Phytosociology, diversity and ecological groups of the adult tree component of a forest remnant in Pernambuco – Brazil

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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 the field. The softwares Mata Nativa version 2 and Excel 2019 were used to process the collected data. Sample sufficiency, classification of ecological groups, diversity, and phytosociology were analyzed. As a result of the research, the density of the adult tree component in the fragment was 1,888 $ind.ha^{-1}$, and the dominance was 21.64 $m^2.ha^{-1}$. These values are following the standards of other studies in Atlantic Forest in the State of Pernambuco. The botanical families with 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. The species of greatest Value of Importance were *Guapira nitida*, *Buchenavia tetraphylla*, *Manilkara* sp., *Byrsonima crassifolia*, and *Sloanea obtusifolia*, respectively. The Shannon-Wiener Diversity Index (H') value was 3.21 $nats.ind^{-1}$, and the Pielou Uniformity Index (J) was 0.73. According to the results obtained, the development process of the adult tree component of the fragment was directly affected by the pasture matrix. However, species diversity has not been compromised, indicating the area's resilience potential.

Keywords: horizontal structure, successional classification, area of ecological tension, brazilian northeast.

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].

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. MATERIAL 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].

Figure 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 5º26'08.34" E and latitude 8°54'20.53" S.

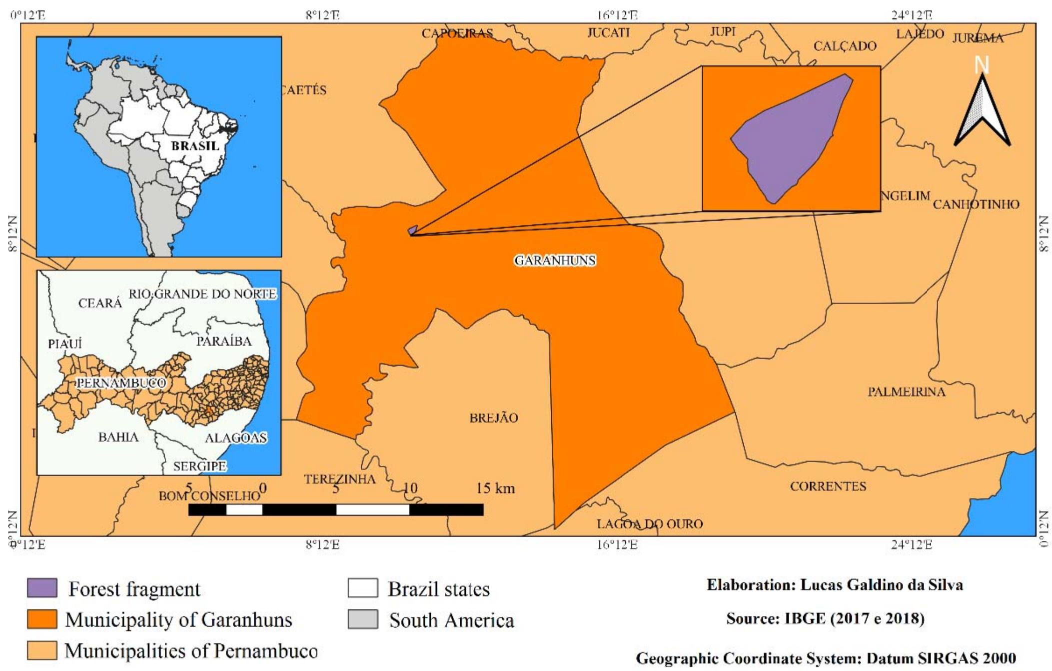

Fig. 1. Location of an Atlantic Forest stretch in Pernambuco, Brazil.

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.

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.

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 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.

Table 1. Phytosociological parameters used to analyze the horizontal structure of the adult tree component of an Atlantic Forest stretch located in Pernambuco, Brazil.

Parameter	Expression	Variables
Absolute Density (AD)	$DA = \frac{n}{Área}$	n = number of individuals of a certain species.
Relative Density (RD)	$DR = \left(\frac{n}{N}\right) * 100$	N = total number of individuals.
Absolute Frequency (AF)	$FA = \left(\frac{pi}{P}\right) * 100$	Pi = number of plots (sample units) with occurrence of species i. P = total number of plots (sample units) in the sample.
Relative Frequency (RF)	$FR = \frac{FAi}{\sum FA} * 100$	AFi = absolute frequency of a certain species. ΣAF = sum of the absolute frequencies of all sampled species.
Absolute Dominance (ADo)	$DoA = \frac{gi}{Área(ha)}$ $gi = \frac{\pi.DAP^2}{4}$	gi = basal area of a certain species. DAP = diameter at the breast height.
Relative Dominance (RDo)	$DoR = \left(\frac{gi}{G}\right) * 100$ $G = \sum gi$	G = basal area of all sampled species.
Value of Importance (VI)	$VI = DR + FR + DoR$	

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 m² e 3.1618 ind/0.025 ha), coefficient of variation (20.54% e 30.28%), and sampling error (9.5% e 14%), it is possible to define statistically that the sampling of the study is satisfactory since the maximum error admitted was of 20%.

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

Parameters	Basal Area (m²)	Density (ind)

n (optimal number of plots)	6 un.	11 un.
Total	10.818 m²	944 ind.
Mean	0.5409 m²/0.025ha	47.2 ind/0.025ha
Standard Deviation	0.1111 m²/0.025ha	14.2961 ind/0.025ha
Variance	0.0123 (m²/0.025ha)²	204.3789 (ind/0.025ha)²
Mean Variance	0.0006 (m²/0.025ha)²	9.9968 (ind/0.025ha)²
Mean Standard Error	0.0246 m²/0.025ha	3.1618 ind/0.025ha
Coefficient of Variation	20.5453 %	30.2884 %
Tabulated t value	2.093	2.093
Absolute Sampling Error	0.0514 m²/0.025ha	6.6177 ind/0.025ha
Relative Sampling Error	9.5104 %	14.0204 %

Figure 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.

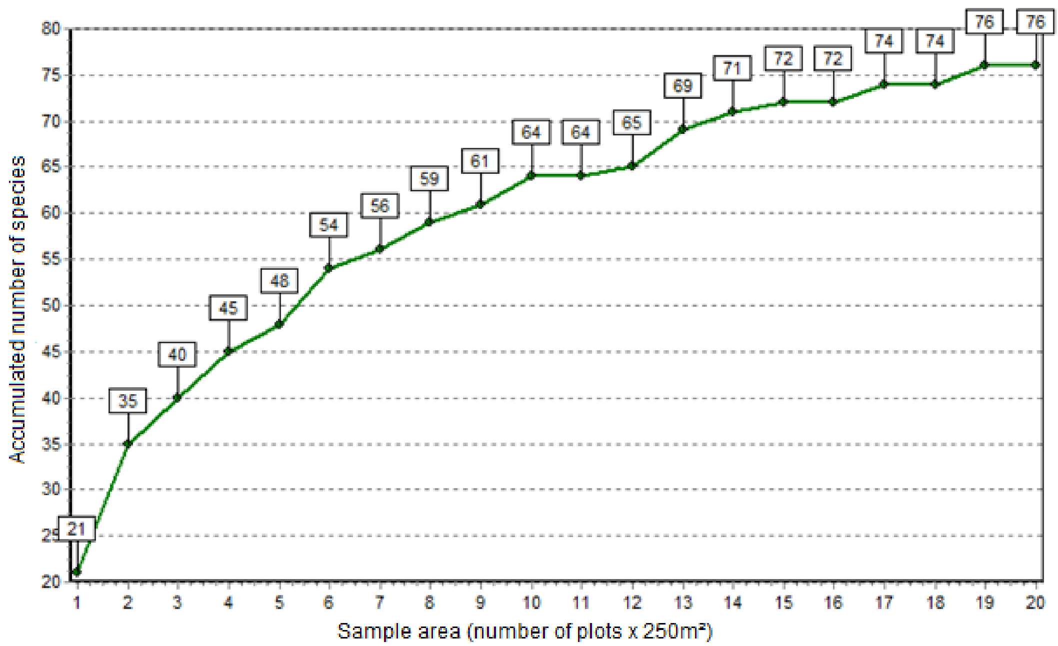

Fig.3. Species x area curve of the adult tree component of an Atlantic Forest stretch located in Pernambuco, Brazil.

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.

Table 3. List of species found in the adult tree component of an Atlantic Forest stretch located in Pernambuco, Brazil.

Family/Species	Ecological Group

Anacardiaceae	
Tapirira guianensis Aubl.	IS
Annonaceae	
Annonaceae 1	NC
Annonaceae 2	NC
Guatteria sp. 1	IS
Guatteria sp. 2	IS
Guatteria pogonopus Mart.	IS
Xylopia frutenscens Aubl.	P
Xylopia ochrantha Mart.	P
Boraginaceae	
Cordia sp.	NC
Cordia superba Cham.	IS
Burseraceae	
Protium heptaphyllum (Aubl.) Marchand	LS
Protium sp.	NC
Capparaceae	
Crateva tapia L.	P
Celastraceae	
Maytenus distichophylla Mart. ex Reissek	IS
Maytenus erythroxyla Reissek	IS
Chrysobalanaceae	
Licania sp.	NC
Clusiaceae	
Clusia nemorosa G.Mey.	IS
Combretaceae	
Buchenavia tetraphylla (Aubl.) R.A.Howard	IS
Elaeocarpaceae	
Sloanea guianensis (Aubl.) Benth.	LS
Sloanea obtusifolia (Moric.) Schum.	IS
Sloanea sp.	NC
Erythroxylaceae	
Erythroxylum squamatum Sw.	IS
Euphorbiaceae	
Maprounea guianensis Aubl.	IS
Fabaceae	
Abarema sp.	NC
Albizia pedicellaris (DC.) L.Rico	IS
Bowdichia virgilioides Kunth	P
Chamaecrista ensiformis (Vell.) H.S.Irwin & Barneby	IS
Fabaceae 1	NC
Fabaceae 2	NC
Inga capitata Desv.	IS
Inga laurina (Sw.) Willd.	IS
Machaerium aculeatum Raddi	P
Stryphnodendron pulcherrimum (Willd.) Hochr.	LS
Tachigali densiflora (Benth.) L.G.Silva & H.C.Lima	IS
Lauraceae	
Lauraceae 1	NC

Ocotea gardnerii (Meisn.) Mez	IS
Ocotea glomerata (Nees) Mez	IS
Ocotea sp.	NC
Lecythidaceae	
Eschweilera ovata (Cambess.) Mart. ex Miers	LS
Malpighiaceae	
Byrsonima crassifolia (L.) Kunth	P
Moraceae	
Brosimum guianense (Aubl.) Huber	IS
Ficus sp.	NC
Myrtaceae	
Campomanesia sp. 1	NC
Campomanesia sp. 2	LS
Myrcia guianensis (Aubl.) DC.	IS
Myrcia splendens (Sw.) DC.	IS
Myrcia sylvatica (G.Mey.) DC.	IS
Myrtaceae 1	NC
Myrtaceae 2	NC
Psidium sp.	NC
Nyctaginaceae	
Guapira opposita (Vell.) Reitz	IS
Guapira nitida (Mart. ex J.A.Schmidt) Lundell	IS
Ochnaceae	
Ouratea hexasperma (A.St.-Hil.) Baill.	IS
Peraceae	
Pogonophora schomburgkiana Miers ex Benth.	LS
Phyllanthaceae	
Hieronyma alchorneoides Allemão	IS
Richeria sp.	NC
Primulaceae	
Myrsine guianensis (Aubl.) Kuntze	P
Rubiaceae	
Alseis pickelii Pilg. & Schmale	IS
Psychotria carthagenensis Jacq.	IS
Rutaceae	
Zanthoxylum rhoifolium Lam.	IS
Salicaceae	
Casearia sylvestris Sw.	P
Sapindaceae	
Allophylus sp.	NC
Cupania oblongifolia Mart.	IS
Cupania racemosa (Vell.) Radlk.	IS
Sapotaceae	
Chrysophyllum cainito L.	IS
Manilkara sp.	NC
Pouteria sp.	NC
Simaroubaceae	
Simarouba amara Aubl.	IS

**Where: P = pioneer; IS = initial secondary; LS = late secondary; NC = no classification.*

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).

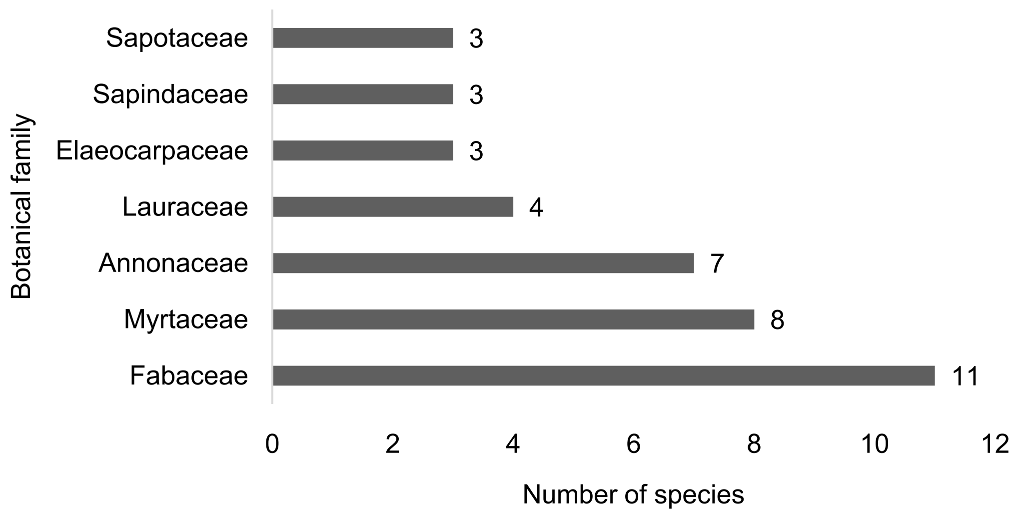

Fig. 4. Botanical families with more species of the adult tree component of an Atlantic Forest stretch located in Pernambuco, Brazil.

The richest family in this study was Fabaceae, represented by 11 species, *Abarema* sp., *Albizia pedicellaris*, *Bowdichia 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 spledens*, *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.

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.

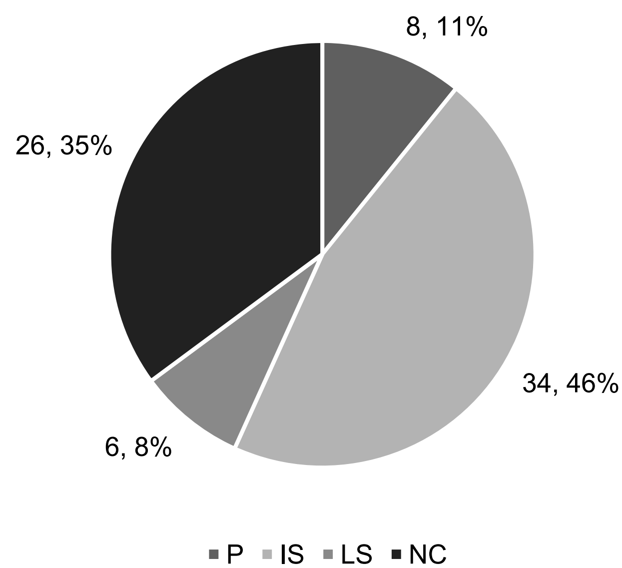

Fig. 5. Successional classification of the species of the adult tree component of an Atlantic Forest stretch located in Pernambuco, Brazil.

In the phytosociological survey, 944 adult individuals were measured, representing an absolute density of 1,888 ind.ha^{-1} and dominance of 21.64 m².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 $m^2.ha^{-1}$.

Table 4. Phytosociological survey of the adult tree component of an Atlantic Forest stretch located in Pernambuco, Brazil.

Species	NI	ΣG	ADo	RDo	AD	RD	AF	RF	VI
Guapira nitida	151	1.532	3.0635	14.16	302	16.00	70	4.88	35.03
Buchenavia tetraphylla	71	1.827	3.6539	16.89	142	7.52	75	5.23	29.64
Manilkara sp.	87	1.058	2.1150	9.78	174	9.22	85	5.92	24.91
Byrsonima crassifolia	70	0.613	1.2263	5.67	140	7.42	95	6.62	19.70
Sloanea obtusifolia	68	0.780	1.5608	7.21	136	7.20	60	4.18	18.60
Bowdichia virgilioides	48	0.494	0.9878	4.57	96	5.08	90	6.27	15.92
Clusia nemorosa	31	0.734	1.4678	6.78	62	3.28	60	4.18	14.25
Guapira opposita	31	0.751	1.5021	6.94	62	3.28	25	1.74	11.97
Protium heptaphyllum	38	0.220	0.4393	2.03	76	4.03	75	5.23	11.28
Tapirira guianensis	30	0.444	0.8876	4.10	60	3.18	45	3.14	10.42
Cupania oblongifolia	37	0.218	0.4366	2.02	74	3.92	60	4.18	10.12
Guatteria pogonopus	35	0.194	0.3878	1.79	70	3.71	60	4.18	9.68
Alseis pickelii	25	0.257	0.5137	2.37	50	2.65	55	3.83	8.86
Campomanesia sp. 2	29	0.106	0.2122	0.98	58	3.07	50	3.48	7.54
Chrysophyllum cainito	17	0.213	0.4267	1.97	34	1.80	30	2.09	5.86
Myrtaceae 1	22	0.064	0.1275	0.59	44	2.33	40	2.79	5.71
Ocotea sp.	24	0.215	0.4298	1.99	48	2.54	15	1.05	5.57
Guatteria sp. 2	15	0.076	0.1511	0.70	30	1.59	45	3.14	5.42
Cordia superba	12	0.076	0.1519	0.70	24	1.27	20	1.39	3.37
Pouteria sp.	3	0.137	0.2746	1.27	6	0.32	10	0.70	2.28
Casearia sylvestris	5	0.037	0.0745	0.34	10	0.53	20	1.39	2.27
Cordia sp.	6	0.021	0.0424	0.20	12	0.64	15	1.05	1.88
Erythroxylum squamatum	5	0.024	0.0479	0.22	10	0.53	15	1.05	1.80
Sloanea sp.	4	0.060	0.1191	0.55	8	0.42	10	0.70	1.67
Sloanea guianensis	5	0.034	0.0683	0.32	10	0.53	10	0.70	1.54
Lauraceae 1	3	0.090	0.1799	0.83	6	0.32	5	0.35	1.50
Licania sp.	3	0.014	0.0286	0.13	6	0.32	15	1.05	1.50
Cupania racemosa	3	0.013	0.0260	0.12	6	0.32	15	1.05	1.48
Stryphnodendron pulcherrimum	3	0.013	0.0253	0.12	6	0.32	15	1.05	1.48
Albizia pedicellaris	2	0.053	0.1059	0.49	4	0.21	10	0.70	1.40
Pogonophora schomburgkiana	1	0.070	0.1406	0.65	2	0.11	5	0.35	1.10
Maytenus erythroxyla	3	0.006	0.0128	0.06	6	0.32	10	0.70	1.07
Myrcia splendens	3	0.006	0.0125	0.06	6	0.32	10	0.70	1.07
Brosimum guianense	1	0.064	0.1289	0.60	2	0.11	5	0.35	1.05
Protium sp.	2	0.006	0.0125	0.06	4	0.21	10	0.70	0.97
Ouratea hexasperma	2	0.005	0.0101	0.05	4	0.21	10	0.70	0.96
Ocotea gardnerii	2	0.030	0.0598	0.28	4	0.21	5	0.35	0.84
Crateva tapia	1	0.036	0.0719	0.33	2	0.11	5	0.35	0.79
Xylopia ochrantha	3	0.010	0.0201	0.09	6	0.32	5	0.35	0.76

Chamaecrista ensiformis	3	0.010	0.0195	0.09	6	0.32	5	0.35	0.76
Abarema sp.	3	0.008	0.0159	0.07	6	0.32	5	0.35	0.74
Machaerium aculeatum	2	0.016	0.0322	0.15	4	0.21	5	0.35	0.71
Undetermined 4	2	0.011	0.0219	0.10	4	0.21	5	0.35	0.66
Guatteria sp. 1	2	0.010	0.0193	0.09	4	0.21	5	0.35	0.65
Maytenus distichophylla	2	0.006	0.0119	0.06	4	0.21	5	0.35	0.62
Maprounea guianensis	1	0.015	0.0294	0.14	2	0.11	5	0.35	0.59
Inga capitata	1	0.014	0.0289	0.13	2	0.11	5	0.35	0.59
Tachigali densiflora	1	0.013	0.0257	0.12	2	0.11	5	0.35	0.57
Fabaceae 2	1	0.010	0.0201	0.09	2	0.11	5	0.35	0.55
Ficus sp.	1	0.010	0.0201	0.09	2	0.11	5	0.35	0.55
Ocotea glomerata	1	0.008	0.0162	0.07	2	0.11	5	0.35	0.53
Eschweilera ovata	1	0.007	0.0143	0.07	2	0.11	5	0.35	0.52
Myrtaceae 2	1	0.006	0.0118	0.05	2	0.11	5	0.35	0.51
Undetermined 6	1	0.006	0.0117	0.05	2	0.11	5	0.35	0.51
Annonaceae 2	1	0.006	0.0112	0.05	2	0.11	5	0.35	0.51
Zanthoxylum rhoifolium	1	0.006	0.0110	0.05	2	0.11	5	0.35	0.51
Hieronyma alchorneoides	1	0.005	0.0108	0.05	2	0.11	5	0.35	0.50
Psychotria carthagenensis	1	0.005	0.0100	0.05	2	0.11	5	0.35	0.50
Myrcia sylvatica	1	0.005	0.0099	0.05	2	0.11	5	0.35	0.50
Annonaceae 1	1	0.005	0.0094	0.04	2	0.11	5	0.35	0.50
Simarouba amara	1	0.004	0.0084	0.04	2	0.11	5	0.35	0.49
Campomanesia sp. 1	1	0.003	0.0069	0.03	2	0.11	5	0.35	0.49
Undetermined 1	1	0.003	0.0066	0.03	2	0.11	5	0.35	0.48
Myrsine guianensis	1	0.003	0.0061	0.03	2	0.11	5	0.35	0.48
Xylopia frutenscens	1	0.002	0.0050	0.02	2	0.11	5	0.35	0.48
Undetermined 3	1	0.002	0.0049	0.02	2	0.11	5	0.35	0.48
Undetermined 5	1	0.002	0.0049	0.02	2	0.11	5	0.35	0.48
Psidium sp.	1	0.002	0.0049	0.02	2	0.11	5	0.35	0.48
Undetermined 2	1	0.002	0.0048	0.02	2	0.11	5	0.35	0.48
Fabaceae 1	1	0.002	0.0046	0.02	2	0.11	5	0.35	0.48
Inga laurina	1	0.002	0.0041	0.02	2	0.11	5	0.35	0.47
Richeria sp.	1	0.002	0.0041	0.02	2	0.11	5	0.35	0.47
Allophylus sp.	1	0.002	0.0036	0.02	2	0.11	5	0.35	0.47
Myrcia guianensis	1	0.002	0.0036	0.02	2	0.11	5	0.35	0.47
Total	**944**	**10.818**	**21.64**	**100**	**1888**	**100**	**1435**	**100**	**300**

**Where: NI = number of individuals sampled in the area of 0.5 ha; ΣG = sum of basal area ($m^2.ha^{-1}$); ADo = absolute dominance ($m^2.ha^{-1}$); RDo = relative dominance (%); AD = absolute density (individuals.ha^{-1}); RD = relative density (%); AF = absolute frequency (%); RF = relative frequency (%); VI = value of importance (%).*

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 tetraphylla*, *Manilkara* sp., *Byrsonima crassifolia*, and *Sloanea obtusifolia* (Fig. 6).

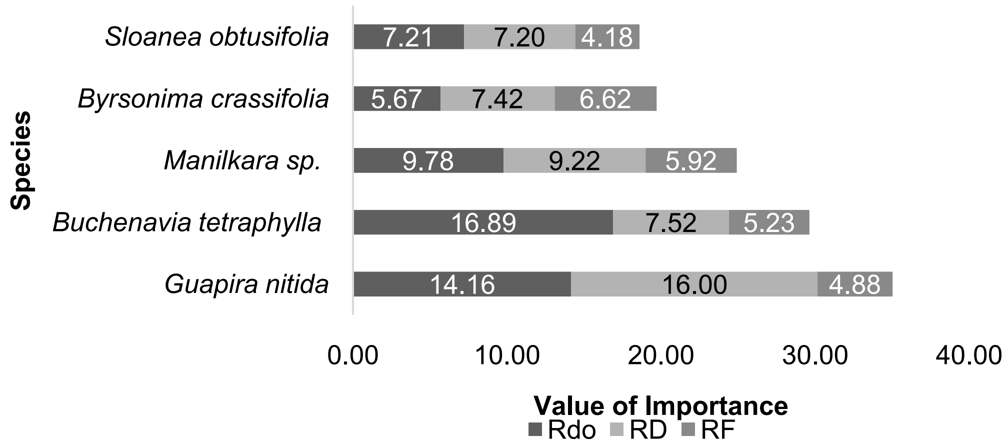

Fig. 6. Five species with the highest value of importance of the adult tree component of an Atlantic Forest stretch located in Pernambuco, Brazil.

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 $m^2.ha^{-1}$. 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.

The pasture matrix that surrounds the forest remnant directly impacts the development efficiency of the tree community, which has been in this process for at least 18 years. Thus, the species that stood out belong to the initial stage of succession, and there is a predominance of species classified as initial secondary and pioneer in general. Despite this, the diversity and uniformity indexes are essential parameters that indicate high diversity and, therefore, good fragment resilience potential.

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COMPETING INTERESTS

"Authors have declared that no competing interests exist.".

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 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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