed a pattern of diametric distribution tending to inverted-J, behaving as expected for the uneven-aged forests.

The *De Liocourt* coefficient showed an unbalanced distribution for the studied species, but with a tendency to remain in the structural arrangement of the forest, as long as human interventions are curbed.

Except for Coccoloba alnifolia, the other highest IVI in the fragment showed an aggregate spatial distribution pattern or with a tendency to group, a fact that allows understanding the behavior of these species in the environment, subsidizing actions aiming the conservation of the fragment studied.

It is suggested that in projects that aim to recover degraded areas in the studied fragment consider the pattern of distribution of the species in the fragment to maintain them in the structural arrangement of the forest.

### REFERENCES


