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Original Research Article

Dispersion Syndrome, Ecological Sucession and Structure of the Arbor Component in an Atlantic Forest Fragment, Pernambuco

ABSTRACT

The Atlantic Forest is considered one of the richest areas of biodiversity on the planet. However, it has been continuously threatened and must receive strategies aiming its restoration and conservation. Thus, the objectives of this work were to evaluate the arboreal component, to classify the ecological succession and the dispersion syndrome and to analyze the structure of a fragment located in the city of Goiana, Pernambuco. For this, 10 plots of 10m x 25m were allocated, where individuals with height greater than or equal to 5.0 m and chest circumference (CC) equal to or greater than 15 cm were sampled. As for dispersion syndrome, species were classified in autochoric, zoochoric and anemochoric, and ecological succession were classified in pioneers, early secondary and late secondary. For structural analysis, vegetation was divided into three classes, representing 0-50%, 50-80% and 80-100% of the maximum total height, and the diametrical structure was distributed in 7 classes with intervals of 5 cm between them. A total of 422 individuals were found, distributed in 47 species and 28 families. In relation to the dispersion syndrome, species were predominantly zoochoric. As for the ecological succession, most species of the area were early and late secondaries. Considering the diametric and hypsometric analysis, it can be seen that individuals were mainly concentrated in the first classes of diameter and height, indicating that the fragment has a high regeneration potential. Thus, with all analysis performed, it can be suggested that the studied fragment is in intermediate stage of succession.

Keywords: Phytosociology; biodiversity; zoochory.

1. INTRODUCTION

The tropical rainforest (Atlantic Forest) is considered one of the world's hotspots [1] considering that it has one of the richest biodiversity on Earth. However, it is under severe and progressive threatening process. Great part of its forest cover disappeared, with only approximately 11.73% left, which are very fragmented, with areas under 50 hectares that are considered insufficient for protection and maintenance of the existing biodiversity [2]. For this reason, it is necessary to develop studies that address ecological and biological characteristics of fragmented environments [3].

Among the ecological studies applied in environments under these conditions, phytosociology verifies the relationships between elements of plant communities and floristic that seeks to understand the distribution of these elements and their geographical occurrence. These factors are fundamental for a satisfactory understanding of forest environments, making it possible to construct a representation of its functioning and subsidize conservation and management strategies [5, 6].

Dispersion is the action by which plants remove their seeds from their vicinity to minimize effects of competition and predation [7, 8]. It is directly related to forest dynamics, acting in control and maintenance of biological diversity [9], since it establishes relationships with pollination and recruitment and thus maintain the spatial distribution pattern and demographic structure of forests [10].

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Another important analysis is the characterization of successional groups, since it makes possible to understand the behavior of species, how it happens and in which stage of the ecological succession the forest environments are [11]. This process can be evaluated considering three criteria: total biomass on the soil, size of the tree populations and composition of species [12].

Finally, structural evaluations of vegetation, both horizontal and vertical, stand out. These are fundamental to understand the stage of forest development [13], serving as indicators of biodiversity and ecosystem services [14]. It is performed using parameters of density, dominance, frequency, coverage and importance values among others, providing information to assist in management and conservation of forest ecosystems [15, 14].

Many studies have addressed only one of the analysis described above [16], [17, 18]. However, in order to clearly and significantly understand the dynamics and composition of a forest area, it is necessary to use as many analysis as possible in order to acquire sufficient data that allow the establishment of efficient management and conservation strategies.

In this context, the objectives of this work were to characterize the arboreal component, to classify the dispersion syndromes and the ecological succession, and to analyse the diametric and hypsometric structures of a fragment of tropical rain forest located in the city of Goiana, Pernambuco.

2. MATERIAL AND METHODS

The present study was developed in a fragment of tropical rainforest with approximately 51.32 hectares located in the city of Goiana, PE (latitude 7 ° 37'30 "S, longitude 34 ° 57'30"W). The climate of the region is As' type, tropical humid with autumn-winter rain [19], with annual average temperatures of 24.8ºC and annual precipitation of 1.990 mm [20].

To enable identification and classification of species in the area, 10 plots of 10m x 25m were randomly installed. Robustness of data was verified by sampling adequacy in which a probability level of 5% was used, with a maximum permissible error of 20%. Within plots, individuals with height greater than or equal to 5.0 m and chest circumference (CC) equal to or greater than 15 cm were sampled. Measurement for height occurred visually, taking a 6-m rod as reference, and for the CC, a metric tape was used.
Sampled species were botanically classified using APG IV [21]. Collected botanical material was herborized and deposited in the Herbarium Sérgio Tavares (HST) of the Federal Rural University of Pernambuco for identification purposes.

For the phytosociological analysis, the following parameters were determined: absolute density (AD) (ind./ha); relative density (RD) (%); absolute frequency (AF); relative frequency (RF); absolute dominance (ADo) (m² / ha); relative dominance (RDo); value of importance (VI) and the Shannon diversity index using Mata Nativa software version 4 [22].

Subsequently, individuals identified at species level were classified by their dispersion syndrome and ecological group. For dispersion, the following categories were adopted: Anemochory (Ane), Autochory (Aut) and Zoochory (Zoo), following methodology stablished by [23]. Regarding the ecological group, species were classified as pioneers, early secondary and late secondary, following [24].

Finally, structural evaluation of the fragment was given. The hypsometric structure followed methodology stablished by [25] dividing the vegetation into three classes representing 0-50%, 50-80% and 80-100% of the total maximum height, respectively. The diametric structure was distributed in 7 classes with intervals of 5 cm between them.

3. RESULTS AND DISCUSSION

Phytosociology

A total of 422 individuals were registered and identified, in which the floristic richness was 47 species distributed in 28 botanical families (Table 1). Among sampled families, 25 were identified and three

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were indeterminate. Regarding species, 35 were identified at species level, nine at gender level and one at family level. Families with the greatest species richness were Fabaceae (17.78) and Myrtaceae (8.89). Six families presented two species (4.44) each: Lecythidaceae, Anacardiaceae, Moraceae, Clusiaceae, Annonaceae and Chrysobalanaceae. The others presented one species (2.22) each.

The representativeness of Fabaceae family is justified by the fact that this group stands out among the most frequent families in the Atlantic Forest [26]. The results found corroborate with the study by [6], who evaluated a tree community of a Atlantic forest fragment in Pernambuco, and with the study of [27] in areas of Ombrophylous Dense Forest in Rio de Janeiro, where families that presented the largest number of species were also Fabaceae and Myrtaceae. [28] highlight the Fabaceae family in their study and justify that it is common for this family to appear in floristic and ecological surveys in Brazil.

Shannon-Wiener index (H ') for the study area was 3.39 nats / individual, higher than 3.26 nats / individual found by [6] and less than 3.91 nats / individuals found by [29] in a forest fragment in Cabo de Santo Agostinho, and [30], which found 3.68 nats / individual in a Atlantic forest fragment in Igarassu, both in the State of Pernambuco. Differences in succession stages, different sampling methodologies, inclusion levels, efforts for taxonomical identification, as well as floristic variations in different communities can explain variations occurring in diversity values in areas of the same phytogeographic region [31].

Table 1. Phytosociological parameters, dispersion syndrome and ecological group of species sampled in an area of Ombrophylous Dense Forest, Pernambuco-Brazil. Values are in descending order of importance value (IV). Where: AD - absolute density (ind./ha); RD - relative density (%);AF - absolute frequency; RF - relative frequency; ADo - absolute dominance (m² / ha); RDo - relative dominance.

Species	Family	Disp. Syn.	Ecol. Group	AF	RF	AD	RD	ADo	RDo	IV
Pogonophora schomburgkiana Miers ex Benth	Peraceae	Aut	ST	80	5,1	180	10,66	0,91	3,49	19,25
Eschweilera ovata Mart. ex Miers	Lecythidaceae	Zoo	SI	70	4,46	96	5,69	2,04	7,78	17,93
Tapirira guianensis Aubl.	Anacardiaceae	Zoo	PI	70	4,46	60	3,55	2,44	9,31	17,33
Manilkara salzmannii (A.DC.) H.J.Lam	Sapotaceae	Zoo	SC	90	5,73	108	6,4	1,08	4,14	16,27
Lecythis pisonis Cambess.	Lecythidaceae	Aut	ST	40	2,55	120	7,11	1,42	5,41	15,06
Coccoloba mollis Casar.	Polygonaceae	Zoo	PI	70	4,46	76	4,5	1,54	5,88	14,84
Thyrsodium spruceanum Benth.	Anacardiaceae	Zoo	SI	90	5,73	84	4,98	0,64	2,45	13,16
Indeterminada 3	SC	SC	SC	90	5,73	68	4,03	0,82	3,12	12,88
Myrcia sp 1	Myrtaceae	Zoo	SI	70	4,46	92	5,45	0,64	2,46	12,37
Clusia nemorosa G.Mey.	Clusiaceae	Zoo	ST	40	2,55	64	3,79	1,28	4,9	11,24
Dialium guianensis (Aubl.) Sandwith	Fabaceae	SC	ST	20	1,27	20	1,18	2,01	7,68	10,14
Apuleia leiocarpa (Vogel) J.F.Macbr.	Fabaceae	Ane/Aut	SI	30	1,91	36	2,13	1,37	5,22	9,26
Indeterminada 2	SC	SC	SC	50	3,18	52	3,08	0,71	2,7	8,96
Eriotheca crenulaticalyx A.Robyns	Malvaceae	SC	SC	30	1,91	64	3,79	0,77	2,95	8,65
Protium heptaphyllum (Aubl.) Marchand	Burseraceae	Zoo	SI	50	3,18	52	3,08	0,49	1,86	8,12
Symphonia globulifera L. f.	Clusiaceae	Zoo	SC	10	0,64	48	2,84	1,19	4,53	8,01
Brosimum rubescens Taub.	Moraceae	Zoo	SI	50	3,18	28	1,66	0,6	2,29	7,13
Himanthantus bracteatus (A. DC.) Woodson	Apocynaceae	Ane	SI	60	3,82	32	1,9	0,25	0,96	6,68
Maytenus distichophylla Mart. ex Reissek	Celastraceae	Zoo	ST	40	2,55	48	2,84	0,22	0,83	6,22
Byrsonima sericea DC.	Malpighiaceae	Zoo	SI	30	1,91	16	0,95	0,61	2,31	5,17
Hirtella hebeclada Moric. ex DC.	Chrysobalanaceae	Zoo	ST	20	1,27	28	1,66	0,55	2,09	5,02

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Bowdichia sp.	Fabaceae	SC	PI	20	1,27	12	0,71	0,78	2,99	4,98
Guatteria pogonopus Mart.	Annonaceae	Zoo	ST	30	1,91	36	2,13	0,12	0,46	4,5
Samanea sp.	Fabaceae	Zoo	PI	20	1,27	8	0,47	0,7	2,69	4,44
Psidium guineense Sw.	Myrtaceae	Zoo	SC	30	1,91	28	1,66	0,19	0,73	4,3
Miconia sp.	Melastomataceae	Zoo	SC	30	1,91	24	1,42	0,17	0,64	3,97
Myrcia sp 2	Myrtaceae	Zoo	SI	30	1,91	20	1,18	0,18	0,69	3,79
Ocotea glomerata (Nees) Mez	Lauraceae	Zoo	SI	30	1,91	20	1,18	0,18	0,69	3,78
Couepia impressa Prance	Chrysobalanaceae	SC	SC	20	1,27	20	1,18	0,3	1,13	3,59
Inga sp.	Myrtaceae	Zoo	PI	20	1,27	12	0,71	0,37	1,4	3,39
Annona sp.	Annonaceae	Zoo	SI	30	1,91	12	0,71	0,2	0,76	3,38
Schefflera morototoni (Aubl.) Maguire et al.	Araliaceae	Zoo	SI	20	1,27	8	0,47	0,41	1,57	3,31
Albizia pedicellaris (DC.) L.Rico	Fabaceae	SC	PI	20	1,27	8	0,47	0,39	1,5	3,25
Myrtaceae sp.	Myrtaceae	SC	SC	30	1,91	12	0,71	0,04	0,16	2,78
Zolernia sp.	Fabaceae	SC	SC	20	1,27	12	0,71	0,09	0,36	2,35
Allophylus edulis (A.St.-Hil. et al.) Hieron. ex Niederl.	Sapindaceae	Zoo	PI	20	1,27	12	0,71	0,08	0,32	2,3
Manilkara salzmannii (A. DC.) H.J.Lam	Sapotaceae	Zoo	PI	20	1,27	12	0,71	0,05	0,18	2,17
Handroanthus impetiginosus (Mart. ex DC.) Mattos	Bignoniaceae	Aut	ST	10	0,64	16	0,95	0,07	0,27	1,86
Erythroxylum squamatum Sw.	Erytroxylaceae	Zoo	ST	10	0,64	12	0,71	0,07	0,28	1,63
Albarena cochliacarpos (Gomes) Barneby & J.W. Grimes	Fabaceae	SC	ST	10	0,64	8	0,47	0,12	0,46	1,57
Indeterminada 1	SC	SC	SC	10	0,64	8	0,47	0,03	0,1	1,21
Simarouba amara Aubl.	Simaroubaceae	Zoo	SI	10	0,64	4	0,24	0,03	0,1	0,98
Senna phlebadenia H.S. Irwin & Barneby	Fabaceae	Aut	SI	10	0,64	4	0,24	0,02	0,09	0,96
Luehea ochrophylla Mart.	Malvaceae	Ane	SI	10	0,64	4	0,24	0,01	0,04	0,91
Artocarpus heterophyllus Lam.	Moraceae	Ane	SI	10	0,64	4	0,24	0,01	0,04	0,91
Total				**1570**	**100**	**1688**	**100**	**26,19**	**100**	**300**

Species with the highest relative frequencies, in decreasing order, were: *Manilkara salzmannii*, *Thyrsodium spruceanum*, Undetermined 3, *Pogonophora schomburgkiana*. Species that presented the highest values for relative density, in descending order, were: *Pogonophora schomburgkiana*, *Lecythis pisonis*, *Manilkara salzmannii*, *Eschweilera ovata* and *Myrcia* sp 1, totalizing 35.31%.

In terms of relative dominance, the species *Tapirira guianensis* presented the highest value, followed by *Eschweilera ovata*, *Dialium guianensis*, *Coccoloba mollis* and *Lecythis pisonis*, representing 36.06% of the total. According to [6], it can be inferred that these species are better exploiting the natural resources of the environment.

The five species that presented the highest values of importance (VI) in decreasing order were: *Pogonophora schomburgkiana*, *Eschweilera ovata*, *Tapirira guianensis*, *Manilkara salzmannii*, and *Lecythis pisonis*.

Dispersion syndrome

It was observed that the fragment presented 23 zoochoric (72%), six anemochoric (19%) and three autochoric (9%) species. The data found in this study corroborate with the findings of [32] for a Dense Ombrophylous Forest in Southern Brazil, where they found that 65.1% of the species were zoochoric, 23.6% anemochoric and 22% autochoric. In tropical regions, dispersion by animals is more frequent than the other forms of dispersion. According to [33], more than 50% of tree species present mechanisms that allow dispersion by vertebrates in Atlantic forests.

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In studies carried out in Atlantic forest in the state of Pernambuco, [34] reached similar values in which 74% of the species were zoochoric, 20% autochoric and 6% anemochoric. In a study in the northern coast of the state of Paraíba, [17] recorded 136 species distributed in 27 families. Regarding dispersion syndrome, these authors found that the most abundant syndrome was zoochory with 58%, followed by autochory with 29% and anemochory with 13%. In relation to the families that stood out the most in the area, Myrtaceae presented predominantly zoochoric individuals.

Studying a restored area in southeastern Brazil, [35] have reached quite similar results, in which anemochoric dispersion and then zoochoric dispersion stand out, but, at individuals level, zoochoric dispersion is highlighted. According to [34] the highest seed richness with zoochoric dispersion in the bank is important for maintenance of the propagating fauna of propagules, mainly at the beginning of the regeneration of the forest after disturbance.

In the study by [36], the most representative dispersion syndrome was zoochoric, being an important factor in the continuity of maintenance of frugivorous animals in the area. Therefore, zoochoric dispersion plays an important role in the maintenance of most advanced stages of successional stages and, indirectly, in their spatial distribution and frequency of forest species.

Ecological succession

Regarding ecological groups, a relevant aspect of this research is the number of species both initial secondary (S_i) and late secondary (S_l) stages, which together represent 57.44% of species and 67.1% of individuals inventoried. On the other hand, initial secondary species represented 28.20% of individuals grouped in 31.91% of species, and late secondary species represented 38.86% of individuals occurring in 25.53% of species. Initial pioneers represented 14.9% of species and 16.59% of individuals of the fragment. No data were obtained from 13 species (27.66%).

Low representativeness of pioneer species may suggest forest maturity [37]. According to [38], occurrence of late secondary species typical of the Atlantic forest is a good indicator of resilience of this community.

Regarding ecological groups, most of the species found are late secondary (Sl). The species *Pogonophora schomburgkiana* (10.7%), *Lecythis pisonis* (7.1%) and *Pisonia ambiguous* (6.4%) were more representative in this group. *Eschweilera ovata* (5.7%), *Myrcia* sp (5.4%) and *Thyrsodium spruceanum* (5%) stood out among initial secondary species (S_i) and the species *Coccoloba mollis* (4.5%) and *Tapirira guianensis* (3.55%) were the most representative among pioneers.

Considering the low floristic representativeness of pioneer species and the number of late secondary (S_l), the expression of an intermediate stage in successional development of the forest was found in this relation [39].

Classification of species in their respective ecological groups has encountered to two primary factors. The first one is that criteria used differ between authors, which leads some species to be classified into distinct groups. The second one refers to the fact that the same species, depending on its genetic characteristics, may respond differently to environmental conditions in regions with different soil and climate, since these responses do not occur for a single environmental factor alone [16]. However, classification in ecological groups combined with structure studies may provide better information on species behavior within a given area.

Structural analysis

Understanding the structure is an essential factor for proper management of a forest, both for economic and environmental purposes, and is also a relevant indicator of the biodiversity of the area. [40, 41]. In addition, it allows identifying how species are distributed, also providing information on successional dynamics [42].

In terms of diametric structure, seven classes with 5 cm intervals were found between each of them in this study, in which the first class comprised individuals from 3 to 8 cm (center 5.5 cm) and the last class ≥ 35, 5 cm. As can be seen in figure 1, the curve followed an “inverted J” distribution, which is a pattern for native forests, with the majority of individuals concentrated in the first class, following a progressive downward trend. Results similar to this were found by [6] in a fragment of Atlantic forest in

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the municipality of Moreno, in Pernambuco, and by [43], in a fragment of Atlantic forest in Recife, located in the same state.

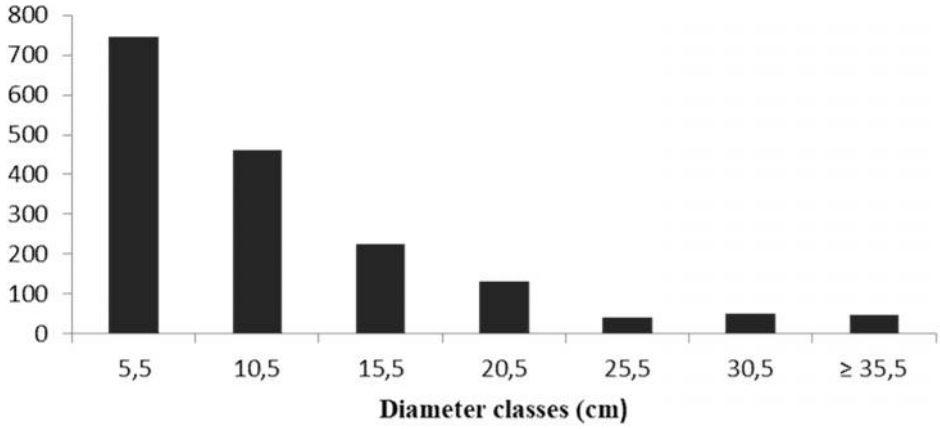

Fig. 1. Diametric distribution of arboreal individuals sampled in an Atlantic forest fragment in Goiana, Pernambuco, 2017.

These results indicate that the fragment is composed mainly of individuals who have reached maturity in recent time. In addition, this suggests that the forest presents potential for regeneration, also indicating that there is recruitment in the area [44, 45]. This type of forest distribution is the most desirable, in a way that allows individuals to continue to participate in natural dynamics [46].

In order to better understand the dynamics of tropical forests in relation to their structure, it is necessary to know the community that compose them, as well as to identify the behavior of each species [47]. Thus, ten species with the highest VI were analyzed (Figure 2).

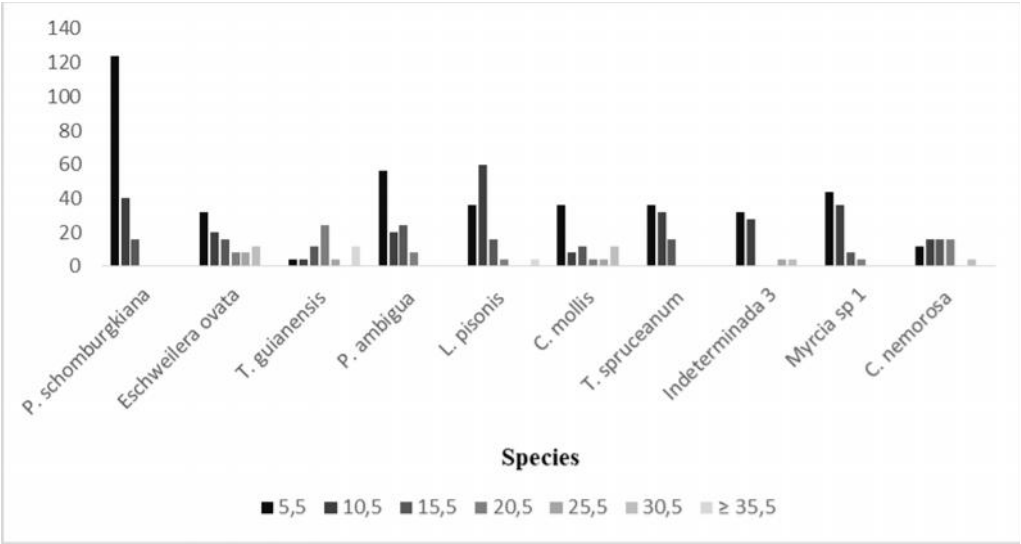

Fig. 2. Diametric distribution of ten species with the highest VI in a fragment of Atlantic forest in Goiana, Pernambuco, 2017.

Of the ten species selected, most showed similar results to the general arrangement, only *T. guianensis*, *L. pisonis* and *C. nemorosa* did not follow the "inverted J" distribution. *T. guianensis* presented the majority of individuals distributed in class 4, different from *L. pisonis* in which the majority of individuals appeared in class 2, and of *C. nemorosa* that presented the same number of individuals equally distributed in classes 2, 3 and 4. These variations may be related to the population ecology of each species, where there are certain discontinuities in the distributions, and there may be

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a total absence of young individuals in some species [48]. This was the case of Undetermined 3, which did not present any individuals in the first class of diameter.

Vertical structure refers to characteristics of the vegetation as a function of vertical height of the trees, being an essential component that helps to describe the ecosystem [49]. Formation of a vertical stratification occurs commonly in tropical forests, where these stands are composed of plant species that have different modes of occupation in response to different light requirements, which may justify the enormous diversity in structurally more complex ecosystems [50].

Therefore, for hypsometric structure, distribution was carried out in three classes, in which the first class included individuals with height ≤ 11.5 cm; in the second, individuals 11.5 to 18.4 cm; and in the last class, individuals with height between 18.4 and 23.1 cm. It was observed that the majority of individuals (69.62%) are concentrated in the first class, followed by the second one with 27.75% and the last class comprising 2.63% of the individuals in the area (figure 3). These results coincide with those found in tropical forests, which present the highest number of individuals in lower stages, characterizing a negative exponential distribution [51]. The same results were found by [6] in his work.

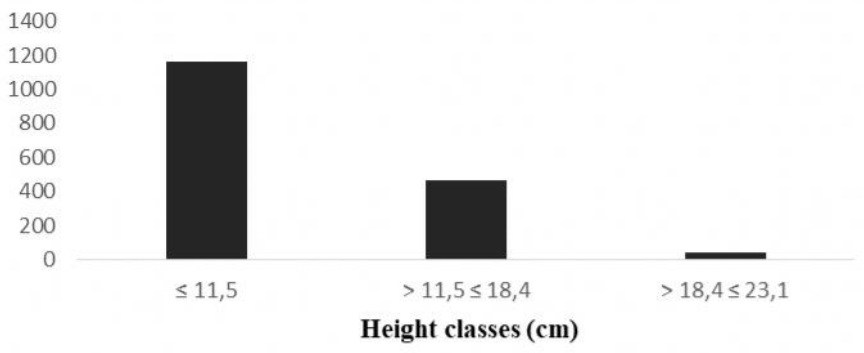

Fig. 3. Hypsometric distribution of arboreal individuals sampled in Atlantic forest fragment in Goiana, Pernambuco, 2017.

As for diametric distribution, hypsometric analysis was also performed for the ten species of higher VI (figure 4). It can be seen that most species followed the pattern, with the largest number of individuals concentrating on the first classes, except for *T. guianensis* and *C. nemorosa* which had the majority of their individuals concentrated in class two. This may suggest that most individuals of these species are in a more advanced stage of succession when compared to others. Only *Eschweilera ovata*, *L. pisonis* ~~*Cambess*~~ and *C. mollis* presented individuals in the highest height class, demonstrating that these species have more individuals that reached maturity. Low representativeness of individuals of other species in the highest height class may indicate that they require higher nutritional requirements or luminosity, for example [18].

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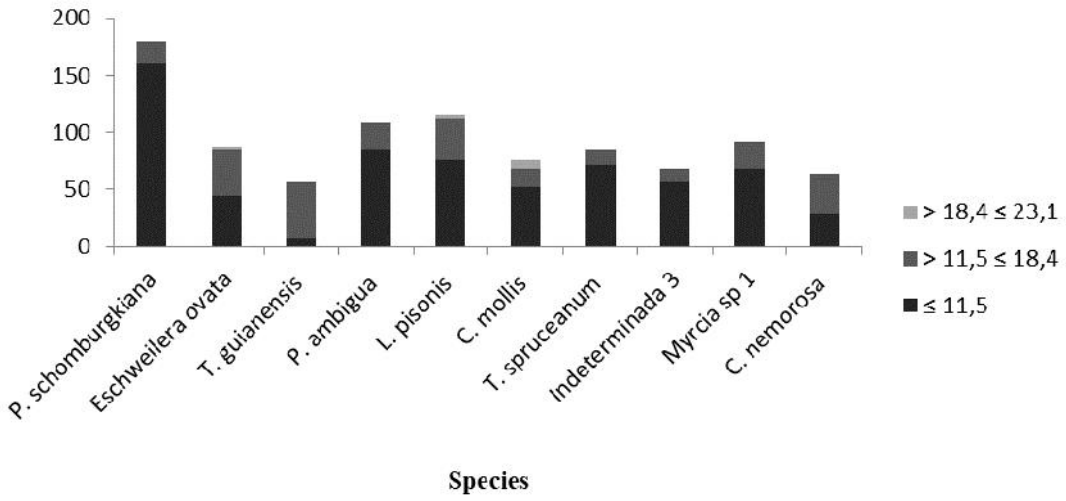

Fig. 4. Hypsometric distribution of the ten species with higher VI sampled in an Atlantic forest fragment in Goiana, Pernambuco, 2017.

The structural study of the forest, combining diametric and hypsometric analysis, allows to assess the stage of forest development through distribution of individuals in different strata [47]. Thus, it can be inferred that the studied fragment presents individuals with high potential of regeneration that fit, mainly, in the first classes of diameter and height, suggesting that the area is at intermediate stage of succession.

4. CONCLUSION

Regarding phytosociological analysis, it can be concluded that the family Fabaceae and Myrtaceae were the most representative for the study area. Most of the species that make up the area have zoochory as dispersion syndrome, with few anemochoric and autochoric species. As for ecological succession, the fragment showed to be predominantly composed of late secondary and early secondary species that recently reached maturity. Regarding structure, individuals were distributed mainly in the first classes of diameter and height, which indicates that the fragment has high regenerative potential. Thus, the analysis allows to infer that the studied fragment is at intermediate stage of succession.

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