Original Research Article

Natural 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 assists 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 undertaken in Parque Estadual Dois Irmãos (PEDI), in Recife, Pernambuco, in which 10 subplots of 1 m x 25 m (25 m²) each was installed. As inclusion criterion, the regenerating individuals of arboreal species should have a 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 via phytosociological parameters such as heights classes for regenerating individuals and diversity index. For data analysis 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 pioneer group, while 48% belonged to the initial secondary group, and 22% to the late secondary group. The distribution of individuals of the species Hirtella racemosa and Chamaecrista ensiformis in the different size and relative density classes allow 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, regeneration.

1. INTRODUCTION

The Brazilian Atlantic Forest is a rainforest, considered one of the major hotspots for being one of the richest biomes in sity globally [1, 2], presenting approximately 14,000 different plant species [3], However, over the past 50 years (up to 2015), the original coverage of this biome has been reduced to 8% [4], due to the advanced stage of fragmentation caused by anthropogenic activities.

The development of studies on natural regeneration in forest fragments is of great importance in understanding the ecological functioning of these ecosystems because they contribute to the assessment of the regenerative power of forests in the face of natural and anthropogenic disturbances [5] and to understand the development of forests [6]. In addition, it is possible to identify and quantify the species present, as well as 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 ever-changing environmental conditions [8]. The environmental areas that are in the process of regeneration, function as a habitat for several native species, while also acting carbon sequestration agents [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 regenerating individuals are considered those plants with their height equal to or greater than one meter, justifying that in this phase the individuals have already adapted to the environment, minimized their mortality rate and facilitated 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 the upper strata in the forest, by the propagation of propagules, the quantity and quality of light, the type of 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 their interaction with 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, 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 is 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

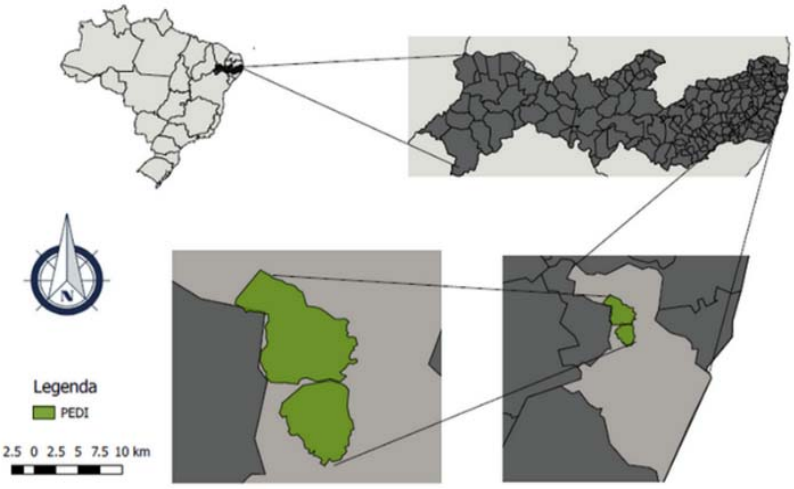

Figure 1. Location of the Atlantic Forest fragment in Recife, Pernambuco, Brazil, with emphasis on the study area.

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 humidity is 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 m 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 0.30 m).

When it was not possible to identify plants in the field, the reproductive and / or vegetative botanical material was collected for later taxonomic 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] as 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 ≤ H ≤ 2.0 m
2	2.0 < H ≤ 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 is the result 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. 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 Value of Importance (VI) (Table 2).]. The representativeness of these species was also highlighted in other regeneration works, such as that of Santiago et al. [27] in a secondary forest fragment of the Botanic Garden of UFJF, Silva et al. [28] in a fragment of the Ombrophilous Dense Forest of Terras Baixas and Rocha et al. [29] in a fragment of Atlantic forest in the city of Igarassu - PE. This result demonstrate that most of these species are able to colonize and develop in the PEDI fragment.

The families that presented the highest number of species, 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 found in fragments of Atlantic Forests and corroborate 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).

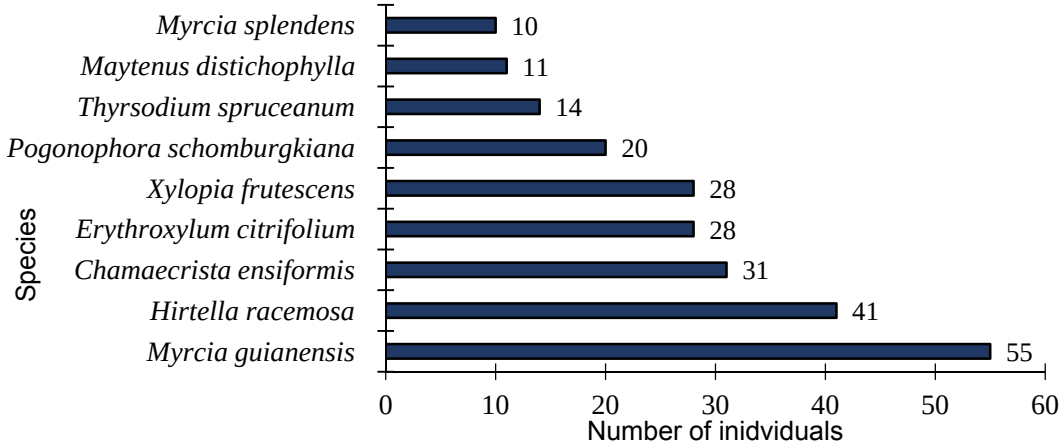

Figure 2. Regenerating species with numbers of individuals equal to or greater than 10 in an urban fragment of Atlantic Forest in Recife, Pernambuco, Brazil.

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 47.83% belong to the group of the initial secondary, 21.74% to the late secondary group and 15,.22% 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].

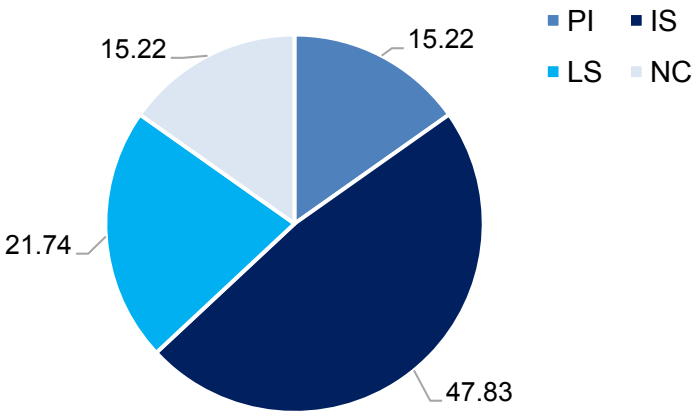

Figure 3. Percentage of successional groups observed in an urban fragment of Atlantic Forest in Recife, Pernambuco, Brazil (being: PI: Pioneers, IS: Initial secondary, LS: Late secondary, NC: No classification).

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 as either 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).

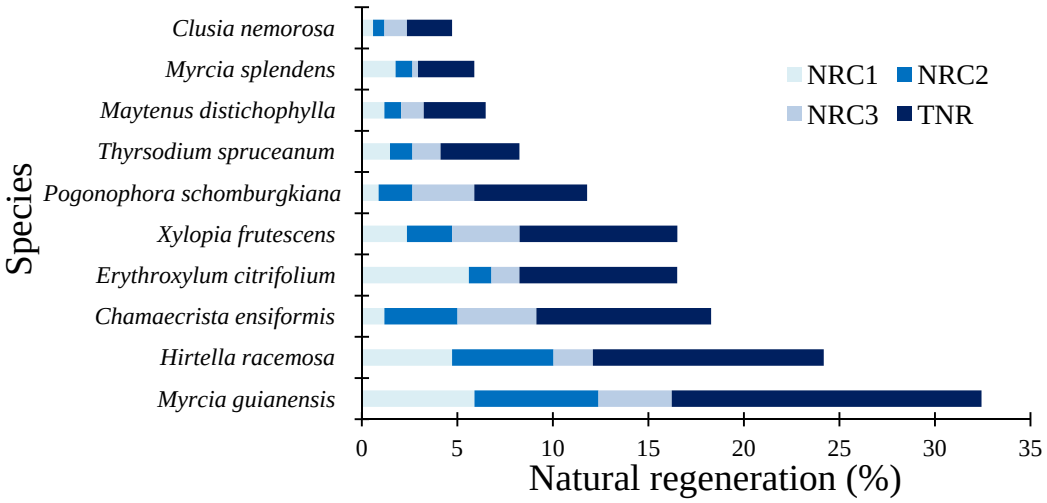

Figure 4. Relation of the 10 species with the highest values of total natural regeneration of the sampled population, expressed as a percentage, sampled in an urban fragment of Mata Atlântica in Recife, Pernambuco, Brazil (being: NRC1: Natural regeneration in Class 1; NRC2: Natural regeneration in Class 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 richness [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 Semi-decidual 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].

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.

REFERENCES

1. Oliveira LSB, Marangon LC, Feliciano ALP, Cardoso MO, Silva VF. Floristic, successional classification and dispersion syndromes in a remnant of Atlantic Forest, Moreno - PE. Brazilian Journal of Agricultural Sciences. 2011; 6 (3): 502-507. DOI: http://dx.doi.org/10.5039/agraria.v6i3a1384

2. Eisenlohr PVLF, Alves LC, Bernacci MCG, Padfurschi RB, Torres BEM, Silver FAM, Santos MA et al. Disturbances, elevation, topography and spatial proximity drive vegetation patterns along an altitudinal gradient of a top biodiversity hotspot. Biodiversity Conservation. 2013; 22 (12): 2767-2783.

3. Forzza RC, Baumgratz JFA, Bicudo CEM, Canals DAL, Carvalho-Junior AA, Rabbit MAN, Costa AF et al. New Brazilian floristic list highlights conservation challenges. Bioscience. 2012: 62 (1): 39-45.

4. Lucas EJ, Bünger. Myrtaceae in the Atlantic forest: their role as a "model" group. Biodiversity and Conservation. 2015; 24 (9): 2165-2180. DOI: http://dx.doi.org/10.1007/s10531-015-0992-7

5. Aparicio WCS, Marangon LC, Ferreira RLC, Aparício OS, Costa Júnior RF. Structure of natural regeneration of tree species in a fragment of Atlantic Forest, Pernambuco. Brazilian Journal of Agricultural Sciences. 2011; 6 (3): 483-488. DOI: http://dx.doi.org/10.5039/agraria.v6i3a791

6. Souto MAG, Boeger MRT. Structure and composition of the regeneration stratum and associated vegetation of different successional stages in eastern Paraná. Forest Science. 2011; 21 (3): 393-406. DOI: http://dx.doi.org/10.5902/198050983798.

7. Range JRV, Botelho SA, Bentes-Range MM. Floristic composition and structure of the natural regeneration of Lower Várzea Secondary Forest in the Amazon Estuary. Tree Review. 2002: 26 (5): 559-556.

8. Santos KF, Ferreira TS, Higuchi P, Silva AC, Vandresen PB, Costa A et al. Natural regeneration of the arboreal component after mortality of a taquara massif in a fragment of mixed ombrophylous forest in Lages - SC. Forest Science. 2015; 25 (1): 107-117.

9. Chazdon RL. Regeneration of tropical forests. Bulletin of the Museu Paraense Emílio Goeldi. Natural Sciences. 2012; 7 (3): 195-238

10. Chadzon RL, Letcher SG, Van Breugel M, Martínez-Ramos M, Bongers F, Finegan B. Rates of change in tree communities of secondary Neotropical forests following major disturbances. Philosophical Transactions of the Royal Society. 2007; 362 (1): 273 – 289. DOI: https://dx.doi.org/10.1098%2Frstb.2006.1990

11. Marangon LC, Soares JJ, Feliciano ALP, Brandão CFLS. Natural regeneration in a fragment of Seasonal Semideciduous Forest in Viçosa, Minas Gerais. Tree Review. 2008; 32 (1): 183-191.

12. Silva SO, Ferreira RLC, Silva JAA, Lira MA, Alves-Júnior FT, Cano MOO, Torres JEL. Natural regeneration in a remnant of caatinga with different use histories in Pernambuco. Tree Review. 2012; 36 (3): 441-450. DOI: http://dx.doi.org/10.1590/S0100-67622012000300006

13. Pinto JRR, Oliveira-Filho AT, Hay JDV. Influence of soil and topography on the composition of a tree community in Central Brazilian valley forest. Edinburgh Journal of Botany. 2005; 61 (1): 69-90.

14. Silva WC, Marangon LC, Ferreira RLC, Feliciano ALP, Costa Júnior RF. Study of the natural regeneration of tree species in fragments of Ombrophilous Dense Forest, Mata das Galinhas, in the municipality of Catende, Zona Sul Mata de Pernambuco. Forest Science. 2007; 17 (4): 321-331.

15. Pinto AVF, Silva MAM, Leite AVL, Nascimento LM, Lins e Silva ACB. Wheel MJN. Floristic and structure of the arboral Community of a regeneration fragment of Atlantic Forest, Igarassu, Pernambuco, Brazil. Revista Agro @ mbiental. 2018; 12 (2): 145-155.

16. Gurevitch J, Scheiner SM, Fox GA. Plant Ecology. 2nd ed. Porto Alegre: Artmed, 2009. 592 p.

17. Garcia CC, MGF Kings, Reis GG, Pezzopane JEM, Lopes HNS, Ramos DC. Natural regeneration of arboreal species in a semideciduous Montana seasonal forest fragment, in the Atlantic Forest domain, in Viçosa, MG. Forest Science. 2011; 21 (4): 677-688.

18. Moura CHR, Bezerra OG, Silva JM. The natural values of the conservation units of Recife: Mata de Dois Irmãos and Mata do Engenho Uchôa. NEMO. 2018; 10 (1): 131-155

19. Köppen W. Translation Corrêa ACB. Geographic System of Climates. Notes and Communication of Geography - Series B: Didactic texts nº 13. Ed. University - UFPE, Department of Geographical Sciences, 1996. 31 p.

20. Moreira EBM, Galvíncio JD. Spatialization of surface temperatures in the city of Recife using UTM images - LANNDSAT 7. Revista de Geografia. 2007; 24 (1): 101-115.

21. Jacomine PKT et al. Exploratory survey: soil recognition in the state of Pernambuco, Recife. Ministry of Agriculture / Northeast Development Superintendence. (Technical Bulletin nº 26; Pedological series nº 14). 1973. 359 p.

22. Machado IC, Lopes AV, Porto KC. Ecological Reserve of Dois Irmãos: studies on a remnant of Atlantic Forest in an urban area. Recife: University Publishing House of UFPE. 1998. 326 p.

23. Lima MS, Freire FJ, Marangon LC, Almeida BG, Ribeiro EP, Santos RL. Forest soils in a fragment of urban forest in the Dois Irmãos Forest, Recife, Pernambuco, Brazil. Floresal Science. 2018; 28 (2): 542-555.

24. APG IV. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. Botanical Journal of the Linnean Society. 2016.

25. Rodal MJN, Sampaio EVSB, Figueiredo MA. Manual on methods of floristic and phytosociological study: caatinga ecosystem. Brasilia: Botanical Society of Brazil. 1992.

26. Alencar AL, Marangon LC, Feliciano ALP, Ferreira RLC, Teixeira LJ. Advanced natural regeneration of native tree species in the understory of Eucalyptus saligna Smith stands, in the Zona Sul Mata de Pernambuco. Forest Science. 2011; 2 (2): 183-192.

27. Santiago DS, Fonseca CR, Carvalho FA. Phytosociology of the natural regeneration of an urban fragment of the Semidecidual Seasonal Forest (Juiz de Fora, MG). Brazilian Journal of Agricultural Sciences. 2014; 9 (1): 117-123.

28. Silva RKS, Feliciano ALP, Marangon LC, Lima RBA. Floristic and ecological succession of the arboreal vegetation in spring area of a fragment of Atlantic Forest, Pernambuco. Brazilian Journal of Agricultural Sciences. 2010; 5 (4): 550-559.

29. Rocha KD, Chaves LFC, Marangon LC, Silva ACBL. Characterization of adult arboreal vegetation in a fragment of Atlantic forest, Igarassu - PE. Brazilian Journal of Agricultural Sciences. 2007; 3 (1): 35-40.

30. Silva-Júnior JF, Marangon LC, Ferreira RLC, Feliciano ALP, Brandão CFLS, Alves-Júnior FT. Phytosociology of the tree component in a remnant of Atlantic Forest in the municipality of Cabo de Santo Agostinho, PE. Brazilian Journal of Agricultural Sciences. 2008; 3 (3): 276-282.

31. Brandão CFLS, Marangon LC, Ferreira RLC, Silva ACBL. Phytosociological structure and successional classification of the tree component in a fragment of Atlantic forest in Igarassu - Pernambuco. Brazilian Journal of Agricultural Sciences. 2009; 4 (1): 55-61.

32. Imaña-Encinas J, Santana OA, Macedo LA, Paula JE. Diametric distribution of a section of the Semidecidual Seasonal Forest in the area of the Cerrado Ecomuseum. Cerne. 2008; 14 (1): 33-45.

33. Budowski G. The distinction between old secondary and climax species in tropical central American lowland rainforest. Tropical Ecology. 1970; 11 (1): 44-48.

34. Fonseca CR, Carvalho FA. Floristic and phytosociological aspects of the tree community of an urban fragment of Atlantic forest (Juiz de Fora, MG, Brazil). Bioscience Journal. 2012; 28 (5): 820-832.

289 35. Lima RBA, Marangon LC, Freire FJ, Feliciano ALP, Silva RKS. Regenerative potential of arboreal species in a fragment
290 of Atlantic Forest, Pernambuco, Brazil. Green Magazine on Agroecology and Sustainable Development. 2017; 12 (4): 666-
291 673.

292 36. Silva WC, Marangon LC, Ferreira RLC, Feliciano ALP, Aparício PS, Costa Júnior RF. Horizontal and vertical structure of
293 arboreal component in natural regeneration phase of Santa Luzia forest, in the municipality of Carende - PE. Tree
294 Review. 2010; 34 (5): 57-66.

295 37. Higuchi P, Reis GG, Pinheiro AL, Silva CT, Oliveira CHR. Floristic composition of the natural regeneration of tree
296 species over a period of eight years in a semideciduous seasonal forest fragment, in Viçosa, MG. Tree Review. 2006; 30
297 (6): 893-904.

298 38. Trentin BE, Estevan DA, Rossetto EFS, Gorenstein MR, Brizola GP, Bechara FC. Forest restoration in the Atlantic
299 forest: passive, nucleation and high diversity planting. Forest Science. 2018; 28 (1): 160-174.

300 39. Rech CCC, Silva AC, Higuchi P, Schimalski MB, Pscheidt F, Schmit AB, Ansolin RD et al. Evaluation of the forest
301 restoration of a degraded APP in Santa Catarina. Forest and Environment. 2015; 22 (2): 194-203.

302 40. Sizenando-Filho FA, Maracajá PB, Diniz-Filho ET, Freitas RAC. Floristic and phytosociological study of the herbaceous
303 flora of the municipality of Messias Targino, RN / PB. Journal of Biology and Earth Sciences. 2007; 7 (2).

304 41. Lima RBA, Silva RKS, Paula MD, Guimarães ETR, Braga ECB. Phytosociological and diametric structure of a fragment
305 of Atlantic forest, Pernambuco, Brazil. Challenges Magazine. 2017; 4 (4): 143-153.

306 42. Lopes CGR, Ferraz EMN, Araújo EL. Physiological characterization of a fragment of Atlantic Forest in the municipality
307 of São Vicente Férrer, PE, Brazil. Brazilian Journal of Bioscience. 2007; 5 (2): 1174-1176

308