Phytosociology, Diversity and Ecological Groups of the Adult Tree Component of a Forest Remnant in Pernambuco – Brazil

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Authors’ contributions

This work was carried out in collaboration among all authors. Authors REC, ACSV, LGS, SCMN, MLB, MDL and CFLSB collected the data. Authors RVL and CFLSB identified the plants. Author REC managed the literature searches, the analyses of the study and wrote the first draft of the manuscript. Author RVL performed the statistical analysis and reviewed the work. Author CFLSB designed the study, wrote the protocol, managed the analyses of the study and reviewed the work. All authors read and approved the final manuscript.

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ABSTRACT

The main objective of this study is to characterize the floristic richness, phytosociological structure, and classify the ecological groups of the adult tree component species in an area of ecological tension (Seasonal Forest and Caatinga) in Pernambuco - Brazil. The study was conducted in Atlantic Forest stretch in Pernambuco – Brazil, from April 2019 to February 2020. Methods adopted for this study includes the allocation of 20 plots, with dimensions of 10 m x 25 m, spaced in 25 m. Each adult individual, with a circumference at breast height (CBH 1.30 m)  ≥ 15 cm, was identified in

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1. INTRODUCTION

The Atlantic Forest is considered one of the regions with top priority for the conservation of its biodiversity, where most species officially threatened with extinction in Brazil inhabit this type of formation [1]. The forests inserted in the Northeast region of Brazil are the ones that suffered most anthropic disturbances over the years, being completely fragmented. Currently, most of its area is characterized by secondary forests [2,3].

The discontinuity and isolation of forests, a process that characterizes forest fragmentation, causes higher sensitivity to disturbances, directly affecting the spatial distribution, availability of natural resources, and, consequently, the survival of species occurring in the region and the environmental services provided [4]. It is necessary to further study the effects of fragmentation in the Atlantic Forest on its biodiversity [5]. Therefore, research works that value the individualities of each region are essential to enable forest management more faithful to nature. These studies involve analyzing the characteristics of the plant community of a given area, such as successional classification, phytosociology, and diversity.

Secondary forests, formed by anthropic or natural disturbances, have ecological succession as the main indicator of vegetation development. They may suffer the influence of invasive species during the process, causing severe disturbances in the forest, according to the degree of competition and the fragility of the environment in this phase [6,7]. Thus, to analyze this process, the classification of ecological groups analyzes the successional stage of the species found about many indicators such as the requirement for sunlight, life span, dispersion, maturation, among other important aspects that will define, throughout the succession process, the establishment of the individual in the community [8]. In this context, ecological succession is one of the primary studies used to understand what measures are needed to be taken to improve the condition of forest remnants, as well as whether these measures are having an effect over time [9].

In addition to ecological succession, studies such as phytosociology allow the characterization of diversity and biological structure in a given ecosystem. This type of study aims to describe the quantitative characteristics of plant communities [10]. It can determine the most important species within the tree component and, in this way, prioritize them and define which measures are a priority for the preservation of the community [11,12]. This type of analysis is widely used in other Brazilian states within the domain of the Atlantic Forest, such as those by Araújo et al. [13], Marchiori et al. [14] and Fantini et al. [15] in the Rio Grande do Norte, São Paulo and Santa Catarina, respectively.

The diversity of forest species is based on two aspects: richness and uniformity. While richness refers to the number of species existing in the community, uniformity indicates how many individuals exist for each species [10]. These analyses present the establishment of populations of certain species in the environment. The forest remnants of the Brazilian northeast have high diversity. The richness level of the species is higher when the area has more protection from anthropic interference [16].

Keywords: Horizontal structure; successional classification; ecological tension; Brazilian Northeast.
In this context, the objective of this study was to characterize the floristic richness, phytosociological structure and classify the ecological group of species of the adult tree component in an area of ecological tension (Seasonal Forest and Caatinga) in Pernambuco – Brazil.

2. MATERIALS AND METHODS

2.1 Study Area and Data Collection

The municipality of Garanhuns, located in the State of Pernambuco - Brazil, has 458,552 km² of the territorial unit area [17]. The climate of this region is humid coastal tropical (As), with an annual temperature average of 21.4°C and annual precipitation of 909 mm [18]. Also, it is a mountainous region with altitude quotas around 900 m [19].

Garanhuns is inserted in an area of ecological tension of the ecotone type between Seasonal Forest and Caatinga [20]. The interaction between vegetation types is considered as an area of ecological tension, where they can be divided into two groups: ecotones or enclaves [20,21]. Ecotone is a transition system, where two or more types of vegetation occur and cause an interpenetration, forming floristic transitions and edaphic contacts [22]. In these areas, there is a lack of studies regarding the understanding of the species behavior [23].

Fig. 1 shows the location of the section within the municipality of Garanhuns. The area of the present study has 23 ha, with a perimeter of 2.1 km and the coordinates longitude 5°26'08.34" E and latitude 8°54'20.53" S.

Based on the researches of Silva et al. [24], Lima et al. [25], and Silva et al. [26], 20 permanent plots of 10 m x 25 m (spaced by 25 m) were systematically allocated, totaling a sample area of 0.5 ha (Fig. 2). The plots were implanted in three tracks, being Track 1 with seven, Track 2 with eight, and Track 3 with five plots. All adult individuals with a circumference at breast height (CBH 1.30 m) ≥ 15 cm were identified in the field.

The identification of the individuals was made in the field with the help of a specialist, according to the Angiosperm Phylogeny Group IV system [27], and the unidentified species were photographed for consultation in herbarium or online literature, describing the species according to their morphological characteristics. For the classification of ecological groups, it was researched the classification of each species in books, scientific articles, theses, and dissertations in regions close to the present study. For example, all volumes of Lorenzi's book Brazilian Trees [28] were used, and the works of Carnaúba et al. [29] and Brandão et al. [30].

The classification of ecological groups divided the species into: Pioneer – light-dependent
Fig. 2. Trails representation, where the plots were allocated for the study of the adult tree component of an Atlantic Forest stretch located in Pernambuco, Brazil.

species that do not occur in the undergrowth; Initial Secondary – species that occur in conditions of medium shading or not very intense luminosity; Late Secondary – species that develop in the undergrowth in conditions of light or dense shade; and No Classification [31,32].

2.2 Sample Sufficiency and Data Analysis

The statistical software Mata Nativa version 2 [33] was used for the calculation of sample sufficiency, data processing, and analysis of phytosociological parameters. Excel for Windows™ 2019 software was used for the generation of graphics.

The sample sufficiency of the survey was calculated for the basal area and density of the individuals, considering a sampling error of at most 20% for 95% confidence probability. The sufficiency of floristic richness was determined by the curve species x area, based on the Fazenda Fojos's 23 ha stretch.

Species diversity was determined by Shannon-Wiener Diversity ($H'$) and Pielou Uniformity ($J$) indexes. According to Mueller-Dombois and Ellenberg [34] the following parameters presented in Table 1 were used for the phytosociological analysis.

The density expresses the total number of individuals in a given community concerning its area; the frequency is given by the number of times that a given species occurs in the sample units and represents the spatial uniformity of that species in the area; dominance indicates how much space area the species occupies by the basal area. Finally, the value of importance is given by adding the parameters mentioned above, pointing out which species is more important, in fact, for that community [10].

3. RESULTS AND DISCUSSION

The analysis of sample sufficiency (Table 2) for the 23 ha fragment showed that the number of plots implanted was sufficient to represent the population of the adult tree component to both parameters since six plots would be necessary according to the basal area and 11 plots according to density. Through the values of mean standard error ($0.0246 \text{ m}^2$ and $3.1618 \text{ ind/0.025ha}$), coefficient of variation (20.54% and 30.28%), and sampling error (9.5% and 14%), it is possible to define statistically that the sampling of the study is satisfactory since the maximum error admitted was of 20%.

Fig. 3 shows the curve of species x area, demonstrating that the number of species tends to stabilization from the 17th plot. Consequently, it is possible to affirm that the number of plots implanted in the study is enough to represent the floristic richness in the analyzed section.
Table 1. Phytosociological parameters used to analyze the horizontal structure of the adult tree component of an Atlantic Forest stretch located in Pernambuco, Brazil

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Expression</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute Density (AD)</td>
<td>( \frac{R}{Area} )</td>
<td>( n ) = number of individuals of a certain species.</td>
</tr>
<tr>
<td>Relative Density (RD)</td>
<td>( \frac{\left(\frac{N}{N}\right) \times 100}{P} )</td>
<td>( N ) = total number of individuals.</td>
</tr>
<tr>
<td>Absolute Frequency (AF)</td>
<td>( \frac{\left(\frac{P_i}{P}\right) \times 100}{P} )</td>
<td>( P ) = number of plots (sample units) with occurrence of species i.</td>
</tr>
<tr>
<td>Relative Frequency (RF)</td>
<td>( \frac{\sum AF \times 100}{P} )</td>
<td>( \sum AF ) = sum of the absolute frequencies of all sampled species.</td>
</tr>
<tr>
<td>Absolute Dominance (ADo)</td>
<td>( \frac{\pi \times DBH^2}{Area} )</td>
<td>( gi ) = basal area of a certain species.</td>
</tr>
<tr>
<td></td>
<td>( \frac{4}{\pi \times DBH^2} )</td>
<td>DBH = diameter at the breast height.</td>
</tr>
<tr>
<td>Relative Dominance (RDo)</td>
<td>( \frac{(\frac{gi}{G}) \times 100}{P} )</td>
<td>( G ) = basal area of all sampled species.</td>
</tr>
<tr>
<td>Value of Importance (VI)</td>
<td>( VI = RD + RF + RDo )</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Sample sufficiency and statistical data from the study on the adult tree component of an Atlantic Forest stretch located in Pernambuco, Brazil

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Basal area (m²)</th>
<th>Density (ind)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n (optimal number of plots)</td>
<td>6 un.</td>
<td>11 un.</td>
</tr>
<tr>
<td>Total</td>
<td>10.818 m²</td>
<td>944 ind.</td>
</tr>
<tr>
<td>Mean</td>
<td>0.5409 m²/0.025ha</td>
<td>47.2 ind/0.025ha</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.1111 m²/0.025ha</td>
<td>14.2961 ind/0.025ha</td>
</tr>
<tr>
<td>Variance</td>
<td>0.0123 (m²/0.025ha)²</td>
<td>204.3799 (ind/0.025ha)²</td>
</tr>
<tr>
<td>Mean Variance</td>
<td>0.0006 (m²/0.025ha)²</td>
<td>9.9968 (ind/0.025ha)²</td>
</tr>
<tr>
<td>Mean Standard Error</td>
<td>0.0246 m²/0.025ha</td>
<td>3.1618 ind/0.025ha</td>
</tr>
<tr>
<td>Coefficient of Variation</td>
<td>20.5453 %</td>
<td>30.2884 %</td>
</tr>
<tr>
<td>Tabulated t value</td>
<td>2.093</td>
<td>2.093</td>
</tr>
<tr>
<td>Absolute Sampling Error</td>
<td>0.0514 m²/0.025ha</td>
<td>6.6177 ind/0.025ha</td>
</tr>
<tr>
<td>Relative Sampling Error</td>
<td>9.5104 %</td>
<td>14.0204 %</td>
</tr>
</tbody>
</table>

Twenty-nine families, 45 genera, and 74 species were identified in the analyzed section (Table 3), of which 45 were identified at the species level, 16 at the genus level, seven at the family level, and six undetermined. The non-identification of all species occurred mainly in very high individuals, or in cases where it was not possible to collect fertile material.

Regarding richness, the families that stood out were Fabaceae (14.8%), Myrtaceae (10.8%), Annonaceae (9.4%), Lauraceae (5.4%), Elaeocarpaceae (4%), Sapindaceae (4%) and Sapotaceae (4%) (Fig. 4).

The richest family in this study was Fabaceae, represented by 11 species, *Abarema* sp., *Albizia pedicellaris*, *Browdichia virgilioides*, *Chamaecrista ensiformis*, *Fabaceae 1*, *Fabaceae 2*, *Inga capitata*, *Inga laurina*, *Machaerium aculeatum*, *Stryphnodendron pulcherrimum*, and *Tachigali densiflora*. Fabaceae is one of the richest families among Brazil's ecosystems, with 212 genera and 2,807 native species in Brazil [35,36]. This family has the characteristic of fixing nitrogen in the soil, which makes it a key-species in the recovery of degraded areas [37,38].

The Myrtaceae was represented by the species *Campomanesia* sp. 1, *Campomanesia* sp. 2, *Myrcia guianensis*, *Myrcia splendid*, *Myrcia sylvatica*, *Myrtaceae 1*, *Myrtaceae 2* and *Psidium* sp. With about 1,000 species belonging to 23...
genera, this family is dominant mainly in Atlantic Forests [39,40]. It has economic importance and is the eighth family with the highest diversity in the Brazilian Northeast [41].

Annonaceae is a family of pantropical distribution, with 30 genera and 260 species in all Brazilian forest formations [42,43]. In this study, it was represented by the species Annonaceae 1, Annonaceae 2, Guatteria sp. 1, Guatteria sp. 2, Guatteria pogonopus, Xylopia frutenscens, and Xylopia ochrantha.

Lauraceae presented the species Lauraceae 1, Ocotea gardnerii, Ocotea glomerata, and Ocotea sp. Occurring mainly in neotropical regions, in lowland forests or intermediate altitudes, the family covers 18 genera and 125 species in the Brazilian Northeast, being one of the rich in diversity in different communities [44,45]. It is one of the families with the highest number of endangered species in Brazil (36 species), according to the Red List of Threatened Species [46].

Elaeocarpaceae was represented by the species Sloanea guianensis, Sloanea obtusifolia, and Sloanea sp. Its occurrence has a greater diversity in the Amazon but also occurs in the biomes Caatinga, Cerrado, Atlantic Forest and Pantanal [36].

Sapindaceae was represented by the species Allophylus sp., Cupania oblongifolia, and Cupania racemosa. It is a family very characterized by endemism, with 88 endemic species of 411 species occurring in Brazil, belonging to 25 genera [47,48]. It inhabits tropical and subtropical regions, with some genera occurring in temperate regions [49].

Finally, the species Chrysophyllum cainito, Manilkara sp., and Pouteria sp. represented the Sapotaceae family. This family has 13 genera in Brazil, encompassing 233 species [50]. In addition to having food potential, the species of the genus Pouteria and Manilkara are great attractions for the timber industry [51].

The relationship of ecological groups between the species found (Fig. 5) was 46% (34) for initial secondary, 35% (26) for no classification, 11% (8) for pioneers, and 8% (6) for late secondary. The representation of species with no classification occurred due to the species identified at the level of genus, family, or indeterminate, where it is not possible to define the ecological group. In the work of Sobrinho [52] and Santos [53], in two forests of Ombrophilous Forest in the State of Pernambuco, the initial secondary ones were also more represented in the classification of ecological groups of the reference ecosystem analyzed. Carnaúba et al. [29] also found the same result in an Ombrophilous Lowland Forest.

![Fig. 3. Species x area curve of the adult tree component of an Atlantic Forest stretch located in Pernambuco, Brazil](image-url)
Fig. 4. Botanical families with more species of the adult tree component of an Atlantic Forest stretch located in Pernambuco, Brazil

Fig. 5. Successional classification of the species of the adult tree component of an Atlantic Forest stretch located in Pernambuco, Brazil

The domain of species classified as initial secondary or pioneer suggests that the forest is young [32], mainly because it means that most of the species there are come from the seed bank, that is, it is a forest that was regenerated naturally not long ago.

In the phytosociological survey, 944 adult individuals were measured, representing an absolute density of 1,888 ind.ha\(^{-1}\) and dominance of 21.64 m\(^2\).ha\(^{-1}\) (Table 4). The values found are close to those of other authors who researched in the State of Pernambuco, such as Nascimento and Rodal [54], who found a density of 1,553 ind.ha\(^{-1}\) and dominance of 39 m\(^2\).ha\(^{-1}\) and Costa Junior et al. [55], in which the density was 1,049 ind.ha\(^{-1}\) and dominance of 23.6 m\(^2\).ha\(^{-1}\).

The species *Buchenavia tetrphylla*, *Guapira nitida*, and *Manilkara* sp. obtained the highest values about relative dominance, density, and frequency, differing only the order between them according to each parameter. Therefore, the five species of most significant value of importance in the analyzed fragment were, respectively, *Guapira nitida*, *Buchenavia tetrphylla*, *Manilkara* sp., *Byrsonima crassifolia*, and *Sloanea obtusifolia* (Fig. 6).
Table 3. List of species found in the adult tree component of an Atlantic Forest stretch located in Pernambuco, Brazil

<table>
<thead>
<tr>
<th>Family/Species</th>
<th>Ecological group</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Anacardiaceae</strong></td>
<td></td>
</tr>
<tr>
<td><em>Tapirira guianensis</em> Aubl.</td>
<td>IS</td>
</tr>
<tr>
<td><strong>Annonaceae</strong></td>
<td></td>
</tr>
<tr>
<td>Annonaceae 1</td>
<td>NC</td>
</tr>
<tr>
<td>Annonaceae 2</td>
<td>NC</td>
</tr>
<tr>
<td>Guatteria sp. 1</td>
<td>IS</td>
</tr>
<tr>
<td>Guatteria sp. 2</td>
<td>IS</td>
</tr>
<tr>
<td>Guatteria pogonopus Mart.</td>
<td>IS</td>
</tr>
<tr>
<td>Xylopia frutescens Aubl.</td>
<td>P</td>
</tr>
<tr>
<td>Xylopia ochrantha Mart.</td>
<td>P</td>
</tr>
<tr>
<td><strong>Boraginaceae</strong></td>
<td></td>
</tr>
<tr>
<td>Cordia sp.</td>
<td>NC</td>
</tr>
<tr>
<td>Cordia superba Cham.</td>
<td>IS</td>
</tr>
<tr>
<td><strong>Burseraceae</strong></td>
<td></td>
</tr>
<tr>
<td><em>Protium heptaphyllum</em> (Aubl.) Marchand</td>
<td>LS</td>
</tr>
<tr>
<td>Protium sp.</td>
<td>NC</td>
</tr>
<tr>
<td><strong>Capparaceae</strong></td>
<td></td>
</tr>
<tr>
<td><em>Crateva tapia</em> L.</td>
<td>P</td>
</tr>
<tr>
<td><strong>Celastraceae</strong></td>
<td></td>
</tr>
<tr>
<td>Maytenus distichophylla Mart. ex Reissek</td>
<td>IS</td>
</tr>
<tr>
<td>Maytenus erythroxyla Reissek</td>
<td>IS</td>
</tr>
<tr>
<td><strong>Chrysobalanaceae</strong></td>
<td></td>
</tr>
<tr>
<td>Licania sp.</td>
<td>NC</td>
</tr>
<tr>
<td><strong>Clusiaceae</strong></td>
<td></td>
</tr>
<tr>
<td>Clusia nemorosa G.Mey.</td>
<td>IS</td>
</tr>
<tr>
<td><strong>Combretaceae</strong></td>
<td></td>
</tr>
<tr>
<td><em>Buchenavia tetraphylla</em> (Aubl.) R.A.Howard</td>
<td>IS</td>
</tr>
<tr>
<td><strong>Elaeocarpaceae</strong></td>
<td></td>
</tr>
<tr>
<td>Sloanea guianensis (Aubl.) Benth.</td>
<td>LS</td>
</tr>
<tr>
<td>Sloanea obtusifolia (Moric.) Schum.</td>
<td>IS</td>
</tr>
<tr>
<td>Sloanea sp.</td>
<td>NC</td>
</tr>
<tr>
<td>Family/Species</td>
<td>Ecological group</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td><strong>Erythroxylaceae</strong></td>
<td></td>
</tr>
<tr>
<td><em>Erythroxylum squamatum</em> Sw.</td>
<td>IS</td>
</tr>
<tr>
<td><strong>Euphorbiaceae</strong></td>
<td></td>
</tr>
<tr>
<td><em>Maprounea guianensis</em> Aubl.</td>
<td>IS</td>
</tr>
<tr>
<td><strong>Fabaceae</strong></td>
<td></td>
</tr>
<tr>
<td><em>Abarema</em> sp.</td>
<td>NC</td>
</tr>
<tr>
<td><em>Albizia pedicellaris</em> (DC.) L. Rico</td>
<td>IS</td>
</tr>
<tr>
<td><em>Bowdichia virgilioides</em> Kunth</td>
<td>P</td>
</tr>
<tr>
<td><em>Chamaecrista ensiformis</em> (Vell.) H.S. Irwin &amp; Barneby</td>
<td>IS</td>
</tr>
<tr>
<td>Fabaceae 1</td>
<td>NC</td>
</tr>
<tr>
<td>Fabaceae 2</td>
<td>NC</td>
</tr>
<tr>
<td><em>Inga capitate</em> Desv.</td>
<td>IS</td>
</tr>
<tr>
<td><em>Inga laurina</em> (Sw.) Willd.</td>
<td>IS</td>
</tr>
<tr>
<td><em>Machaerium aculeatum</em> Raddi</td>
<td>P</td>
</tr>
<tr>
<td><em>Stryphnodendron pulcherrimum</em> (Willd.) Hochr.</td>
<td>LS</td>
</tr>
<tr>
<td><em>Tachigali densiflora</em> (Benth.) L.G.Silva &amp; H.C.Lima</td>
<td>IS</td>
</tr>
<tr>
<td><strong>Lauraceae</strong></td>
<td></td>
</tr>
<tr>
<td>Lauraceae 1</td>
<td>NC</td>
</tr>
<tr>
<td><em>Ocotea gardnerii</em> (Meisn.) Mez</td>
<td>IS</td>
</tr>
<tr>
<td><em>Ocotea glomerata</em> (Nees) Mez</td>
<td>IS</td>
</tr>
<tr>
<td><em>Ocotea</em> sp.</td>
<td>NC</td>
</tr>
<tr>
<td><strong>Lecythidaceae</strong></td>
<td></td>
</tr>
<tr>
<td><em>Eschweilera ovata</em> (Cambess.) Mart. ex Miers</td>
<td>LS</td>
</tr>
<tr>
<td><strong>Malpighiaceae</strong></td>
<td></td>
</tr>
<tr>
<td><em>Byrsonima crassifolia</em> (L.) Kunth</td>
<td>P</td>
</tr>
<tr>
<td><strong>Moraceae</strong></td>
<td></td>
</tr>
<tr>
<td><em>Brosimum guianense</em> (Aubl.) Huber</td>
<td>IS</td>
</tr>
<tr>
<td><em>Ficus</em> sp.</td>
<td>NC</td>
</tr>
<tr>
<td><strong>Myrtaceae</strong></td>
<td></td>
</tr>
<tr>
<td><em>Campomanesia</em> sp. 1</td>
<td>NC</td>
</tr>
<tr>
<td><em>Campomanesia</em> sp. 2</td>
<td>LS</td>
</tr>
<tr>
<td><em>Myrcia guianensis</em> (Aubl.) DC.</td>
<td>IS</td>
</tr>
<tr>
<td><em>Myrcia splendens</em> (Sw.) DC.</td>
<td>IS</td>
</tr>
<tr>
<td><em>Myrcia sylvatica</em> (G.Mey.) DC.</td>
<td>IS</td>
</tr>
<tr>
<td>Family/Species</td>
<td>Ecological group</td>
</tr>
<tr>
<td>---------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Myrtaceae 1</td>
<td>NC</td>
</tr>
<tr>
<td>Myrtaceae 2</td>
<td>NC</td>
</tr>
<tr>
<td>Psidium sp.</td>
<td>NC</td>
</tr>
<tr>
<td>Nyctaginaceae</td>
<td></td>
</tr>
<tr>
<td><em>Guapira opposita</em> (Vell.) Reitz</td>
<td>IS</td>
</tr>
<tr>
<td><em>Guapira nitida</em> (Mart. ex J.A.Schmidt) Lundell</td>
<td>IS</td>
</tr>
<tr>
<td>Ochnaceae</td>
<td></td>
</tr>
<tr>
<td><em>Guapira nitida</em> (Mart. ex J.A.Schmidt) Lundell</td>
<td>IS</td>
</tr>
<tr>
<td>Peraceae</td>
<td></td>
</tr>
<tr>
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</tr>
<tr>
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</tr>
<tr>
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<tr>
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<tr>
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<tr>
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<tr>
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</tr>
<tr>
<td><em>Manilkara sp.</em></td>
<td>NC</td>
</tr>
<tr>
<td><em>Pouteria sp.</em></td>
<td>NC</td>
</tr>
<tr>
<td>Simaroubaceae</td>
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<tr>
<td><em>Simarouba amara</em> Aubl.</td>
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*Where: P = pioneer; IS = initial secondary; LS = late secondary; NC = no classification*
Table 4. Phytosociological survey of the adult tree component of an Atlantic Forest stretch located in Pernambuco, Brazil

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<th>RDo</th>
<th>AD</th>
<th>RD</th>
<th>AF</th>
<th>RF</th>
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<td>0.0099</td>
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<td>0.0094</td>
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<tr>
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<tr>
<td>Species</td>
<td>NI</td>
<td>( \Sigma G )</td>
<td>ADo</td>
<td>RDo</td>
<td>AD</td>
<td>RD</td>
<td>AF</td>
<td>RF</td>
<td>VI</td>
</tr>
<tr>
<td>-----------------------</td>
<td>----</td>
<td>----------------</td>
<td>-----</td>
<td>-----</td>
<td>----</td>
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<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
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<td>0.03</td>
<td>2</td>
<td>0.11</td>
<td>5</td>
<td>0.35</td>
<td>0.48</td>
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<tr>
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<td>0.0050</td>
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<td>0.47</td>
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<tr>
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<td>0.0036</td>
<td>0.02</td>
<td>2</td>
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<td>5</td>
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<td>0.47</td>
</tr>
<tr>
<td>Myrcia guianensis</td>
<td>1</td>
<td>0.002</td>
<td>0.0036</td>
<td>0.02</td>
<td>2</td>
<td>0.11</td>
<td>5</td>
<td>0.35</td>
<td>0.47</td>
</tr>
<tr>
<td>Total</td>
<td>944</td>
<td>10.818</td>
<td>21.64</td>
<td>100</td>
<td>1888</td>
<td>100</td>
<td>1435</td>
<td>100</td>
<td>300</td>
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</table>

*Where: NI = number of individuals sampled in the area of 0.5 ha; \( \Sigma G \) = sum of basal area (m².ha⁻¹); ADo = absolute dominance (m².ha⁻¹); RDo = relative dominance (%); AD = absolute density (individuals.ha⁻¹); RD = relative density (%); AF = absolute frequency (%); RF = relative frequency (%); VI = value of importance (%)
**Guapira nitida**, the most important species of the analyzed fragment, is part of the family Nyctaginaceae. It is an initial secondary species, endemic to Brazil and presents a shrubby arboreal habit [56]. It occurs in Atlantic forests, being dense and open ombrophilous forest or in sandbanks, or seasonal semi-deciduous lowland forest [57,58], but prefers the interiors of the coastal Atlantic Forest, with the presence of humidity and shade [59].

**Buchenavia tetraphylla** belongs to the family Combretaceae, and it is characterized as initial secondary. It is neotropical, occurring from the island of Cuba to the State of Rio de Janeiro [60].

The genus **Manilkara** sp., of the Sapotaceae family, was identified in 19 species in Brazil, in 23 different vegetational formations, being them Amazon forest, Atlantic Forest, Caatinga and Cerrado, with 12 occurring in the Brazilian Northeast [61,62]. However, some species of the genus are not collected due to the vast territorial area of the States or the lack of expeditions and research [63].

The species **Byrsonima crassifolia** is a pioneer species belonging to the family Malpighiaceae, which occurs in all regions of Brazil, except in the southern region. It prefers dry and elevated soils of sandy and poor soils [64]. Also, according to the author, **Byrsonima crassifolia** is a deciduous, heliophytic, and selective xerophytic plant. Its frequency is moderate to discontinuous, and its density varies according to the vegetation and region of occurrence. This species is essential for the maintenance of solitary bees, animals that naturally have their populations reduced [65].

**Sloanea obtusifolia** belongs to the family Elaeocarpaceae and occurs in the Atlantic Forest, where there has been a drastic reduction of the original vegetation in the last ten years. It belongs to the group of initial secondary. The population of the species is significantly reduced due to the use of wood for various purposes, being considered “vulnerable” by the Flora Red List of the Espírito Santo [66,67].

From these data, the Shannon-Wiener Diversity Index (H’) calculated for this fragment was 3.21 nats.ind\(^{-1}\). On the other hand, the Pielou Uniformity Index (J) was 0.73, that is, 73% of uniformity.

The Shannon-Wiener Diversity Index (H’) values in forest environments usually vary between 1.5 and 3.5, sometimes exceeding 4 nats.ind\(^{-1}\) [68]. The value found for this parameter is following those found in other studies of different forest phytophysiognomies in the State of Pernambuco, such as Cola et al. [69], with 3.44 nats.ind\(^{-1}\); Silva Júnior et al. [70] found 3.91 nats.ind\(^{-1}\) and Rocha et al. [71] showing 3.6 nats.ind\(^{-1}\). The value calculated in the present study is within the forest environment standards mentioned earlier. Despite being a secondary forest surrounded by pastures, the diversity index was not compromised. As no exotic/invasive species were found, the process of regeneration of the environment is satisfactory in terms of species diversity.
The Pielou Uniformity Index indicates that 27% more species are missing for the fragment to reach its maximum point of diversity [72]. A similar result to those found by Santos [53], which was 78% and by Holanda et al. [73] of 77%, both in the State of Pernambuco. It can be stated that the uniformity of the analyzed fragment is under the pattern of the fragments of the region.

Although the property adopts agricultural and livestock production, these indices indicate high diversity and uniformity. This aspect can be encouraged by the adjacent areas to the fragment that were abandoned and allowed to regenerate.

4. CONCLUSION

In the present study, 74 tree species were found, belonging to 29 families, with a density of 1,888 ind.ha$^{-1}$ and the dominance of 21.64 m².ha$^{-1}$. These values agree with the values found in studies in nearby regions. The botanical families greatest richness are, respectively, Fabaceae, Myrtaceae, Annonaceae, Lauraceae, Elaeocarpaceae, Sapindaceae and Sapotaceae.

Regarding the ecological groups, 46% of the species were classified as initial secondary. This information demonstrates that the fragment is in a medium or secondary stage of development, where, with no anthropic interference in the dynamics of the fragment, it can reach maturity.

The most important species being *Guapira nitida*, *Buchenavia tetraphylla*, *Manilkara* sp., *Byrsonima crassifolia*, and *Sloanea obtusifolia*, respectively, four of them are characterized as initial secondary and one of them as a pioneer. This information corroborates with the analysis of succession found in the studied area, pointing to the medium stage of regeneration.

The value of the Shannon-Wiener Diversity Index ($H'$) was 3.21 nats.ind$^{-1}$, and the Pielou Uniformity Index ($J$) was 0.73. They indicate that the analyzed stretch has a high diversity and a good pattern of uniformity of the adult tree component species, making it essential to continue its conservation. These values are a consequence of regeneration in the areas adjacent to the fragment.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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