Original Research Article

Natural Regeneration and Ecological Succession in an Urban Fragment of the Atlantic Forest in Pernambuco, Brazil

ABSTRACT

The development of studies on natural regeneration in fragments of the Atlantic Forest contributes to evaluate the regenerative power of forests against natural and anthropic disturbances. So, the objective of the work was to analyze the structure of the regenerative component and ecological succession of arboreal species in an urban fragment of Atlantic Forest. The study was realized in Parque Estadual Dois Irmãos (PEDI), in Recife, Pernambuco, in which 10 subplots of 1 m x 25 m (25 m²) each were installed. As inclusion criterion, the regenerating individuals of arboreal species should have height equal to or greater than one meter and circumference at the height of the chest (CAP 1.30 m) inferior to 15 cm. The individuals were classified as the ecological groups origin (native or exotic species) and were calculated phytosociological parameters, heights classes for regenerating individuals and diversity index. For the analysis of the data the software Mata Nativa version 4.05 was used. The families that presented the highest number of species were: Myrtaceae and Fabaceae. It was observed that 15% of the species belong to the group of the pioneers, 48% of the species belong to the group of the initial secondary and 22% to the group of the late secondary ones. The distribution of individuals of the species Hirtella racemosa and Chamaecrista ensiformis in the different size and relative density classes allows us to affirm that these species act directly in the process of ecological succession. The fragment is in the initial secondary stage of succession.

Keywords: Dense Ombrophylous Forest; Secondary succession; Phytosociological parameters.

1. INTRODUCTION

The Brazilian Atlantic Forest is a rainforest, considered one of the major hotspots for being one of the richest biomes in biodiversity in the world [1, 2], presenting approximately 14,000 different species of plants, [3], However, over the past 50 years, the original coverage of this biome has been reduced to 8% [4], caused by the advanced stage of fragmentation caused by the anthropogenic.

The development of studies on natural regeneration in forest fragments is of great importance for understanding the ecological functioning of these ecosystems, because they contribute to assess the regenerative power of forests in the face of natural and anthropogenic disturbances and to understand the development of forests [5, 6]. In addition, it is possible to identify and quantify the species present, as also to evaluate and monitor their distribution [7]. However, understanding the pattern of regeneration of tree species is a complex activity, because it depends on the relationship between intrinsic and extrinsic factors, linked to the physiological and ecological characteristics of the species and the environmental conditions [8].

The areas that are in the process of regeneration, function as habitat for several native species, acting mainly on carbon sequestration [9]. The history of land use, present fauna in the regeneration area, physical, chemical and biological characteristics of the soil, seed bank and proximity to native forests are the main factors that influence the rate of regeneration [10].

Thus are considered as regenerating individuals, those with height equal to or greater than one meter, justifying that in this phase the individuals have already adapted to the environment, minimizing the mortality rate and facilitating the morphological characterization for the subsequent species classification [11,12].

The number of species present in natural regeneration is directly influenced by the species that occupy upper strata in the forest, by the propagation of propagules, quantity and quality of light, substrate and other growth factors [13]. Therefore, through the characterization and evaluation of natural regeneration it is possible to predict the regenerative potential of ecosystems, acting as an important subsidy in management decisions [14].

The context, it can be said that the process of ecological succession is influenced by the morphological and physiological characteristics of the plant species, with their interaction with other species (plants and / or animals) and through interaction with the abiotic components [15]. These factors have a strong influence on the structure, abundance of species and community diversity [16].

Therefore, to know the forest stock and its distribution in the plant community, a qualitative-quantitative study of natural regeneration is necessary [17]. So, knowledge of the development and temporal dynamics of the vegetation cover is a valuable tool for landscape planning and for decisions about conservation strategies and restoration of forest resources. This study aimed to analyze the structure of the regenerative component and ecological succession of tree species in an urban fragment of Atlantic Forest in Recife, Pernambuco, Brazil

2. MATERIAL AND METHODS

The study was carried out in Parque Estadual Dois Irmãos (PEDI), located in the metropolitan region of Recife, state of Pernambuco, between the neighborhoods of Dois Irmãos, Apipucos, Sítio dos Pintos, Macaxeira and Córrego Jenipapo, located at the geographic coordinates 07° 59' 30" and 08° 01' 00" S and 34° 56' 30" and 34° 57' 30" W. The forest fragment had 384.4 hectares, going to 1,157.72 hectares, through state decree n. 40,547 of March 28, 2014 [18]. Of the total area, 14 hectares are occupied by the zoo.

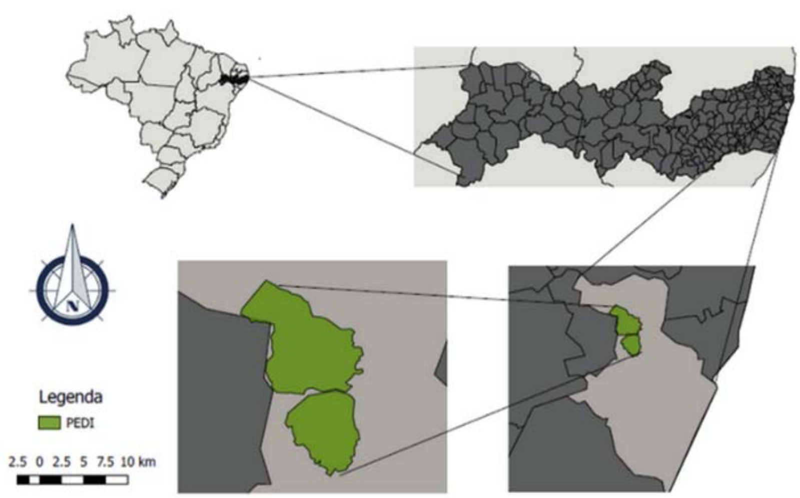

Figure 1. Location of the Atlantic Forest fragment in Recife, Pernambuco, Brazil, with emphasis on the study area.

The climate of the region is As' tropical humid coastal, with average monthly temperatures over 25.5 ° C [19]. The annual rainfall is greater than 1,600 mm and relative air humidity around 80% [20]. The vegetation cover present in the area is a fragment of Ombrophilous Lowland Forest and the soils are constituted by Yellow Latosols, Yellow Argisols and Gleysols, whose texture varies from sandy to sandy-clay, with acid pH of 4 to 5 [21,22,23].

The study was carried out in the new area of PEDI, in which 10 plots of 10 mx 25 m (250 m²) each were installed randomly. For the study of natural regeneration, a subplot of 1 m x 25 m (25 m²) was installed on the left side of each plot, identifying all the regenerating individuals inside.

As inclusion criterion, individuals of tree species with height equal to or greater than 1 meter and circumference at breast height (CAP 1,30 m) of less than 15 cm were considered regenerating. The individuals were identified, whenever possible at family and species level and, measured the heights and circumference of the height of the base (CAB 0.30m).

When it was not possible to identify in the field, the reproductive and / or vegetative botanical material was collected for later identification in the Herbário Sérgio Tavares from to de Ciência Florestal da Universidade Federal Rural de Pernambuco (DCFL/UFRPE). The species were classified into families according to the Angiosperm Phylogeny Group IV system [24]. For a description of the botanical nomenclature and their respective authors, the List of Brazilian Flora Species available in the virtual environment http://floradobrasil.jbrj.gov.br/.

Individuals were classified according to successional groups and origin (exotic or native species). Three height classes (H) were used for species classification [11], presented in Table 1.

The phytosociological parameters (density, frequency and relative dominance and importance value) were calculated, the diversity was estimated according to the diversity indexes of Shannon - Weaver (H '), Pielou Equability (J) and Simpson' s (C) dominance index. For the analysis of the data the software Mata Nativa version 4.05 was used.

Table 1. Height classes for regenerating individuals.

Classes	Height of individuals
1	$1.0 \leq H \leq 2.0$ m
2	$2.0 < H \leq 3.0$ m
3	H > 3.0 e CAP < 15.0 cm

Source: [11].

3. RESULTS AND DISCUSSION

In the survey of the natural regeneration of the tree species in the implanted portion, 339 individuals belonging to 46 species and 26 families were sampled (Table 2). The number of species found in the surveys are consequences of a set of variables, such as site topography, soil characteristics, pluviometric indexes, degradation status and successional stage [25].

The most representative families were Myrtaceae, Fabaceae and Erythroxylaceae with 80, 39 and 30 individuals, respectively, together accounting for 43.95% of the richness. The most representative families were Myrtaceae, Fabeceae and Erythroxylaceae with 80, 39 and 30 individuals, respectively, together accounting for 43.95% of the wealth. Two of these families of higher representativity were also found in a study of natural regeneration of native tree species in sub-forest of Eucalyptus saligna Smith [26].

Table 2. Phytosociological parameters of the natural regeneration in an urban fragment of the Atlantic Forest in Recife, Pernambuco, Brazil (where: NI: Number of Individuals; RD: Relative density (%); RF: Relative frequency (%); RDo: Relative dominance (%); VI: Value of importance (%); O: Origin; N: Native; E: Exotic).

Family/Species	NI	RD	RF	RDo	VI (%)	O
Anacardiaceae						
Anacardium occidentale L.	1	0.29	0.83	1.06	0.73	N
Tapirira guianensis Aubl.	2	0.59	1.65	0.78	1.01	N
Thyrsodium spruceanum Benth.	14	4.13	4.13	6.15	4.81	N
Thyrsodium sp.	1	0.29	0.83	0.04	0.39	N
Annonaceae						
Xylopia frutescens Aubl.	28	8.26	6.61	8.46	7.78	N
Apocynaceae						
Himatanthus bracteatus (A. DC.) Woodson	7	2.06	4.13	2.59	2.93	N

Rauwolfia sp.	1	0.29	0.83	0.08	0.4	-
Araliaceae						
Schefflera morototoni (Aubl.) Maguire et al.	1	0.29	0.83	0.16	0.43	N
Burseraceae						
Protium heptaphyllum (Aubl.) Marchand	1	0.29	0.83	0.09	0.4	N
Celastraceae						
Maytenus distichophylla Mart. Ex Reissek	11	3.24	4.13	2.92	3.43	N
Maytenus guianensis Klotzsch ex Reissek	3	0.88	1.65	0.30	0.94	N
Chrysobalanaceae						
Hirtella racemosa Lam.	41	12.09	5.79	7.38	8.42	N
Licania kunthiana Hook.f.	1	0.29	0.83	0.11	0.41	N
Clusiaceae						
Clusia nemorosa G.Mey.	8	2.36	3.31	2.89	2.85	N
Erythroxylaceae						
Erythroxylum citrifolium A.St.-Hil	28	8.26	5.79	4.75	6.26	N
Erythroxylum sp.	1	0.29	0.83	1.37	0.83	-
Erythroxylum squamatum Sw.	1	0.29	0.83	0.04	0.39	N
Fabaceae						
Abarema cochliacarpos (Gomes) Barneby & J.W.Grimes	2	0.59	0.83	0.53	0.65	N
Abarema filamentosa (Benth.) Pittier	4	1.18	2.48	1.87	1.84	N
Chamaecrista ensiformis (Vell.) H.S.Irwin & Barneby	31	9.14	4.13	16.66	9.98	N
Plathymenia foliolosa Benth.	1	0.29	0.83	0.60	0.57	N
Pterocarpus sp.	1	0.29	0.83	0.25	0.46	-
Hypericaceae						
Vismia guianensis (Aubl.) Choisy.	3	0.88	2.48	1.35	1.57	N
Lacistemataceae						
Lacistema robustum Schnizl.	2	0.59	0.83	0.72	0.71	N
Lauraceae						
Ocotea glomerata (Nees) Mez	1	0.29	0.83	0.03	0.38	N
Lecythidaceae						
Lecythis pisonis Cambess.	2	0.59	0.83	1.07	0.83	N
Melastomataceae						
Miconia albicans (Sw.) Triana	1	0.29	0.83	0.18	0.44	N
Miconia ciliata (Rich.) DC.	7	2.06	3.31	1.29	2.22	N
Miconia guianensis (Aubl.) Cogn	1	0.29	0.83	0.06	0.39	N
Miconia prasina (Sw.) DC.	5	1.47	2.48	1.98	1.98	N
Meliaceae						
Trichilia lepidota Mart.	1	0.29	0.83	0.47	0.53	N
Moraceae						
Sorocea hilari Gaudich.	2	0.59	0.83	0.26	0.56	N
Myrtaceae						
Myrcia guianensis (Aubl.) DC.	55	16.22	5.79	11.46	11.16	N
Myrcia splendens (Sw.) DC.	10	2.95	4.13	1.18	2.75	N
Myrcia sylvatica (G.Mey.) DC.	8	2.36	4.13	3.19	3.23	N
Myrcia tomentosa (Aubl.) DC	4	1.18	2.48	1.38	1.68	N
Myrciaria ferruginea O.Berg.	3	0.88	2.48	0.39	1.25	N
Nyctaginaceae						
Guapira laxa (Netto) Furlan	5	1.47	0.83	1.41	1.24	N
Ochnaceae						
Ouratea polygyna Engl.	1	0.29	0.83	0.47	0.53	N
Peraceae						

Pera ferruginea (Schott) Müll. Arg.	1	0.29	0.83	0.08	0.4	N
Pogonophora schomburgkiana Miers ex Benth.	20	5.9	2.48	8.68	5.69	N
Polygonaceae						
Coccoloba sp.	8	2.36	3.31	1.64	2.43	-
Rubiaceae						
Salzmannia sp.	1	0.29	0.83	0.04	0.39	-
Salicaceae						
Casearia javitensis Kunth	5	1.47	2.48	2.48	2.14	N
Sapindaceae						
Allophylus edulis (A.St.-Hil. Et al.) Hieron. Ex Niederl	2	0.59	1.65	0.28	0.84	N
Cupania racemosa (Vell.) Radlk	2	0.59	0.83	0.85	0.76	N
Total	339	100	100	100	100	-

In relation to the phytosociological structure, the seven species of greatest Importance Value were *Myrcia guianensis, Chamaecrista ensiformis, Hirtella racemosa, Xylopia frutescens, Erythroxylum citrifolium, Pogonophora schomburgkiana* e *Thyrsodium spruceanum*, which together made up 54.1% of the total VI (Table 2).

The representativeness of these species was also highlighted in other regeneration works, such as that of [27] in a secondary forest fragment of the Botanic Garden of UFJF, [28] in a fragment of the Ombrophilous Dense Forest of Terras Baixas and [29] in a fragment of Atlantic forest in the city of Igarassu - PE. Thus, the results of this work have demonstrated that most of these species are able for colonization and development of the PEDI fragment.

The families that presented the highest number of species, orderly in descending order were: Myrtaceae and Fabaceae with five species, Anacardiaceae and Melastomataceae with four species, Erythroxylaceae with three species, Apocynaceae, Peraceae, Celastraceae and Chrysobalanaceae with two species each, together they represented 78.47% of advanced natural regeneration. These families are among the most important in fragments of Atlantic Forest and corroborate with the results of other works carried out in the Atlantic Forest [1, 30, 31]. The importance of the Fabaceae family is emphasized, since it ensures productivity in most terrestrial ecosystems, due to their performance in nitrogen fixation.

The three species that have the highest VI stand out due to the high values of density and dominance in the area, *Myrcia guianensis* was the one with the highest values for all the estimated parameters The ecophysiological and environmental characteristics in which the species are inserted, some may not reach large diameters [32].

Among the species raised in the study, the nine species that presented the number of individuals greater or equal to ten were: *Myrcia guianensis, Hirtella racemosa, Chamaecrista ensiformis, Xylopia frutescens, Erythroxylum citrifolium, Pogonophora schomburgkiana, Thyrsodium spruceanum, Maytenus distichophylla* and *Myrcia splendens* (Figure 2).

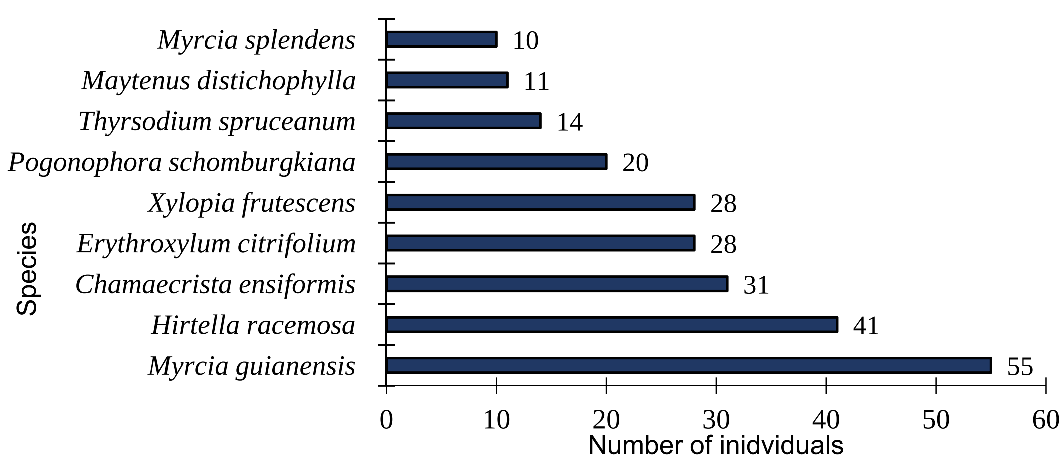

Figure 2. Regenerating species with numbers of individuals equal to or greater than 10 in an urban fragment of Atlantic Forest in Recife, Pernambuco, Brazil.

All are native species of the Atlantic Forest biome, and among them five species are initial secondary. The nine species together represent 67.55% of all regenerating individuals in the area and are the most homogeneous species, since they were sampled in almost all plots.

Regarding the successional classification of species, it is observed that 48% belong to the group of the initial secondary, 22% to the late secondary group and 15% to the pioneer group, equivalent to 22, 10 and 7 species, respectively (Figure 3). Of the total sampled, 7 species were not classified, representing 13%. The successional stage of a forest fragment is indicated by the successional group that presents a percentage greater than 50% of individuals [33].

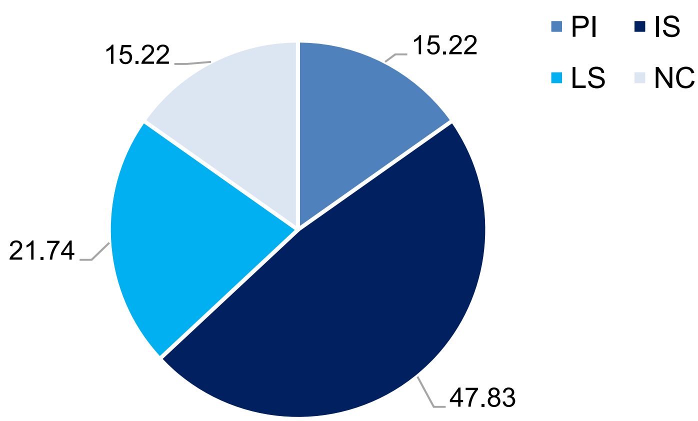

Figure 3. Percentage of successional groups observed in an urban fragment of Atlantic Forest in Recife, Pernambuco, Brazil (being: PI: Pioneers, IS: Initial secondary, LS: Late secondary, NC: No classification).

The greater number of initial secondary species may be related, since the area does not present clearings, hindering the permanence of the pioneer species, seeing that they need the solar incidence to survive.

The greatest cause of precedence begins with the fact that the forest fragment has several years of natural regeneration, may not be able to progress to other successional phases, or this process is occurring slowly [34].

The increase of the initial secondary species in a forest fragment may indicate what occurred previously in that site some fragmentation, distribution and / or disturbance [35].

In relation to regeneration by height class, the percentages were: 35.10%, 30.38% and 34.51%, for classes 1, 2 and 3, respectively. Of the 46 species sampled, 15 were found in the three classes, 10 species in two classes and 21 species only in one height class (Figure 4).

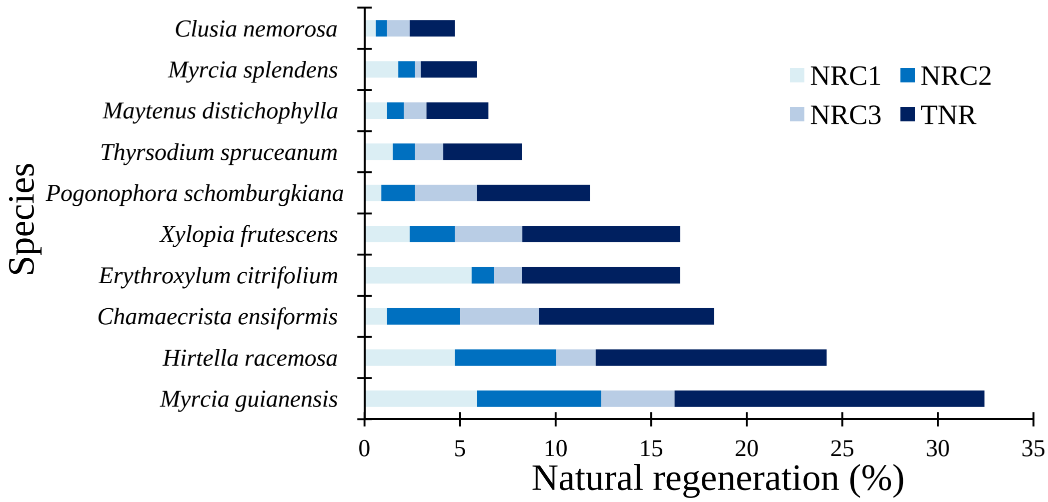

Figure 4. Relation of the 10 species with the highest values of total natural regeneration of the sampled population, expressed as a percentage, sampled in an urban fragment of Mata Atlântica in Recife, Pernambuco, Brazil (being: NRC1: Natural regeneration in Class 1; NRC2: Natural regeneration in Class 2; NRC3: Natural regeneration in Class 3; TNR: Total natural regeneration).

Among the species collected in this study, the ones with the highest percentages of Natural Regeneration in Class 1 were: Myrcia guianensis (5,90%), *Erythroxylum citrifolium* (5,60%), *Hirtella racemosa* (4,72%) and *Xylopia frutescens* (2,36%). In Class 2 of height were: *Myrcia guianensis* (6.49), *Hirtella racemosa* (5.31%), *Chamaecrista ensiformis* (3.83%) and *Xylopia frutescens* (2.36%). While in Class 3 height, the following stand out: *Chamaecrista ensiformis* (4,13%), *Myrcia guianensis* (3,83%), *Xylopia frutescens* (3,54%) and *Pogonophora schomburgkiana* (3,24%).

Of the total sampled species, 27 presented total natural regeneration values lower than 1.0, with the passage of time these species may present greater difficulty to regenerate or may occur the establishment of late species in these ecosystems [36]. The occurrence of low regeneration of these species may be related to environmental conditions, mainly by the closure of the canopy that will provide better conditions to the species that are tolerant to shading [37], for these reasons it is necessary to monitor these species in the long term [5].

Regarding diversity, the Shannon-Weaver index for regenerating individuals was 3.04 nats.ind-1 exhibiting high diversity in the area, a value similar to that found by [38] with 3.01 in an area of restoration with planting in high diversity. The greater diversity of these individuals indicates that the process of restoration of that area is occurring properly, because it is expected that in the initial phases an increase in diversity occurs with the occurrence of the establishment of new species [39]. With this, it can be seen that a community that presents high diversity is directly related to its rich [40].

The Pielou equability was 0.79 indicating that the species found are nicely distributed. The value was lower than that found by [41] with 0.81 in the Atlantic Forest fragment and similar to that found by [27] in the Semidecidual Seasonal Forest area with 0.74. These results are common for fragments of Atlantic forests in the state of Pernambuco [5].

The Simpson dominance index was 0.93 indicating that this area has a high diversity. The diversity indexes are considered high for the secondary formations of Atlantic Forest, showing that these formations are well conserved [42].

4. CONCLUSION

The most representative families were: Myrtaceae, Fabaceae and Anacardiaceae.

The distribution of the individuals of *Hirtella racemosa* and *Chamaecrista ensiformis* in the different size and relative density classes, allows to affirm that these species act directly in the process of ecological succession.

From the obtained results, it can be inferred that the fragment is in the initial secondary stage of succession.

Species that present low natural regeneration may, over time, be replaced by other species as the changes in the forest composition of that site occur. Therefore, it is necessary to have a continuous monitoring of these species in the new area of Parque Estadual Dois Irmãos.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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